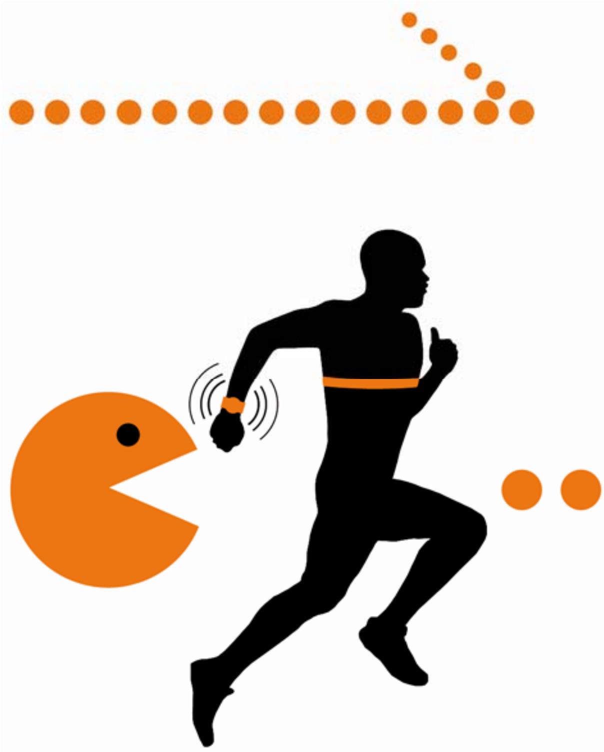
International Journal of Computer Science in Sport



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Serious Games for Sports and Health

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Editorial

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Playing games is a ubiquitous and fascinating activity all over the world being performed by young and old, rich and poor. Whereas playing games in general has a positive connotation regarding leisure, learning and development, this is not equally true for digital games – unfortunately often exclusively associated with negative associations about violence, addiction, and sedentary life style.

Since the 1990ies a new label has entered the stage: Serious Games (SG). SG denote video/digital games that are played not only for fun, enjoyment, and entertainment, but also for other purposes like learning, education, prevention, and therapy. SG can be defined as digital games and game-based applications going beyond fun, including gaming concepts and/or technologies plus further technologies and (domain-specific) methodologies (see fig. 1). Hence, SG have a great potential for many application areas – our bold hypothesis is that Serious Games are useful for virtually all possible application domains and markets.

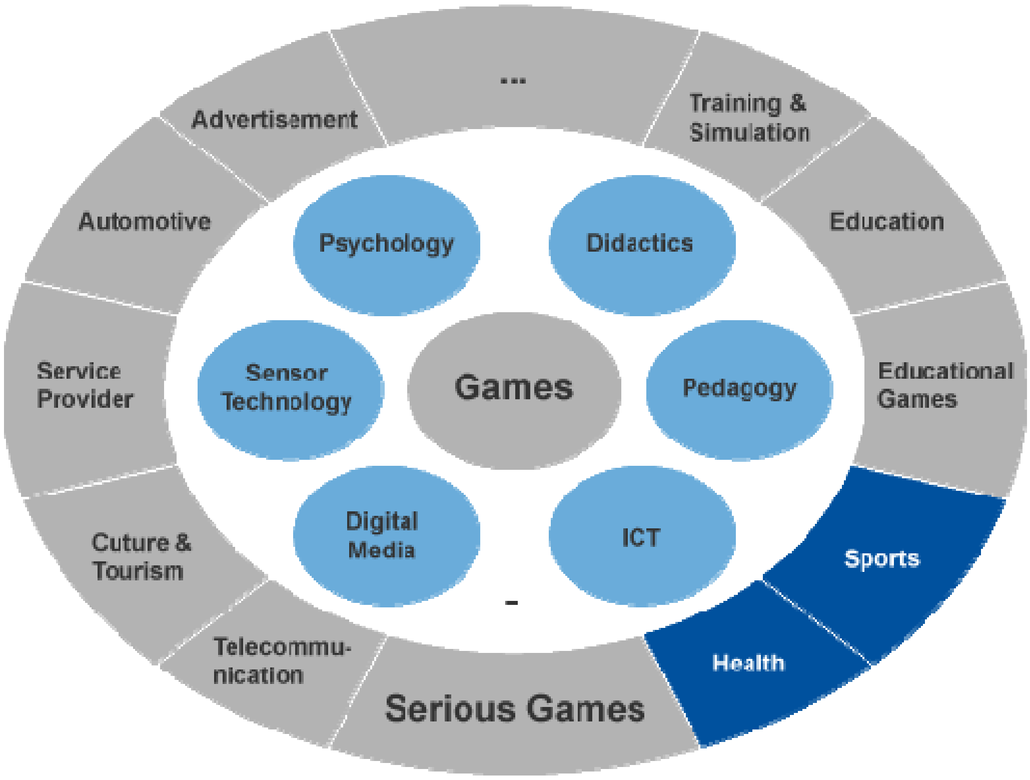

Figure 1. Understanding of Serious Games.

During the GameDays 2010 discussions focussed on two very important application areas: Sports and Health. Applying SG to Sports and Health is on the one hand very promising because of great significance of sport, exercising, and health-related behaviour like physical activity, nutrition, smoking, sexual behaviour, or social behaviour to name but a few. On the other hand fig. 1 illustrates that reconciling true gaming experience and changing behaviour is not at all trivial. A dynamic balance has to be established between fun, enjoyment, flow etc. on the one hand and achieving the serious goals and purposes on the other hand.

