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Games and Simulations for Diabetes Education

Nathan Patterson, Moses Wolfenstein, Susan Millar, Richard Halverson, and Kurt Squire

This paper highlights the thinking of the Education Research Challenge Area (ERCA) of the Morgridge Institute for Research on developing games and simulations for personalized medicine, particularly in the area of diabetes education. Motivating our effort is the increasing need to communicate insights about cutting-edge areas in science, such as personalized medicine and epigenetics. Our goal is to address this need by producing digital games for learning that genuinely engage a wide audience. Digital media, such as games for health, have demonstrated success in reaching broad audiences. In this paper, we draw on these precedents to develop (a) a set of design principles to guide the next generation of games for health and (b) a series of hypothetical games for diabetes based on these principles.

Games for Health: An Overview

An Emerging Need for a New Generation of Games for Health

It is no secret that health care is a critically important national concern. As legislators, insurance companies, and medical professionals debate how to reshape the structure and characteristics of health care delivery in the U.S., and as medical researchers rapidly add new tools and processes for improving care, there will be an increasing need for quality health education venues to successfully inform a wide variety of publics about new options (IBM Global Business Services, 2006). Unfortunately, current information dissemination practices privilege audiences already familiar with traditional health care documentation—whether on paper, websites, or video—and contribute to a widening gap between health care haves and have-nots. Critically, a substantial proportion of health care have-nots are children and young adults.

Digital media are an obvious avenue for engaging adolescents and young adults with medical and health care information. A recent report found that on average youth pack nearly 11 hours of digital media content into their daily lives, including 1.5 hours of video game play (Rideout, Foehr, & Roberts, 2010). Games for health can leverage the expanding world of new digital media to create compelling learning experiences incorporating accurate, up-to-date health care information in such a way as to produce transformational change. This sort of transformational change is particularly important for diseases like type 1 and type 2 diabetes that can emerge early in life, can be exacerbated by early and midlife living habits, and require deep changes in lifestyle.

Creating such compelling media—media that can have a broad impact in today's crowded marketplace—requires understanding the principles of effective media design: how people learn and how to design for broad impact. The last 20 years have seen a revolution in how people interact with media, with media environments becoming more deeply participatory than ever before. Today's users expect opportunities to actively shape the environments of which they are a part, as evidenced by the evolution of the games industry, with its multiplayer games, virtual worlds, and social games using networks like Facebook (Jenkins, 2006). Creating compelling media also requires incorporating learning principles derived from modern cognitive science, such as the principle that people learn best through simulated experiences and active engagement of their identities. Today's video games, often based on underlying simulations and situated within participatory learning communities, offer new models for how to instantiate learning theories in domains such as science education (Gaydos & Squire, 2010).

It is within this context that we frame two challenges that inform ERCA work:

- How can we design compelling games that relevant audiences will actually play and from which they will actually learn valued ways of thinking and acting?

- How can we take such innovations beyond proof-of-concept demonstrations and penetrate the media-saturated lives of today's youth?

Opportunities exist to use new distribution networks like Xbox LIVE, the Apple App Store, Android Market, Steam, and Facebook. However, to leverage these networks effectively, media must be designed to be social from the ground up. The ERCA group seeks to both leverage existing media user networks and create an original network to reach global impact. Effective informal science education tools available through these networks could transform both formal and informal science education.

Context of Games for Health

For generations, health education for laypeople consisted only of what they learned during secondary education and visits to their doctors. However, within the last two decades, the proliferation of household computers and Internet access have allowed many people to educate themselves about their illnesses and injuries. The speed at which information can now be shared has allowed organizations and agencies such as the American Diabetes Association, the U.S. Centers for Disease Control and Prevention, and the National Institutes of Health to drastically expand and improve upon their health outreach efforts.

It is no longer just a matter of consumer *ability* to obtain health care information this way; increasingly, it is a matter of consumer *responsibility*. IBM's (2006) report, *Healthcare 2015*, highlighted the role of "increased consumer responsibility for personal health management" (p. iii) and the need for the health care industry to focus on preventive care and chronic condition management. For example, in the context of the growing diabetes epidemic, public health resources are helping increasing numbers of people to learn more about their disease and organize support communities. Thus, as self-motivated learning and organizing become ever more important, the need increases for new education and outreach resources and efforts that complement those currently available. It is essential for doctors and patients alike to understand the deep implications of personalized, patient-driven health care.

Video games and game-based technologies are emerging as one of the most engaging and entertaining venues for meeting this emerging need for personal health care management resources (Lieberman, 1998; Turnin et al., 2001; Lieberman, 2006; Sawyer & Smith, 2008; Thai et al., 2008). Indeed, self-care and health care management have been a major focus of games for health from early on (Lieberman, 1998) and continue to receive attention from both academic and commercial developers (Hawn, 2009).

The first wave of educational video game development, which took place during the 1970s and ’80s, relied heavily on the capacity of digital media to engage learners, specifically through challenge, curiosity, control, fantasy, competition, and cooperation (Malone, 1981). These efforts, epitomized by games like *Math Blaster*, sought to use game play as a means of increasing time on task. They were successful across a variety of areas, from mathematics to diabetes management (Cordova & Lepper, 1996; Lieberman, 1998).

Studies of this first wave of games produced understandings of how to use the engaging properties of games in many areas, including health care. For example, early research into games as a stress reduction tool for children receiving chemotherapy provided case-based evidence (consisting of self-report and “low-*n*” observation data) that games can reduce stress associated with treatment (Kolko & Rickard-Figueroa, 1985). During this same period, research on the use of games by young burn victims reported positive clinical outcomes—not only reduced attention to pain, but also observable advances in recovery of hand, wrist, and elbow motion (Adriaenssens, Eggermont, Pyck, Boeckx, & Gilles, 1988).