In this Special Edition of the International Journal of Computer Science in Sport selected papers are published that contribute substantially to the discussion of SG in Sport and Health.

The topics of the scientific papers range from fundamental issues of SG in Sports and Health to concrete applications in the fields of Sports and Health-related behaviour. The editors feel confident that this selection of papers confirms that high-quality research and development (R&D) is going on in the SG realm. The papers also show that despite some successful proofs of concept R&D concerning SG in Sports and Health is still in its infancy. The key problems like sustainability, sound scientific substantiation, adequate balance of reality and virtuality and appropriate settings are still to be solved. To be successful R&D projects require interdisciplinary cooperation of experts in technology, psychology, pedagogy, and the application fields like Sports and Health. The editors also hope that more researchers and developers are inspired by the papers to start engaging in this interesting and challenging field. Needless to say, that high-quality R&D has its price.

Design of Video Games for Children's Diet and Physical Activity Behavior Change

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Abstract

Serious video games (VG) offer new opportunities for promoting health related diet and physical activity change among children. Games can be designed to use storylines, characters, and behavior change procedures, including modeling (e.g., engaging characters make changes themselves, and face and overcome challenges related to fruit and vegetable (FV) and physical activity (PA) goal attainment and/or consumption), skill development (e.g., asking behaviors; virtual recipe preparation), self regulatory behaviors (problem solving, goal setting, goal review, decision making), rewards (e.g., points and positive statements generated by the program), immediate feedback (e.g., through characters and/or statements that appear on the computer screen at critical decision points), and personalization (e.g., tailored choices offered at critical junctures, based on responses to baselines questions related to preferences, outcome expectancies, etc). We are in the earliest stages of learning how to optimally design effective behavior change procedures for use in VG, and yet they have been demonstrated to change behavior. As we learn, VG offer more and better opportunities for obesity prevention that can adjust to individual needs and preferences.

VIDEO GAME, MEDIATING VARIABLES, HEALTH BEHAVIOR CHANGE PROCEDURES, CHILDREN, DIET, PHYSICAL ACTIVITY

Introduction

Youth obesity has risen dramatically over the past few decades (Ogden et al., 2006). Overweight and obesity combined reached approximately 50% in some US ethnic minority children (Baranowski et al., 2006). Obese youth are more likely to become obese adults (Serdula et al., 1993). The prevalence of obesity has been implicated in increased risk for type 2 diabetes (T2D) (Fagot-Campagna et al., 2000). Increased fruit and vegetable (FV) intakes are the only food groups that have shown some consistency in association with decreasing the risk of obesity (Dennis, Flack, & Davy, 2009; Rolls, Drewnowski, & Ledikwe, 2005) and T2D (Kastorini & Panagiotakos, 2009). Unfortunately youth consumed well below the recommended minimum of five FV servings (Baranowski, Smith et al., 1997; Domel et al., 1993) and were physically active

(PA) for much less than the recommended 60 min of moderate to vigorous physical activity (MVPA) per day (Troiano et al, 2008). Finding ways to help youth consume more FV and be more PA will help decrease their risk of developing adult obesity and T2D.

Serious video game (VG) interventions have been effective at promoting dietary change among youth (Baranowski, Baranowski, Cullen, Marsh et al., 2003). Our recent review demonstrated that most health-related VG had some positive outcome (Baranowski, Buday, Thompson, & Baranowski, 2008). Serious VG offer the promise of effective behavior change by immersing children in a story that exposes them to related behavior change procedures within the game (Baranowski et al., 2008), and have the potential for broad public health benefit because, once created, they can be made widely available at low cost. To the extent serious VG increase FV intake and PA, they can contribute to healthier lifestyle changes among children. Starting those changes early offers promise of preventing both adult and child obesity.

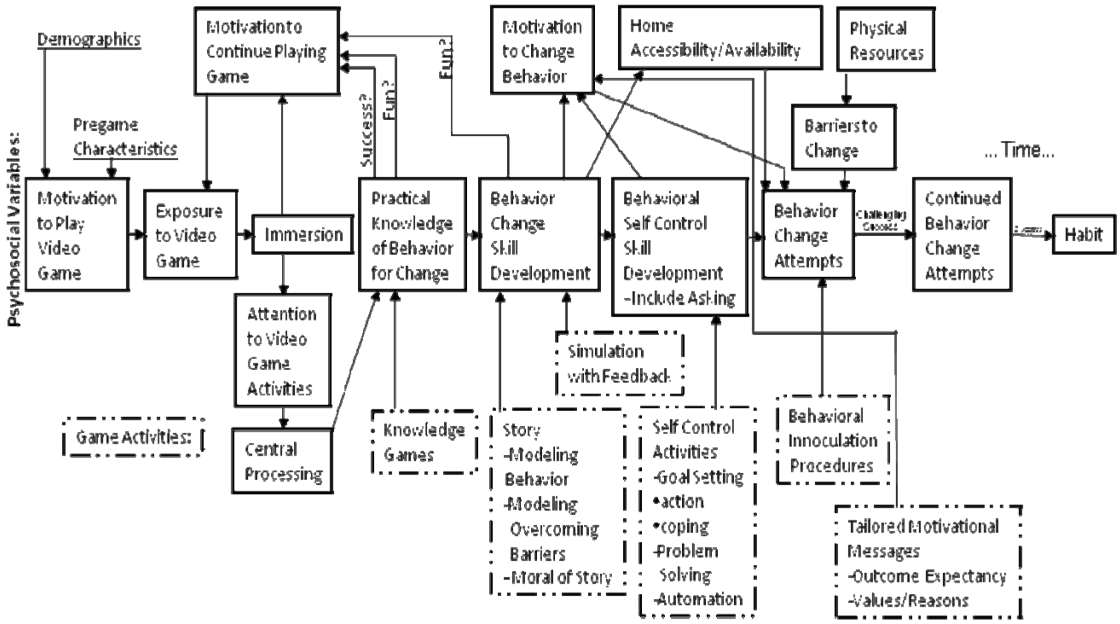
Model of Behavior Change

Behavior change interventions must be predicated on proven highly predictive and causal models of behavior (Baranowski, Cerin, & Baranowski, 2009). Mediators are intermediate variables in the pathways between the VG intervention and dependent variables, and represent the mechanisms through which the independent variables exert their effect (Baranowski, Lin, Wetter, Resnicow, & Hearn, 1997; Bauman, Sallis, Dzewaltowski, & Owen, 2002). Some VG have a narrow focus and tend to emphasize increased knowledge (Peng, 2009) which may be necessary, but insufficient, for behavior change (Contento et al., 1995). In behavioral interventions, mediators are obtained from the theory or theories selected to guide the development of the intervention (Baranowski, Anderson, & Carmack, 1998; Baranowski, Lin et al., 1997). It is common to have more than one mediator (Baranowski, Lin et al., 1997; Baranowski et al., 1998), and it is likely that behavior is moderated (i.e. different outcomes at different levels of the variable) by factors other than mediators (e.g. demographics) (Baranowski, Lin et al., 1997). It is critical to use theories that have high predictive value (otherwise changing a variable with low predictive value would not substantially change the behavior); are causal (changing a noncausal variable would not change the behavior); clearly identify and target mediators with specific change procedures (Michie & Prestwich, 2009); and assess potential moderators (to design different intervention procedures for different levels of the moderating variable) (Baranowski, Lin et al., 1997). A behavior change procedure is an activity or message delivered by the VG that is targeted at the meaningful mediator.

A conceptual model is helpful that describes the process by which behavior change occurs and identifies where behavior change procedures influence the process. The model in Figure 1 is a preliminary specification of such a model. The sequence of influences across the psychosocial (mediating) variables to behavior change is in the middle and top rows; the FV behavior change procedures are along the bottom. This model incorporates ideas from Self Determination Theory (Ryan & Deci, 2000), the Elaboration Likelihood Model (Petty & Cacioppo, 1986), and Social Cognitive Theory (Bandura, 1986; Baranowski, Perry, & Parcel, 2002). Specifying this model enables clear tests of whether the intervention components influence mediators which should in turn provide future guidance to enhance the effectiveness of methods to achieve change in the desired directions (Baranowski, Lin et al., 1997; Baranowski et al., 1998).

Designing interventions to effect change in mediators is likely to result in a body of scientific knowledge about how interventions change behavior.

Figure 1. Process Model of Possible Mechanisms for Children's Dietary and Physical Activity Change in Video Games



Self Determination Theory (SDT) (Ryan & Deci, 2000) posits motivation as the strongest factor driving behavior. Motivation can be intrinsic (i.e. the joy of doing the behavior – e.g. preference for eating FV, fun or enjoyment from playing games) or extrinsic (i.e. influences external to the individual- e.g. parent praises child for eating fruit). Intrinsically motivated behavior tends to be sustained for a greater length of time compared to extrinsically controlled behavior, which requires continued reinforcement from someone (e.g. a prize, etc). SDT posits three factors promote intrinsic motivation: (1) competence (similar to self-efficacy, abilities to successfully do the behavior), (2) autonomy (independence to choose the behavior, control over the behavior), and (3) relatedness (ties to other people, agreement with their own deeply held personal values). Food-related values explaining why people select certain types of foods have been documented (Resnicow et al., 2008). Previous studies have used personal values and their reasons (statements that tie values to behaviors) as motivation to change behavior (Resnicow et al., 2008). Reasons statements are similar to outcome expectancies, the only variable shown to repeatedly mediate dietary behavior changes (Cerin, Barnett, & Baranowski, 2009). In a study to repeatedly motivate obesity-related behavior change, a list of values and attributes was identified and given to the participants who were asked about their most important values and their relation with their health behavior. Motivational messages were then tailored to these personal values (Resnicow et al., 2008). Distinctions are drawn in the model (Figure 1) between initial motivation to play the game, motivation to continue playing, and motivation to change behavior. Each is critical to promoting health related behavior change through FV play, but influenced in different ways. Figure 1 is a starting point to guide VG development, and will be revised as we learn more both about how the behavior change process works (from basic behavior change research) and how to design VG procedures to promote behavior change.

The Elaboration Likelihood Model (ELM) (Petty & Cacioppo, 1986) proposes that messages are processed in two different pathways: central or peripheral. The central pathway is more likely to result in lasting change (Petty & Cacioppo, 1986), and involves conscious attention to and evaluation of the message (Petty & Cacioppo, 1986). The amount of elaboration (i.e., the cognitive effort devoted to processing a message) is determined by motivation and ability. If motivation and ability are high, elaboration is more likely to occur. If motivation and/or ability are low, elaboration is less likely to occur. Motivation is enhanced by personal relevance, while ability is enhanced by skill development (Petty & Cacioppo, 1986). Therefore, emphasizing personal relevance (i.e., tailoring to personal preferences and characteristics) (Kreuter et al., 2000) and enhancing ability to process and use the information (i.e., skill development) (Baranowski, Baranowski, Cullen, Marsh et al., 2003) likely result in high message elaboration, i.e. the child thinking more thoroughly about the messages in the VG, and promote behavior change. Computer-based programs were an effective channel for tailoring to personal characteristics (Webb, Joseph, Yardley, & Michie, 2010) and enhancing message elaboration (Evans et al., 1998).