Video games were also directed toward condition management. Some of the best examples of “serious games” (games developed with entertainment technologies and production techniques, but for non-entertainment ends) emerged in this area. These games addressed a range of health challenges, from attention deficit hyperactivity disorder to sexually transmitted diseases (cf. Goldsworthy & Schwartz, 2008), but most focused on asthma and diabetes. In the area of asthma studies, we highlight work (a) by the Yale University Department of Pediatrics and the Yale Child Study Center on the computer-based game *Asthma Command* (Rubin et al., 1986) and (b) by Lieberman on the effectiveness of the Health Hero Network game *Bronkie the Bronchiasaurus* (Lieberman, 1995). Both of these games were found to be effective tools for raising patients’ asthma knowledge and increasing self-efficacy for asthma self-management. Also, in the case of *Asthma Command*, the experimental group displayed a trend toward the reduction of medical visits due to acute asthma attacks. In the next section, we review in some detail games focused on diabetes, the second major focus of games for health.

We currently are in the midst of a second wave of educational game development and research. This wave is distinguished from the first in that it is grounded in cognitive science research on how commercial games and simulations function as effective learning tools (Gee, 2003; Squire, 2006). That is, researchers are basing the new learning games on knowledge of how good commercial games function as powerful learning spaces through features like just-in-time and on-demand feedback and challenges designed to encourage player experimentation. This current generation of games for learning is designed to achieve specific learning objectives and, when appropriate, to help meet educational standards.

Health games continue to make up a significant segment of the serious games sector and generally take the shape of either training tools for medical professionals or games designed to raise public or patient awareness about health care and self-care (Sawyer & Smith, 2008). Donner, Goldstein, and Loughran (2008, p. 59) have described games for health as fitting into five categories:

- Exercise games (e.g., fitness, coaching, health promotion)

- Brain fitness games (e.g., cognitive fitness, brain training)
- Condition management games (e.g., diabetes, asthma, cancer, pain management)
- Healthy eating games (e.g., weight management, obesity)
- Professional training games (e.g., simulations for training surgeons, first responders, etc.)

Of these, exercise games (sometimes referred to as *exergames*) and brain fitness games have achieved particularly noteworthy success in the commercial domain. However, health games have also been an essential test bed for the development of professional and clinical training tools (Bauman, 2007). Simulations and games like *HumanSim* (a game designed to help health care professionals sharpen their assessment and decision-making skills) and *Zero Hour: America's Medic* (a game designed to prepare first responders for disasters) have been at the forefront of ongoing efforts to harness the power of games for professional health care training. Institutions engaged in training health care professionals have also begun using games like *JDoc*, a junior doctor medical simulator designed to train preservice professionals (Sliney & Murphy, 2008), and adopting online virtual worlds like *Second Life* to introduce students to various aspects of nursing practice (Skiba, 2009; Nelson & Blenkin, 2007; Tsai et al., 2008). Finally, evidence points to the effectiveness of video games in managing health conditions—for example, as tools for reducing pain and anxiety in patients engaged in a painful course of treatment or physical therapy (Vasterling, Jenkins, Tope, & Burish, 1993; Pegelow, 1992).

Games for Diabetes

The number of cases of type 2 diabetes (diabetes mellitus type 2) has reached epidemic levels in the U.S., and prediabetes, a precursor to type 2 diabetes, is considered the largest national health care issue (U.S. Centers for Disease Control and Prevention [CDC], 2007). Direct and indirect costs associated with prediabetes and type 2 diabetes were estimated to be at least $174 billion in 2007 (American Diabetes Association, 2008). Common injuries, illnesses, and resulting health care costs associated with diabetes are often preventable using methods widely discussed in research and practice (CDC, 2007; Reece, 2006). Yet the lifestyle changes and self-care management principles that can prevent many of the side effects of prediabetes and type 2 diabetes frequently go unheeded because they are poorly understood or misunderstood by the general public. Although many education outreach tools and programs are currently available, the lives and resources that are lost to the diabetes epidemic underscore the need for new and innovative ways of making self-care diabetes management principles more readily understood by wide and diverse audiences.

Among the available education tools designed to improve diabetes patient outcomes are, as we noted above, many educational games. These include casual games (*INSULOT*, *Detective*, *Buildup Blocks*; Aoki et al., 2004; Aoki, Ohta, Okada, Oishi, & Fukui, 2005), collections of diabetes-related minigames wrapped in narratives (*Escape from Diab*, *Nanoswarm*; Buday, 2006; Reichstein, 2006), classic side-scrolling video games (*Packy and Marlon*, *Captain Novolin*; Raya Systems, 1992, 1995), and glucose-monitoring peripherals related to games (*Glucoboy*, *Bayer DIDGET*; Wessel, 2004, 2009). In addition, the increasingly popular exergaming subgenre is being explored as a tool for reducing obesity-related health risks, including diabetes (Lieberman, 2006). Many of the games listed in Table A1 (see appendix) utilize diabetes as a secondary game play mechanic or use it as motivation in the game's overall narrative. Although few of these games have achieved commercial success or widespread distribution, there is good evidence of the positive effects of these diabetes education tools.

As video game production for both consoles and home computers entered a new era in the 1990s, games targeted at health care objectives began to evolve, along with research into their effectiveness. The Health Hero games for the Super Nintendo console represent one of the more advanced efforts from this period. Production of these games brought researchers and software developers together in an effort to target specific health-related behavioral outcomes while maintaining an entertaining playing experience (Lieberman, 2001). In evaluating these games, Lieberman and her colleagues obtained not only player self-report data to identify attitudes about health games and changes in perceptions of health and safety issues, but also longitudinal data through partnerships with health care providers. Her studies showed positive findings. For example, the diabetes education game *Packy and Marlon*, used in partnership with hospitals, resulted in a 77% drop in urgent doctor visits among type 1 diabetes patients who had the game at home (Lieberman, 1998).

A recent resurgence of development of educational video games focusing on diabetes education and management is promising to bring new life to the field. A popular approach is to use established games and game genres to help ensure that game play is both entertaining and educational. Games in this generation range from diabetes-focused classic casual games, to games that incorporate diabetes-related questions into game play (Pratt, n.d.), to graphically intensive action games that add a diabetes narrative and layers of abstraction (*The Magi and the Sleeping Star*). Given the low success rate of games using this approach, it might be argued that the approach is ill-advised. However, advances in video game development tools and knowledge of instructional design may prove to be exactly what diabetes games need to achieve widespread success.

One subset of games presents diabetes as the core game play mechanic by having the player assume a caretaker role for a character with diabetes. These games are modeled on the Tamagotchi, a Japanese handheld digital pet. This extremely successful game—more than 70 million have sold—requires players to care for an egg using a handheld device that is often attached to a keychain (see Figure 1).