Goal setting, often associated with personal control (self regulatory skills) in Social Cognitive Theory (SCT) (Bandura, 1986; Baranowski et al., 2002), is thought to be a critical component of behavior change. Goals regulate behavioral performance through four mechanisms: 1) goals direct attention and activity towards actions that are relevant to goal accomplishment (Locke, Shaw, Saari, & Latham, 1981), 2) mobilize resources (personal and social) needed to achieve the goal; 3) when there are no time constraints, goals affect persistence (i.e., directed effort over time) (Locke & Latham, 1994); and 4) guide self regulatory skills (e.g. problem solving), avoiding distractions (Bandura & Simon, 1977; Gollwitzer, 1999; Locke et al., 1981; Terborg, 1976). Characteristics of the goals also appear to make a difference. Specific**,** proximal (Bandura & Schunk, 1981)**,** appropriate (Maibach & Cotton, 1995) goals framed in terms of positive outcomes (Higgins, 1997) appear to be associated with goal attainment. Goal setting is a common feature in dietary behavior change interventions among youth (Baranowski et al., 1990; Baranowski et al., 2000, Coates, Jeffery, & Slinkard, 1981, Cullen, Bartholomew, & Parcel, 1997, Domel et al, 1993; Howison, Neidermyer, & Shortridge, 1988; Killen et al., 1989; Ma & Contento, 1997; Nader, Sallis, & Patterson, 1989; Parcel, Simons-Morton, O'Hara, Baranowski, & Wilson, 1989; Perry, Tremblay, Signorile, Kaplan, & Miller, 1997; Perry, Mullis, & Maile, 1985; Perry, Stone, & Parcel, 1990; Simons-Morton, Coates, & Saylor, 1984; Walter & Wynder, 1989; White & Skinner, 1988). A review of dietary intervention studies revealed use of the four step goal setting process was needed for positive results (Cullen, Baranowski, & Smith, 2001). Goal setting as a change procedure has recently been refined to consist of two separate, but connected, phases: goal intentions and implementation intentions (Gollwitzer, 1999). Goal intentions are a statement of what is intended (i.e., “My goal is to x”) (Brandstatter, Lengfelder, & Gollwitzer, 2001), whereas implementation intentions are a statement of how (e.g., when/where/in what way) the goal will be achieved (e.g., “If y happens, I will z”) (Gollwitzer, 1999). A critical feature of implementation intentions is that they provide an opportunity to determine in advance, rather than in situ, how to meet one’s goal by examining possible situations and selecting the ones most likely to lead to goal attainment, thereby creating commitment to a specific response in pre-identified situations (Brandstatter et al., 2001; Gollwitzer, 1999). Thus, environmental cues, rather than conscious thought, trigger a goal-directed response, thereby automatizing behavior, even in times of high cognitive load (Brandstatter et al., 2001), thereby making it more likely the goal will be attained

(Bargh, Gollwitzer, Lee-Chai, Barndollar, & Trotschel, 2001). Strong implementation intentions that link a cue with a planned response can even be effective at overcoming habitual behavior patterns (Gollwitzer, 1999). For implementation intentions to be effective, commitment to both goal intention and implementation intention is needed (Gollwitzer, 1999).

Incorporating VG elements that resonate with a target audience makes video games more appealing. Transportation Theory posits that one can be immersed into a story at the diegetic level (i.e., the game's story world) through mental imagery, emotional investment, and disregard for what is going on in reality, and likely affect beliefs or attitudes in accordance with the narrative (Green & Brock, 2002; Green & Brock, 2000). Because VG can be interactive narratives, transportation in a VG world also includes participatory activity in a virtual reality. Thus, the game environment must closely match player's expectations; the player's actions must have a significant impact on the game environment; and the established conventions of the environment must remain consistent throughout the game. Therefore, serious VG that have personal appeal, are perceived as personally relevant, and meet player's game-play expectations are more likely to create an immersive experience. While making immersion possible, the story can also be the source of SCT-based change procedures, such as modeling of behaviors, overcoming barriers to change, and enhancing motivation through the story arch and moral of the story (Baranowski et al., 2008).

Video Game Enabled Change Mechanisms

Researchers have started to systematically categorize intervention procedures and thereby promote comparability across studies (Michie & Prestwich, 2009). VG behavior change procedures need to be interfaced with these categories. Knowing how best to design these change mechanisms through VG delivered procedures is in early development. The original Squire's Quest! (SQ) (Baranowski, Baranowski, Cullen, Marsh et al., 2003), was a 10-session, 5-week Interactive Multi-Media version of the GIMME 5 curriculum, which took approximately 20 minutes/session to complete. The major themes of the GIMME 5 curriculum were included in SQ!, which was evaluated among elementary school students (Baranowski et al., 2000; Domel et al., 1993). In the VG, a child-friendly medieval motif with a castle, knights, king, queen and wizard, was used to promote FV intake. Based on SCT (Bandura, 1986) and ELM (Petty & Cacioppo, 1986), SQ! was designed to a) enhance children's preferences for FV, by increasing exposure and by virtually preparing FaSST (Fast, Simple, Safe, and Tasty) recipes; b) increase the home availability and accessibility of FV by using "asking skills" (i.e. activities to have children ask for their favorite FV at meals and snacks, put FV on the shopping list, ask to go shopping for their favorite FV, ask to go to fast food places that offer FV, and select FV off the fast food menus); c) reach out to parents through recipe preparation assignments; and d) virtually train the children in preparation of simple FV recipes and to set recipe goals (i.e., skill development). In addition, SQ! employed the self control techniques of setting goals for change, self monitoring performance, problem solving with unattained change goals, and self reward for attained goals (Bandura, 1986; Baranowski et al., 2002; Baranowski, Baranowski, Cullen, Marsh et al., 2003). Outcome analyses from 1600 4th grade students attending 26 Houston area elementary schools revealed an increase of 0.9 servings of FV after completing SQ! (Baranowski, Baranowski, Cullen, Marsh et al., 2003). Secondary analyses revealed that meal-specific changes occurred (Cullen, Watson, Baranowski, Baranowski, & Zakeri, 2005): fruit snack and lunch consumption of regular vegetables, two of the SQ! goals, significantly increased. The lack of change at breakfast and dinner indicated further work in this area was warranted. Attaining recipe preparation goals also resulted in more FV intake (Cullen, Watson, Zakeri, Baranowski, & Baranowski, 2007) and students with low baseline F preferences, attained more F goals resulting in increased post F consumption (Cullen et al., 2004). Among those with low baseline V consumption, attaining one V goal was related to higher post V consumption. For boys and those with high baseline FV consumption, attaining three general goals was related to increased FV intake. Low income students who attained the specific goal to consume F at snack, or FV at a convenience store, reported greater intakes of the target items (Cullen et al, 2004). This is one of the first reports that goal setting was effective in promoting dietary change among children.

The Girls' health Enrichment Multi-Site (GEMS) Fun, Food and Fitness (FFF) study pilot tested (n=39) an obesity prevention intervention among 8 year-old African American girls (Baranowski, Baranowski, Cullen, Thompson et al., 2003). The intervention included a four-week summer day camp followed by an 8-week web-based intervention. Skills (asking, negotiation, goal setting/review, problem solving, decision making, self reward, and motor skills) were taught during the summer day camp and reinforced and generalized during the 8-week web-based intervention. The web-based intervention included theory-based comic books, problem solving, decision making, goal setting and review, and fun game links. A corresponding 8-week parent (primarily mothers) web-based intervention was delivered to augment the girls' intervention. Self regulatory skills (e.g., problem solving, goal setting, and goal review) were major components of both web-based interventions. No separate evaluation of these skills was conducted due to the small sample, but changes in dietary intake between the treatment/comparison groups were in the desired direction (Baranowski, Baranowski, Cullen, Thompson et al., 2003).

The Fun, Food and Fitness treatment girls' web site was converted to a stand-alone e-Health intervention, called Food, Fun and Fitness Internet Program for Girls (Thompson, Baranowski, Cullen, & Baranowski, 2007). In the original GEMS FFF project, log on rates were less than desirable (<50%) (Baranowski, Baranowski, Cullen, Thompson et al., 2003). This was a concern, since log on rate determines intervention dose. The goal of this study was to determine the effect of reinforcement schedule (i.e., immediate vs. delayed) on log on rate. The log on rate was 74.5% and attrition was <10% (Thompson, Baranowski, Cullen, Watson, Canada et al., 2008). Significant increases were also observed in FV consumption, physical activity, and FV self efficacy between baseline and post assessment (Thompson, Baranowski, Cullen, Watson, Liu et al, 2008). While recruitment of participants for studies is often challenging, families were eager to participate in this web based intervention with cartoons and games (Thompson et al., 2006).

Computer-based manga-style comics (Allen & Ingulsrud, 2003) were designed along with parallel fact sheets promoting problem solving skills to overcome common barriers to physical activity among 14-15 year old African-American, Asian-American, Euro-American, and Hispanic youth. The study tested components of Dual Code Theory (Paivio, 1991) in relation to PA. Preliminary data suggest that computerized fact sheets, which encouraged the use of imagination, resulted in deeper levels of information processing and enhanced PA self-efficacy to a greater extent than the manga-style comics, which did not encourage the use of imagination. This suggests that fantasy-based storylines that encourage the use of imagination may promote deeper levels of information processing.

Two 8-week Boy Scout Achievement badge program interventions were developed: one emphasizing increased PA, and one emphasizing increased FV intake. Each program had troop activity and web interactivity components. The web-based interventions included Boy Scout characters modeling desired behaviors, goal setting and goal review. The Fit for Life Badge program (Jago et al., 2006) demonstrated an increase in the amount of light intensity PA in participants who began the program in the Spring, but no increase among participants who began the program in the Fall. This suggests that the intervention resulted in increased PA, but only if the participants received the intervention during a time period that facilitated increased PA. For the 5 A Day Badge program (Thompson et al., 2009), significant changes were observed in F consumption, home availability, and self-efficacy in the treatment group as compared to the comparison group immediately following the intervention, but not 6 months later. Low fat V consumption increased significantly in the Spring wave comparison group, but not in the treatment group.