***Figure 1.* A Tamagotchi game device for keychains.**

Tamagotchi-style games include such titles as *The Diabetic Dog* and *Tamagoya* (or *Egg Breeder*). In *The Diabetic Dog,* players take responsibility for a dog that has type 1 diabetes and are rewarded at the end of each day based on how well they cared for it. In *Tamagoya*, players take care of an egg with type 1 diabetes that needs to be fed, exercised, and given insulin. Where *Tamagoya* and *The Diabetic Dog* differ is that there is a clear end point to *Tamagoya*: the egg hatches. By contrast, *The Diabetic Dog* is open-ended: players can continue to receive rewards and purchase new items to care for their dogs indefinitely. Both games succeed in creating an emotional tie between the player and the diabetic character. The player must provide proper diabetes care and management, or the dog will be taken back to the shelter (*Diabetic Dog)* or the eggs will not hatch (*Tamagoya*).

Clearly, games for diabetes learning represent one of the most developed areas in the world of health games. There exist quality examples of games that portray the patient experience, help maintain health equilibrium, and simulate the biology of the disease. There are also game genres ranging from side-scrolling platformers to third-person shooters to systems-balancing *SimCity*-style games. We know something about which games and game elements are more or less successful. This history of prior development provides insights that can inform a new generation of games for health. Next, we draw on these insights and on cognitive science to advance four basic principles of effective game design.

ERCA Design Principles

Jim Gee's (2003) pioneering work, *What Video Games Have to Teach Us About Learning and Literacy*, detailed more than 30 principles of game design that contribute to learning. Four principles distilled from Gee's work guide ERCA research and design practices:

1. Create a tight marriage among content, game play, and valued ways of thinking and acting.

2. Motivate learning through social engagement.

3. Assess learning through game play.

4. Provide cutting-edge content that integrates new medical technologies.

We address each of these below.

Create a Tight Marriage Among Content, Game Play, and Valued Ways of Thinking and Acting

One design option used in early online games for learning seeks to integrate the "content" to be learned (concepts, skills, practices, etc.) into a game play "genre" (e.g., side-scrollers, first-person shooters, third-person action games, or puzzles). The theory motivating this option is that because a genre provides recognizable contexts to situate game play, people will be able to readily engage with other games developed in the same genre. An additional assumption is that if a genre is sufficiently well known to *be* a genre, it must be engaging to players. To produce a game of this type, new narrative or graphical content is inserted into an existing game that exemplifies an established genre, with relatively little attention given to the fit between the new content and the game genre. A couple of examples are *Spore* (Wright, 2008) and *Oregon Trail*

(Rawitsch, Heinemann, & Dillenberger, 1971). What these environments gain in genre recognition, game play, and associated engagement, they may lose in fit with the content domain.

Another early learning game design option eschews the use of proven game genres and seeks instead to structure each game in line with the online research tools (usually simulation tools) used by experts in the content domains. Designers who adopt this "content expertise" option develop game environments that operate more like stripped-down versions of the tools actually used in research practices. A number of examples can be found in the model repository for the agent-based programming language NetLogo (Wilensky 1999). What these environments gain in fit with the content domains, they may lose in genre recognition, game play, and the associated engagement.

We propose that it is useful to think of games that hew closely to either the content expertise option or the game genre option as two ends of a continuum on which we can place potential game design ideas, as illustrated in Figure 2. Games that do not deviate much from the genre are located on the right side of the continuum (b); those that stick close to the tools of practice are located on the left side of the continuum (a). We suggest that there is a "sweet spot" midway between the two extremes—an opportunity for design that both adapts existing game genres to the unique demands of the content and allows experts to refashion content in terms of game genre affordances. Finding this sweet spot requires close collaboration and iterative interaction between content experts and game designers.

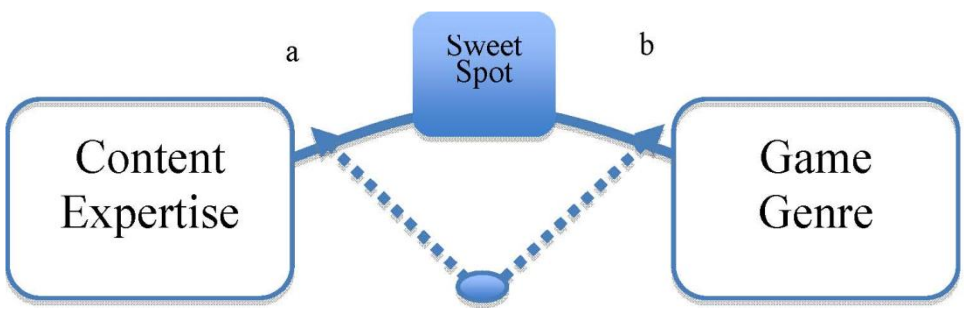

Figure 2. **Spectrum of content and game play integration into serious games.**

The game called *Resilient Planet*, developed by Filament Games (a company based in Madison, Wisconsin, that collaborates with ERCA), provides an excellent example of how to work in the design sweet spot. For example, one of Filament's tasks was to develop a game for the JASON Project that would help players navigate the world of marine biology. To frame player interaction, *Resilient Planet* adapted a third-person action-adventure genre. However, rather than designing for that genre, Filament designers worked closely with marine zoologists, botanists, and ecologists to understand the guiding metaphors and practices these researchers used to guide their own work. Often, the organizing heuristics that guide professional work are tacit and unreported in research papers or documentaries. Yet, these conceptual organizers constitute precisely the type of insights that can induct players into research worlds. By iteratively adapting the action-adventure genre to capture how the researchers thought about their world, the Filament designers developed a game that creates an authentic yet engaging learning environment—they hit the sweet spot. The ERCA research team proposes that creating authentic game-based learning environments of this type *requires* this kind of designer–content expert collaboration.

Motivate Learning Through Social Engagement

The integration of the Internet into game design is helping to address the common critique of electronic game play as an isolating activity (Lenhart et al., 2008). Internet-mediated game play sparks various forms of social interaction. Massively multiplayer online games, for example, rely on complex social interactions to coordinate large-scale activities. Internet-mediated games such as fantasy sports develop communities of interest that constitute the “field” in which games are played. Most strategy and shooter games now devote as much design attention to the online cooperative and competitive components as to the single-player experience. Outside the game itself, Internet forums act as community development sites that organize players into communities and provide information about game play and development. Steinkuehler and Duncan (2009) found that interactions in these forums largely consist of social knowledge construction activities such as citing and gathering evidence, warranting claims, and building original models to argue for best play strategies.

Even players who are not active participants in game forums generally benefit from such knowledge construction activities. Social networking, fan fiction, and political activists also use the Internet to shape information-based communities (Jenkins, 2006). Mediated social interaction is the path through which these digital media experiences take root in people’s lives. Our point here is that games that seek to influence the life knowledge and habits of adolescent and young adult audiences need to involve viable links to the virtual and in-person social communities in which they are engaged.

The evocation of community plays a critical role in helping players translate in-game content into persistent social practices. This can be done in several ways. The hardest way is to develop a new form of game interaction and then hope that a community organizes around it. An easier path is to embed game activities within already thriving virtual communities. The success of *Farmville* within Facebook is a good example of how game activities can flourish in established social communities. Yet another path is to link games to in-person communities. After-school activities such as YOUmedia, media production organizations such as ReelWorks.org, and more traditional groups such as 4-H or Boy Scouts use games to address and extend organizational practices. Finding the relevant communities upon which games can build is an important aspect of the design challenge.

Assess Learning Through Game Play

One of the primary reasons games have recently come back into the educational media spotlight is their capacity to provide players with immediate and ongoing assessment and to provide researchers and educators with rich data sets for evaluating learning (Jenkins et al., 2006). Despite wildly different surface features, games and assessments share basic structural elements. In particular, both are structured by rule sets that determine how individuals can engage with artificial tasks resulting in quantifiable outcomes (Behrens, Frezzo, Mislevy, Kroopnick, & Wise, 2006). This analysis aligns closely with Gee’s seminal work on how good games operate as effective learning tools by providing (a) formative feedback to players through onscreen events during game play and (b) summative benchmarks for players through the game’s end states (Gee, 2003). As Shaffer and his colleagues (2009) have noted, the potential of games as assessment tools is further enhanced by their ability to record rich streams of data about learning in progress.

Evaluation studies of games for health have generally targeted player reactions to games, clinical outcomes, or both (Baranowski, Buday, Thompson, & Baranowski, 2007). The most common type of data, player self-report, provides the opportunity to measure individuals' feelings about a game, its effects, and their sense of self-efficacy after playing. Studies targeting clinical outcomes—and these are more limited in number—provide some insight into the effectiveness of health games as elements in a prevention or treatment regimen (Baranowski et al., 2007). Clinically focused evaluations also point toward the type of assessment measures that will be available to researchers once new games for health are designed to take advantage of integrated data collection and reporting capabilities.

For example, more recent studies have begun to take full advantage of games as a medium that functions both as part of a treatment or self-care regimen and as a source of data on the effectiveness of the treatment. An evaluation of the cancer treatment game *Re-Mission* (Kato, Cole, Bradlyn, & Pollock, 2008) showed that the game had a positive effect on (a) patient efficacy as measured through self-report and (b) treatment adherence as measured through objective measures and self-report. Subsequently, several modified versions of the game—emphasizing either the game narrative or the game play—were deployed to investigate whether the effects observed in the initial study remained. The researchers determined that the high game play/low narrative version of the game had more impact on treatment adherence, whereas the low game play/high narrative version resulted in a more substantial increase in patient efficacy (Lieberman, 2008).

While work around *Re-Mission* and other current-generation health games indicates how games can be utilized to advance evaluation-oriented research, exergaming and brain fitness games have pushed formative feedback mechanics for player health into the mainstream market, with users increasingly turning to their console or handheld system for regular measures of their physical condition or mental acuity (Nintendo, 2005; Sugiyama & Matsunaga 2008). Meanwhile, advances in feedback in other educational games—like those designed by Filament Games for the JASON Project (natural science) and the iCivics initiative (law and civil rights)—have begun to illustrate how formative and summative feedback systems can be more fully integrated into games to provide meaningful assessment data to both student players and instructors.

A number of researchers have addressed the problem of how to embed assessment mechanisms into serious games that work as effectively as the feedback mechanics of commercial games. Shute, Ventura, Bauer, and Zapata-Rivera (2009) advanced the notion that traditional assessment is disruptive to the natural learning that takes place in a gaming environment and advocated "stealth assessment" instead. Shute et al. emphasized that the rich data generated through most game play is fundamentally different from the assessment data obtained in traditional learning contexts, because in games the very processes of play provide primary evidence of learning. These researchers particularly emphasized that the simulation underlying a game needs to be close enough to the targeted skills to provide an evolving picture of the player's skill progression over time. Making the same general point, Behrens et al. (2006) eloquently stated:

> It is important to note that in these types of situations [i.e., learning games], the assessment cycle continues in very small loops that provide immediate and detailed and unobtrusive formative feedback. In this way the assessment structure is ubiquitously embedded in the system and the examinee/player does not experience interruptions to instruction for separate assessment activities. (p. 8)

While assessment of the player's performance is an important aspect of game design, the issue of transfer has dominated the educational psychology literature about intervention effects. Simply put, the transfer question is about how skills, knowledge, or practices developed in one context can be successfully activated or applied in another context, at another time. Traditionally, the focus has been on how in-school learning shapes out-of-school behavior. The transfer problem is critical when we revisit the typical methods for evaluating games for health. It is not enough for players to remember the lessons learned in the context of game play; rather, for health games to be truly effective, players need to behave differently. We mention here two strategies that can be used to facilitate transfer; each relies on creating meaningful links between game play and a player's prior conceptual, social, or environmental experience. First, the game itself can be designed to evoke aspects of the players' world in ways that facilitate reflective embrace of in-game lessons and practices. This is the least expensive but most difficult and uncertain transfer strategy to pursue, simply because the game designer cannot know how (or whether) players will internalize game play. Second, game play can take place in a social context that facilitates transfer and reflection upon core game activities. Actors in this social context can actively work with players to draw out lessons from game play in order to shape out-of-game behaviors (see Squire, 2005, for an example).