Understanding player preferences and expectations should enhance the development of effective, immersive serious behavior change VG. While studies have reported ethnic and gender differences in time spent playing VG and game-play preferences, few have examined regional differences in these variables. We employed both quantitative (surveys) and qualitative (focus groups) methods to determine preferences for storyline genres and plot content of non-violent VG as well as computer access, knowledge and game-play frequency among low-income urban middle school students in Texas (n=196) and rural middle school students in North Carolina (n=66) (Thompson, Thompson et al, 2010). Lower income White and Other/Native American students played VG more frequently than African-American or Hispanic students. North Carolina students were more likely to have home computers than Texas students. Although focus group participants preferred action VG with some violence, they had positive reactions to challenging adventure VG with male and female characters of diverse ethnicities and narratives without overt sexual overtones.

Based on these middle-school student preferences, two VG, "Escape from Diab" and "Nanoswarm: Invasion from Inner Space", were designed to enable adolescents to modify diabetes-related lifestyle behaviors (FV and W intakes, PA, and physical inactivity behavior change) (Thompson, Baranowski et al., 2010). The games were immersive (story with interesting likeable characters), interactive (responded to player's input), adaptive (tailored to player's behaviors, values, and psychosocial characteristics), and entertaining (used compelling narrative, characters and settings to make learning fun). The games presented challenging, but doable: 1) practical knowledge-based games that used mastery learning to enable children to learn what constitutes desired behavior (e.g. "What counts as a vegetable?" taught children not to increase french-fries, avocados, or fried onion rings to meet their dietary change goals); 2) goal-setting activities tailored to a child's current behaviors and preferences; 3) problem solving routines to enable children to identify effective strategies to overcome likely barriers to behavior changes; 4) motivational statements tailored to a child's values; and 5) energy balance games to enable children to select appropriate portions and aerobic/strength enhancing physical activities.

Each VG had 9 sessions with approximately 40 minutes of game-play per session, totaling approximately 6 hours of total game-play. At the end of each session, the child could return to re-play non-behavior change mini games, and related video segments, but could not redo the goal review or goal setting portions of the game. A session by session description of each of the components in Diab has been published (Baranowski et al., 2010). There was progressively increasing complexity in the energy balance games across sessions. Despite randomization there were some differences in mean levels by group at baseline and no differences at post 1 assessment. The preliminary diet outcome data analyses revealed statistically significant ($p<0.000$) impact on FV intake (effect size (f)=0.17), and it's component F ($f=0.15$, $p<0.002$) and regular V ($f=0.09$, $p<0.064$) at post 3. This reflected an increase in the treatment group of 0.42 FV servings and in the control group a decline of 0.61 FV servings, or a combined change difference of approximately 1 FV serving. For PA, there was a suggestive increase in minutes of MVPA ($f=0.08$, $p<0.107$). This reflected an increase in the treatment groups of 2.6 min MVPA at immediate post and in the control group a decline of 4.3 min MVPA in the same time intervals or approximately 7 minutes difference. These behavior changes are comparable to or better than most reported in the literature with children. There were no changes in BMI indicators, but the time interval (2-3 mo) was too short to expect changes. Post game questionnaires with children and interviews with parents revealed that most children (80-90%) enjoyed playing both Diab and Nano.

Active VG may promote enhanced physical activity. Several active VG have been demonstrated to promote moderate to vigorous physical activity when done by the right people under the right circumstances (Barnett, Baranowski, & Cerin, 2010). Two field studies, however, indicated that children often get bored with the games after a week and no longer used them (Barnett et al, 2010). We have been funded to conduct an experiment in which children were randomly assigned to receiving a Wii console and two active VG or a Wii console and two inactive VG, and observe their use and activity over a six week period per game. Children in both conditions wear an accelerometer for a week at baseline, the first and sixth weeks after receiving the first VG, and the first and sixth weeks after receiving the second VG. A nice feature of the Wii is an internal record of when a Wii VG was played on that unit, thereby providing an objective measure of VG use.

Even more innovative ways are needed to use VG to promote behavior change. Vegetable (V) consumption has been associated with lower caloric intake (Rolls, Ello-Martins, & Tohill, 2004), lower fat intake (Gorbach et al., 1990; Stevens, Glasgow, Toobert, Karanja, & Smith, 2003; Subar, Ziegler, Patterson, Ursin, & Graubard, 1994; Ursin et al; 1993) and lower body mass index (BMI) (Crooks, 2000; Tohill, Seymour, Serdula, Kettel-Khan, & Rolls, 2004). V parenting practices have influenced children's intake (Fisher, Mitchell, Smiciklas-Wright, & Brich, 2002). Authoritative parenting practices in particular were associated with increased children's V intake (Patrick & Nicklas, 2005) and decreased obesity (Wardle & Carnell, 2006). Interventions to enhance authoritative V parenting practices should increase children's V intake and lower risk of overweight (Epstein et al., 2001). Authoritative V parenting can be thought of as a skill based performance, i.e. a parent has a set of skills (or does not) for effectively encouraging their child to eat vegetables and uses those skills during meals. "Training" with simulations of interactions and feedback on performance should enhance skill based performance (Salas & Cannon-Bowers, 2001). Simulation of parent-child feeding interactions with modeling of the parenting behavior and feedback on quality of performance (i.e. "training") should build V parenting skills and self efficacy (Salas & Cannon-Bowers, 2001). VG simulating real world experiences have been sophisticated enough to train adults in learning to fly airplanes (Goettl & al., 1996; Gopher, Weil, & Bareket, 1994; Jentsch & Bowers, 1998). We are working on simulating the parent's experience in parent-child feeding interactions to train parents in effective V parenting skills.