Provide Cutting-Edge Content That Integrates New Medical Technologies

We believe that creating compelling digital media in meaningful social contexts grounded in core research insights will provide a means for reaching new audiences. To develop such games in the area of health, a two-pronged strategy is needed. First, game design teams must include content-area researchers to ensure that games present research findings accurately and connect effectively with new audiences. Second, advances in consumer medical technologies need to be integrated into the game play experience to facilitate transfer of game play lessons into meaningful life contexts.

The games for health movement has already advanced the development of peripheral devices for gaming, therapy, and simulation. Game-based technology has helped the health care industry develop advanced task training devices, including mannequins for emergency response and medical training. These devices, which blend traditional manual interfaces with powerful computer simulations, are often used to introduce and train clinicians in the use of technology-specific equipment and procedures, such as intubation, ultrasound, endoscopy, and laparoscopy (Bauman, 2007; Cooper & Taqueti, 2004; Gould & Bauman, in press; Glavin & Maran, 2003; Seropian, 2003). Researchers and developers have also created technologies for patient therapy and treatment regimens, including:

- A wheelchair interface for patients suffering from spinal cord injuries that promotes exercise and rehabilitation by linking video game play to wheelchair propulsion (O'Connor et al., 2000);

- Heartbeat-based games that rely on a simple heart rate monitor that can be utilized with commercially available handheld devices (e.g., Active Ingredient's *'Ere Be Dragons*); and

- A blood sugar peripheral attachment for Nintendo's Game Boy and DS handheld systems called *Glucoboy* (superseded by Bayer *DIDGET*) designed to help gaming patients manage their diabetes.

Perhaps most important, games for health have crossed over into commercial game development, particularly with games developed for Nintendo's console and handheld systems. With the release of the Wii console system, exergaming entered the center of the video game console market. More than 50 million Wii units have sold, and the Wii Fit game and its accessory, the Wii Balance Board, are highly profitable products. The Wii Balance Board has been found to be composed of medical-quality components, yet it sells at roughly $1/200^{th}$ the cost of force platforms currently used by medical professionals (Clark et al., 2010).

In the area of diabetes, the integration of innovative peripherals with video games is just beginning (e.g., *Glucoboy* and *DIDGET*). The paucity of games utilizing diabetic patient input is not due to a lack of available patient data input methods. Patient data can be input using a wide variety of available diabetes monitoring devices including Bluetooth-enabled blood glucose meters (e.g., BodyTel's GlucoTel, Entra Health Systems' MyGlucoHealth Meter, Alive Technologies' Diabetes Management System) and even mobile phones with built-in meters (Carroll, Marrero, & Downs, 2007). Increased device connectivity creates opportunities for new and innovative ways to integrate real-world player data into game play, while also allowing for assessment of the impact of the game on the player's diabetes management through enhanced patient data collection.

Hypothetical Diabetes Game Based on ERCA Principles

In this section, we present three games of a hypothetical series to illustrate how the ERCA design principles outlined above might guide the development of diabetes games, as well as health games generally.

The initial game of the hypothetical series (Game 1) would draw on the Tamagotchi game model discussed earlier, requiring players to use a variety of strategies to maintain the internal equilibrium of a virtual diabetic pet. The game would incorporate scientifically accurate models of diabetic responses into game play. The results of Game 1 testing would inform the development of a second game of the series based on mobile and medical technologies. The incorporation of location-based game play and connectivity to glucose monitors would enhance the assessment and research tools integrated into Game 2. Game 3 would then incorporate social networking to appeal to an expanding audience.

The virtual game space would be designed to shape the context for learning assessment. Assessment information would be provided to players during play and to other players in the virtual community. It would be aggregated to help gamers playing roles as health care professionals understand how individual play experiences aggregate into large-scale epidemiological trends. Finally, data on player progress would be collected in order to evaluate the effectiveness of the game.

Game 1: Care for a Diabetic Animal

In the initial game of the series, the player would arrive at a local shelter to adopt a virtual diabetic animal. The player would be allowed to choose from a variety of animals, each with different internal metabolic and equilibrium states. The player would have to properly feed, exercise, and medicate his or her animal and introduce it into a virtual space, the player's "apartment," where its health would depend on meaningful design of and interaction within the space. The virtual space for each player would include a market for purchasing in-game equipment and other virtual items to populate the space and allow the players to care for their animals.

The internal state of the player's animal would be carefully designed to reflect how diabetes unfolds in the life of an organism. In particular, establishing a deep structural similarity between the animal's internal state and its managed behavior would help the player understand the connections between diabetes health and activities. The player would receive ongoing feedback about the animal's health, and as the game progressed, the player could acquire more nuanced tests to discern the patterns of diabetic expression in the animal's world. These tests would help the player decide which kinds of foods and activities would promote health and which kinds of animal friends in the community would help make the animal happier.

Player actions in game would be monitored and a database of player statistics compiled in order to assess learning. Game play assessment would be designed to answer questions such as:

- How large are the fluctuations in internal system levels for players' animals? Can players maintain acceptable levels? Which kinds of activities lead to establishing equilibrium levels? Which kinds of social interactions lead to healthy inner states?
- How well do players maintain a healthy state for their animals? (This would be an evolving average over a period of days or weeks of game play.)
- How long does it take for players to balance their purchases? For example, how well do players recognize the link between healthier diets and better maintained metabolism levels?
- How does players' care for animals evolve over time? How long does it take for players to realize the connections between diet, exercise, and medication?

Game 2: Animals Go Mobile

The second game would expand on the original to allow players to localize game experiences via mobile technologies. Players with diabetic conditions could use their own health information, accessed through medical technologies, to shape the internal state of their animals. The game would use GPS, a common feature on new application-enabled cellular phones, to record the amount of exercise (walking or running) players get in a day, allocating an equivalent amount of exercise to their animals. Bluetooth connectivity—another common feature of most application-enabled cellular phones—could also be used to create a closer relationship between players' and animals' health via Bluetooth-enabled blood-glucose monitors. By collecting data from connected devices, researchers could study large and diverse populations of people with prediabetes or type 2 diabetes. These data could be used to improve models of diabetic conditions and track the effectiveness of medications.

Player assessment could also be expanded by adding common mobile device functionality to the game, enabling researchers to address questions such as:

- If players are given options of nearby restaurants and menus, do their food choices for themselves affect their choices for their animals?

- Do players' food choices for their animals improve over time, or do players simply vary their animals' use of insulin?

- If given an incentive (e.g., extra in-game points) to exercise along with their animals, with the exercise movement tracked via GPS data, do players increase the proportion of time spent in actual exercise? How much of an incentive is needed to encourage players to engage in physical activity instead of playing with their animals on the computer?

- Do players' levels of physical activity evolve over time?

Game 3: Animals Get Social

The third game of the series would incorporate features from two very successful social networking sites: Facebook and *Whyville*. *Whyville* features—such as virtual environments that allow user interaction and dialogue, sponsored minigames, and new and innovative ways of creating intellectual discourse (Foley & Torre, 2004)—would enhance the animal game's education and outreach capabilities. The virtual environments could include a number of different backdrops, including a street block with apartment buildings in which the animals and their owners live (Game 1 would already have provided users with the ability to personalize their "apartments"), restaurants equivalent to the most popular locations chosen by players in Game 2, locations where the animals could exercise (swimming pool, running track, football and soccer fields, etc.), and a number of other locations based around the minigames already developed for the animal series.

By utilizing Facebook's free application programming interfaces (APIs), the animal game would be incorporated into the most popular social networking website in the United States. This added functionality would allow players to assist others by making exercise and diet recommendations. Because players would come from diverse backgrounds and environments, they would face different food and exercise challenges. By allowing users to help design diet and exercise routines for each other, the game would use the power of crowdsourcing to come up with ways for players to overcome challenges such as limited choices of food or lack of traditional exercise locations and activities.

The community dimension of Game 3 would open up a whole new area of assessment possibilities, making it possible to address questions such as:

- Given support through a community of users and a customized diet and exercise routine, how well do players accept the opinions of the crowd? That is, do players adopt the new routines?

(Player data could be tracked and analyzed using a combination of inputs from the mobile and computer-based games.)

- Does a community forum help players reflect on the lessons of practice, and if so, how?
- Given the changed missions and challenges that result from user-created content, do players develop new strategies for their animals to adjust to environmental disturbances, and if so, how?

Conclusions

Prediabetes and type 2 diabetes are the largest health care issue in the United States. Because the characteristics of these diseases are specific to each patient, personal health management is especially necessary, which greatly increases the need to effectively educate affected individuals about their disease and its management. The continuing growth of the diabetes epidemic underscores the need for new and innovative methods of diabetes education and outreach.

Initial studies have shown that educational health games have had significant impacts on patient health, and that diabetes games, in particular, can lead to promising patient outcomes (Lieberman, 1998). Educational games with integrated assessment offer a unique way of analyzing the learning process and can produce insightful feedback on what will and will not work. They can deliver diabetes educational content while collecting data to improve diabetes research. Advanced forms of game-enabled data collection can allow researchers to analyze diverse populations of prediabetes and type 2 diabetes patients on a scale that dwarfs previous studies. The ERCA team at the Morgridge Institute for Research believes that such educational games offer the innovative, engaging, and entertaining solution that diabetes education and outreach need to help fight the expanding epidemic.

References

Adriaenssens, P., Eggermont, E., Pyck, K., Boeckx, W., & Gilles, B. (1988). The video invasion of rehabilitation. *Burns*, *14*(5), 417–419. doi:10.1016/0305-4179(88)90015-0

American Diabetes Association. (2008). Economic costs of diabetes in the U.S. in 2007. *Diabetes Care*, *31*(3), 596–615.

Aoki, N., Ohta, S., Masuda, H., Naito, T., Sawai, T., Nishida, K., . . . Fukui, T. (2004). Edutainment tools for initial education of type-1 diabetes mellitus: Initial diabetes education with fun. *Medinfo*, *11*(Pt. 2), 855–859.

Aoki, N., Ohta, S., Okada, T., Oishi, M., & Fukui, T. (2005). INSULOT. *Diabetes care*, *28*(3), 760.

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2007). Playing for real: Video games and stories for health-related behavior change. *American Journal of Preventive Medicine*, *34*(1), 74–82.

Bauman, E. (2007). *High fidelity simulation in healthcare* (Doctoral dissertation, University of Wisconsin–Madison). Retrieved from Dissertations & Thesis @ CIC Institutions. (Publication no. AAT 3294196).

Behrens, J. T., Frezzo, D., Mislevy, R., Kroopnick, M., & Wise, D. (2006). *Structural, functional and semiotic symmetries in simulation-based games and assessments*. Retrieved from http://www.education.umd.edu/EDMS/mislevy/CiscoPapers/Games.pdf

Buday, R. (2006). *Nanoswarm: Invasion from Inner Space* [video game]. Retrieved from http://www.nanoswarmthegame.com/

Carroll, A. E., Marrero, D. G., & Downs, S. M. (2007). The HealthPia GlucoPack™ Diabetes Phone: A usability study. *Diabetes Technology & Therapeutics*, *9*(2), 158–164.

Clark, R. A., Bryant, A. L., Pua, Y., McCrory, P., Bennell, K., & Hunt, M. (2010). Validity and reliability of the Nintendo Wii Balance Board for assessment of standing balance. *Gait & Posture*, *31*(3), 307–310.

Cooper, J., & Taqueti, V. (2004). A brief history of the development of mannequin simulators for clinical education and training. *Quality and Safety in Health Care*, *13*(Supplement 1), i11–i18. doi:10.1136/qshc.2004.009886

Cordova, D., & Lepper, M. R. (1996). Intrinsic motivation and the process of learning: Beneficial effects of contextualization, personalization, and choice. *Journal of Educational Psychology*, *88*(4), 715–730.

Diabetic Dog [video game]. (2009). Adobe Flash. Nobel Web AB. Retrieved from http://nobelprize.org/educational_games/medicine/insulin/about.html

Donner, A., Goldstein, D., & Loughran, J. (2008). Health e-games market report: Status and opportunities. San Francisco, CA: Physic Ventures.

Farmville [video game]. (2009). Adobe Flash. Zynga.

Foley, B. J., & Torre, D. L. (2004). Who has Why-Pox: A case study of informal science education on the net. In *Proceedings of the 6th International Conference on Learning Sciences* (pp. 598–598). Santa Monica, CA: International Society of the Learning Sciences.