Discussion

Intervention research in general needs strong tests of models of behavior, behavior change and of the efficacy and effectiveness of the touted behavior change procedures (Baranowski et al., 2009). VG interventions need this as well. From a research design perspective a VG is a perfect purveyor of behavior change research because once programmed, it provides a constant stimulus. That is, in contrast to program delivery by humans, VG just delivers what was programmed in exactly the same way every time. Thus, it is not affected by how the deliverer felt that morning, whether they were experiencing a need to control or humiliate others, or other human frailties. In this way the VG is a perfect instrument for designing behavior change experiments. Since behavior change procedures (e.g. goal setting) do not work in isolation from other knowledge and motivational components of an intervention, one behavior change procedure in a VG can be selected and systematically varied within an otherwise constant intervention. For example, Thompson and colleagues selected goal setting within the original Squire's Quest! game, which was demonstrated to increase 4th grade children's fruit and vegetable consumption, and have systematically varied goal intentions (yes/no) and implementation (yes/no) intentions. Thus within the context of an otherwise successful intervention, the game will test the separate and combined contributions of goal and implementation intention to behavior change. This is a very promising method for testing change procedures that should be used in other studies.

Little has been said about "fun". VG playing is fun, which serves as an intrinsic motivator. Why VG playing is fun is probably some combination of active involvement (interactivity), overcoming challenges, making choices and observing consequences without placing one's self at risk, immediate feedback, increasing difficulty through levels of game play (difficult but not impossible challenges), and personally relevant story and characters, in meaningful situations. Research is needed on why VG are fun and how to maximize this fun experience to maximize the effectiveness of VG for behavior change.

Conclusion

Games can be designed to use storylines, characters, and behavior change components, including modeling (e.g., engaging characters face and overcome challenges related to FV and PA goal attainment and/or consumption), skill development (e.g., asking behaviors), self regulatory behaviors (problem solving, goal setting, goal review, decision making), rewards (e.g., points and positive statements generated by the program), immediate feedback (e.g., through characters and/or statements that appear on the computer screen at critical decision points), and personalization (e.g., tailored choices offered at critical junctures, based on responses to baselines questions related to preferences, outcome expectancies, etc). We are in the earliest stages of learning how to optimally do this in VG. As we learn, VG offer more and better opportunities for obesity prevention.

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References

Allen, K. & Ingulsrud, J. (2003). Manga literacy: popular culture and the reading habits of Japanese college students. *Journal of Adolescent and Adult Literacy, 46*, 674.

Bandura, A. (1986). *Social Foundations for Thought and Action: A Social Cognitive Theory*. Englewood Cliffs, NJ: Prentice Hall.

Bandura, A. & Schunk, D. H. (1981). Cultivating competence, self-efficacy, and intrinsic interest through proximal self-motivation. *Journal of Personality and Social Psychology, 41*, 586-598.

Bandura, A. & Simon, K. (1977). The role of proximal intentions in self-regulation of refractory behavior. *Cognitive Therapy Research, 1*, 177-193.

Baranowski, T., Anderson, C., & Carmack, C. (1998). Mediating variable framework in physical activity interventions. How are we doing? How might we do better? *American Journal of Preventive Medicine, 15* (4), 266-297.

Baranowski, T., Baranowski, J., Cullen, K. W., Marsh, T., Islam, N., Zakeri, I., et al. (2003). Squire's quest! Dietary outcome evaluation of a multimedia game. *American Journal of Preventive Medicine, 24* (1), 52-61.

Baranowski, T., Baranowski, J., Cullen, K. W., Thompson, D. I., Nicklas, T., Zakeri, I., et al. (2003). The Fun, Food and Fitness Project (FFFP): The Baylor GEMS pilot study. *Ethnicity and Disease, 13* (suppl 1), 1-30 -39.

Baranowski, T., Baranowski, J., Thompson, D., Buday, R., Jago, R., Abdelsamad, D., et al. (2010). Video game play induced health behavior change among children. *American Journal of Preventive Medicine, submitted.*

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for real: video games and stories for health-related behavior change. *American Journal of Preventive Medicine, 34* (1), 74-82.

Baranowski, T., Cerin, E., & Baranowski, J. (2009). Steps in the design, development and formative evaluation of obesity prevention-related behavior change trials. *International Journal of Behavioral Nutrition and Physical Activity, 6*, 6.

Baranowski, T., Cooper, D. M., Harrell, J., Hirst, K., Kaufman, F. R., Goran, M., et al. (2006). The STOPP-T2D Prevention Study Group. Presence of diabetes risk factors in a large U.S. eighth-grade cohort. *Diabetes Care, 29* (2), 212-217.

Baranowski, T., Davis Hearn, M., Resnicow, K., Baranowski, J., Doyle, C., Smith, M., et al. (2000). Gimme 5 fruit, juice and vegetables for fun and health: Outcome evaluation. *Health Education & Behavior, 27*, 96-111.

Baranowski, T., Henske, J., Simons-Morton, B., Palmer, J., Hooks, P., Tiernan, K., et al. (1990). Dietary change for CVD prevention among Black-American families. *Health Education Research, 5* (4), 433-443.

Baranowski, T., Lin, L., Wetter, D., Resnicow, K., & Hearn, M. (1997). Theory as mediating variables: why aren't community interventions working as desired? *Annals of Epidemiology, 7*, 89-95.

Baranowski, T., Perry, C. L., & Parcel, G. (2002). How individuals, environments, and health behaviors interact: Social Cognitive Theory. In K. Glanz, F. M. Lewis & B. Rimer (Eds.), *Health Behavior and Health Education: Theory, Research and Practice, 3rd edition* (pp. 246-279). San Francisco: Jossey-Bass.