Gaydos, M., & Squire, K. (2010). Citizen science: Designing a game for the 21st century. In R. Van Eck (Ed.), *Interdisciplinary models and tools for serious games: Emerging concepts and future directions* (pp. 289–305). Hershey, PA: Information Science Reference.

Gee, J. P. (2003). *What video games have to teach us about learning and literacy*. New York, NY: Palgrave Macmillan.

Glavin, R., & Maran, N. (2003). Integrating human factors into the medical curriculum. *Medical Education*, *37*(Supplement 1), 59–64.

Goldsworthy, R., & Schwartz, N. (2008). Development and evaluation of a multimedia-enhanced STD/HIV curriculum for middle schools. *Journal of Educational Multimedia and Hypermedia*, *17*(3), 413–444.

Gould, J., & Bauman, E. (in press). Virtual reality in medical education. In S. Tsuda, D. Scott, & D. Jones (Eds.), *Textbook of simulation, surgical skills, and team training*. Woodbury, CT: Cine-Med.

Hawn, C. (2009). Games for health: The latest tool in the medical care arsenal. *Health Affairs*, *28*(5), w842–w848.

IBM Global Business Services. (2006). *Healthcare 2015: Win-win or lose-lose? A portrait and a path to successful transformation*. Somers, NY: Author. Retrieved from http://www-935.ibm.com/services/us/gbs/bus/pdf/healthcare2015-win-win_or_lose-lose.pdf

Jenkins, H. (with Clinton, K., Purushotma, R., Robison, A. J., & Weigel, M.). (2006). *Confronting the challenges of participatory culture: Media education for the 21st century*. Chicago, IL: MacArthur Foundation.

Kato, P. M., Cole, S. W., Bradlyn, A. S., & Pollock, B. H. (2008). A video game improves behavioral outcomes in adolescents and young adults with cancer: A randomized trial. *Pediatrics*, *122*(2), e305–e317. doi:10.1542/peds.2007-3134

Kolko, D., & Rickard-Figueroa, J. (1985). Effects of video games on the adverse corollaries of chemotherapy in pediatric oncology patients: A single-case analysis. *Journal of Consulting and Clinical Psychology*, *53*(2), 223–228.

Lenhart, A., Kahne, J., Middaugh, E., Macgill, A. R., Evans, C., & Vitak, J. (2008). Teens, video games, and civics. *Pew Internet & American Life Project, September*, *16*.

Lieberman, D. A. (1995). *Three studies of an asthma education video game: Report to the National Institute of Allergy and Infectious Diseases*. Bethesda, MD: National Institutes of Health.

Lieberman, D. A. (1998, July). *Health education video games for children and adolescents: Theory, design, and research findings*. Paper presented at the annual meeting of the International Communication Association, Jerusalem, Israel.

Lieberman, D. A. (2001). Management of chronic pediatric diseases with interactive health games: Theory and research findings. *The Journal of Ambulatory Care Management*, *24*(1), 26–38.

Lieberman, D. A. (2006). *Dance games and other exergames: What the research says*. Retrieved from http://www.comm.ucsb.edu/faculty/lieberman/exergames.htm

Lieberman, D. A. (2008). *Impacts of narrative, nurturing, and game-play on health-related outcomes in an action-adventure health game*. Unpublished manuscript, University of California, Santa Barbara.

Lieberman, D. A. (2009). Designing serious games for learning and health in informal and formal settings. In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.), *Serious games: Mechanisms and effects* (pp. 117–130). New York, NY: Routledge.

The Magi and the Sleeping Star [video game]. Game Equals Life. Retrieved from http://themagigame.net/

Malone, T. W. (1981). Toward a theory of intrinsically motivating instruction. *Cognitive Science*, *5*(4), 333–369. doi:10.1207/s15516709cog0504_2

Nelson, D., & Blenkin, C. (2007). The power of online role-play simulations: Technology in nursing education. *International Journal of Nursing Scholarship*, *4*, 1263–1277.

Nintendo. (2005). *Brain Age* [video game]. Nintendo Wii, DS. Nintendo.

O'Connor, T. J., Cooper, R. A., Fitzgerald, S. G., Dvorznak, M. J., Boninger, M. L., VanSickle, D. P., & Glass, L. (2000). Evaluation of a manual wheelchair interface to computer games. *Neurorehabilitation & Neural Repair*, *14*(1), 21–31.

Pegelow, C. H. (1992). Survey of pain management therapy provided for children with sickle cell disease. *Clinical Pediatrics, 31*(4), 211–214. doi:10.1177/000992289203100404

Pratt, W. (n.d.). Wanda Pratt's research page. Retrieved from http://faculty.washington.edu/wpratt/research.html

Rawitsch, D., Heinemann, B., & Dillenberger, P. (1971). *The Oregon Trail* [video game]. Brøderbund, The Learning Company, Gameloft.

Raya Systems. (1992). *Captain Novolin* [video game]. Super NES. Raya Systems.

Raya Systems. (1995). *Packy and Marlon* [video game]. Super NES. Raya Systems.

Reece, E. A. (2006). Diabetes-related birth defects are preventable. *OB/GYN News*, *41*(7), 42.

Reichstein, J. (2006). *Escape from Diab*. Archimage [video game]. Retrieved from http://www.escapefromdiab.com/

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). *Generation M^2: Media in the lives of 8- to 18-year-olds*. Retrieved from http://www.kff.org/entmedia/upload/8010.pdf

Rubin, D. H., Leventhal, J. M., Sadock, R. T., Letovsky, E., Schottland, P., Clemente, I., & McCarthy, P. (1986). Educational intervention by computer in childhood asthma: A randomized clinical trial testing the use of a new teaching intervention in childhood asthma. *Pediatrics*, *77*(1), 1–10.

Sawyer, B., & Smith, P. (2008, February). *Serious games taxonomy*. Presented at the Serious Games Summit, 2008 Game Developers Conference, San Francisco, CA.

Seropian, M. (2003). General concepts in full scale simulation: Getting started. *Anesthesia and Analgesia*, *97*, 1695–1705.

Shaffer, D. W., Hatfield, D., Svarovsky, G. N., Nash, P., Nulty, A., Bagley, E., . . . Mislevy, R. (2009). Epistemic network analysis: A prototype for 21st-century assessment of learning. *International Journal of Learning and Media*, *1*(2), 33–53.

Shute, V. J., Ventura, M., Bauer, M. I., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded assessment to monitor and foster learning: Flow and grow. In U. Ritterfeld, M. J. Cody, & P. Vorderer (Eds.), *The social science of serious games: Theories and applications* (pp. 295–321). Philadelphia, PA: Routledge/LEA.

Skiba, D. (2009). Nursing education 2.0: A second look at Second Life. *Nursing Education Perspectives*, *30*, 129–131.

Sliney, A., & Murphy, D. (2008). JDoc: A serious game for medical learning. In C. Dini & S. Dascalu (Eds.), *Proceedings of the First International Conference on Advances in Computer-Human Interaction* (pp. 131–136). Washington, DC: IEEE Computer Society.

Squire, K. (2005). Changing the game: What happens when video games enter the classroom. *Innovate: Journal of online education*, *1*(6). Retrieved from http://innovateonline.info/pdf/vol1_issue6/Changing_the_Game-__What_Happens_When_Video_Games_Enter_the_Classroom_.pdf

Squire, K. (2006). From content to context: Video games as designed experiences. *Educational Researcher*, *35*(8), 19–29.

Steinkuehler, C., & Duncan, S. (2009). Scientific habits of mind in virtual worlds. *Journal of Science Education & Technology*, *17*(6), 530–543. doi:10.1007/s10956-008-9120-8

Sugiyama, T., & Matsunaga, H. (2008). *Wii Fit*. Nintendo.

Thai, A., Lowenstein, D., Ching, D., & Rejeski, D. (2009). *Game changer: Investing in digital play to advance children's learning and health.* New York, NY: The Joan Ganz Cooney Center at Sesame Workshop. Retrieved from http://www.rwjf.org/files/research/gamechanger200906232.pdf

Tsai, S.-L., Chai, S.-K., Hsieh, L.-F., Lin, S., Taur, F.-M., Sung, W.-S., & Doong, J.-L. (2008). The use of virtual reality computer simulation in learning Port-a-Cath injection. *Advances in Health Sciences Education*, *13*(1), 71–87.

Turnin, M. C., Tauber, M. T., Couvaras, O., Jouret, B., Bolzonella, C., Bourgeois, O., . . . Hanaire-Broutin, H. (2001). Evaluation of microcomputer nutritional teaching games in 1,876 children at school. *Diabetes & Metabolism*, *27*(4 Pt. 1), 459–464.

U.S. Centers for Disease Control and Prevention. (2007). *National diabetes fact sheet, 2007*. Retrieved from http://www.cdc.gov/diabetes/pubs/pdf/ndfs_2007.pdf

Vasterling, J., Jenkins, R. A., Tope, D. M., & Burish, T. G. (1993). Cognitive distraction and relaxation training for the control of side effects due to cancer chemotherapy. *Journal of Behavioral Medicine*, *16*(1), 65–80.

Wessel, P. (2004). *Glucoboy* [video game]. Game Boy Advance. Guidance Interactive Healthcare.

Wessel, P. (2009). *DIDGET* [video game]. Game Boy DS. Bayer.

Wilensky, Uri. (1999). *NetLogo*. Evanston, IL: Northwestern University, Center for Connected Learning and Computer-Based Modeling. Retrieved from http://ccl.northwestern.edu/netlogo

Wright, W. (2008). *Spore* [video game]. Windows, OS X, iPhone. Electronic Arts.

Appendix

Table A1

Video Games Focusing on Type 1 and Type 2 Diabetes

Game title	Game play	Diabetes focus	Release date	Impact assessment
Packy and Marlon	Players assume the role of two diabetic elephants who must make the right decisions about diet and insulin use (side-scrolling action game).	Types 1 & 2	1995	Self-assessment and statistical assessment of self-concepts, social support, knowledge, self-care, health outcomes, and hemoglobin (HbA1c)
Captain Novolin	Players assume the role of a diabetic superhero who must fight off invaders while making choices about diet and insulin doses (side-scrolling action game).	Types 1 & 2	1995	N/A
Tamagoya (Egg Breeder)	Players must care for an egg with type 1 diabetes by exercising it, feeding it, and administering insulin to it (Tamagotchi-style game).	Type 1	2004	Player self-assessment of entertainment, usability, and clinical usefulness using Likert scale
Tantei (Detective)	The player assumes the role of a detective chasing a criminal. The detective must maintain proper blood glucose levels by finding food and insulin (vertical-scrolling action game).	Type 1	2004	Player self-assessment of entertainment, usability, and clinical usefulness using Likert scale
Magic Toom (Buildup Blocks)	Players must build up colored blocks while also feeding their characters foods appropriate to their changing plasma glucose levels.	Type 1	2004	Player self-assessment of entertainment, usability, and clinical usefulness using Likert scale
INSULOT	Players play a slot machine designed to teach the relationship between plasma glucose level, carbohydrates, and insulin dosage. They then estimate an insulin dose based on calories and carbohydrates contained in the foods shown.	Type 1	2005	Player self-assessment of entertainment, usability, and clinical usefulness using Likert scale
Escape from Diab	Players navigate a 3-D world in which junk food is free and healthy food costs money. The 3-D environment is a wrapper for a series of minigames designed to teach about dietary and lifestyle choices.	Type 2/obesity prevention	2006	N/A
Nanoswarm	Players navigate a miniaturized vessel through the human body. There are a number of minigames within the game that focus on diabetes-related topics.	Type 2	2006	N/A
Glucoboy	Players earn reward points by maintaining good blood sugar control, as measured by the *Glucoboy* peripheral attachment. Points can be used to unlock mini-games on the Glucoboy cartridge.	Types 1 & 2	2007	N/A
Bayer DIDGET	Players earn reward points by maintaining good blood sugar control, as measured by the *DIDGET* Gameboy DS add-on. There are minigames similar to those packaged with *Glucoboy*.	Types 1 & 2	2009	N/A
Testing for Hypoglycemia While Driving	Players must make decisions about what action to take with regard to their blood glucose levels and timing of their travel to and from school.	Type 1	2009	Player self-assessment of usability using Likert scale