Baranowski, T., Smith, M., Hearn, M., Lin, L., Baranowski, J., Doyle, C., et al. (1997). Patterns in children's fruit and vegetable consumption by meal and day of the week. *Journal of the American College of Nutrition, 16*, 216-223.

Bargh, J., Gollwitzer, P., Lee-Chai, A., Barndollar, K., & Trotschel, R. (2001). The automated will: nonconscious activitation and pursuit of behavioral goals. *Journal of Personality and Social Psychology, 81*, 1014-1027.

Barnett, A., Baranowski, T., & Cerin, E. (2010). Active videogames: An opportunity for increasing physical activity in youth (in press). *Journal of Physical Activity & Health*.

Bauman, A. E., Sallis, J. F., Dzewaltowski, D. A., & Owen, N. (2002). Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *American Journal of Preventive Medicine, 23* (2), 5-14.

Brandstatter, V., Lengfelder, A., & Gollwitzer, P. M. (2001). Implementation intentions and efficient action initiation. *Journal of Personality and Social Psychology, 81* (5), 946-960.

Cerin, E., Barnett, A., & Baranowski, T. (2009). Testing theories of dietary behavior change in young using the mediating variable model with intervention programs. *Journal of Nutrition Education and Behavior, 41* (5), 309-318.

Coates, T., Jeffery, R., & Slinkard, L. (1981). Heart healthy eating and exercise: introducing and maintaining changes in health behaviors. *American Journal of Public Health, 71*, 15-23.

Contento, I., Balch, G. I., Bronner, Y. L., Lytle, L., Maloney, S. K., Olson, C. M., et al. (1995). The effectiveness of nutrition education and implications for nutrition education policy, programs, and research: A review of research. *Journal of Nutrition and Education, 27*, 277-418.

Crooks, D. (2000). Food consumption, activity, and overweight among elementary school children in an Appalachian Kentucky community. *American Journal of Physical Anthropology, 112*, 159-170.

Cullen, K., Baranowski, T., & Smith, S. (2001). Using goal setting as a strategy for dietary behavior change. *Journal of the American Dietetic Association, 10*, 562-566.

Cullen, K., Bartholomew, K., & Parcel, G. (1997). Girl Scouting: An effective channel for nutrition education. *Journal of Nutrition Education, 29* (86-91).

Cullen, K. W., Watson, K., Baranowski, T., Baranowski, J. H., & Zakeri, I. (2005). Squire's Quest: intervention changes occurred at lunch and snack meals. *Appetite, 45* (2), 148-151.

Cullen, K. W., Watson, K. B., Zakeri, I., Baranowski, T., & Baranowski, J. H. (2007). Achieving fruit, juice, and vegetable recipe preparation goals influences consumption by 4th grade students. *International Journal of Behavioral Nutrition and Physical Activity, 4*, 28.

Cullen, K., Zakeri, I., Pryor, E., Baranowski, T., Baranowski, J., & Watson, K. (2004). Goal setting is differentially related to change in fruit & vegetable consumption among 4th grade children. *Health Education Research, 38*, 258-269.

Dennis, E. A., Flack, K. D., & Davy, B. M. (2009). Beverage consumption and adult weight management: A review. *Eating Behaviors, 10* (4), 237-246.

Domel, S., Baranowski, T., Davis, H., Thompson, W., Leonard, S., Riley, P., et al. (1993). Development and evaluation of a school intervention to increase fruit and vegetable consumption among 4th and 5th grade students. *Journal of Nutrition Education, 25*, 345-349.

Epstein, L., Gordy, C. C., Raynor, H. A., Beddome, M., Kilanowski, C. K., & Paluch, R. (2001). Increasing fruit and vegetable intake and decreasing fat and sugar intake in families at risk for childhood obesity. *Obesity Research, 9*, 171-178.

Evans, J., Collier, J., Crook, I., Garrud, P., Harris, P., MacKinlay, D., et al. (1998). Using multimedia for patient information - a program about nocturnal enuresis. *British Journal of Urology, 81* (Suppl 3), 120-122.

Fagot-Campagna, A., Pettitt, D. J., Engelgau, M. M., Burrows, N. R., Geiss, L. S., Valdez, R., et al. (2000). Type 2 diabetes among North American children and adolescents: an epidemiologic review and a public health perspective. *Journal of Pediatrics, 136* (5), 664-672.

Fisher, J. O., Mitchell, D. C., Smiciklas-Wright, H., & Brich, L. L. (2002). Parental influences on young girls' friut and vegetable, micronutrient and fat intakes. *Journal of the American Dietetic Association, 102*, 58-64.

Goettl, B. & al. (1996). Alternating task modules is isoderonal distributed training of complex tasks. *Human Factors 38*, 330-346.

Gollwitzer, P. (1999). Implementation intentions: Strong effects of simple plans. *American Psychology, 54*, 493-503.

Gopher, D., Weil, M., & Bareket, T. (1994). Transfer of skill from a computer game trainer to flight. *Human Factors 36*, 387-405.

Gorbach, S. L., Morrill-LaBrode, A., Woods, M. N., Dwyer, J. T., Seller, W. D., Henderson, M., et al. (1990). Changes in food patterns during a low-fat dietary intervention in women. *Journal of the American Dietetic Association, 90*, 802-809.

Green, M. & Brock, T. (2002). In the mind’s eye: Transportation-imagery model of narrative persuasion. In J. J. S. M. C. Green, & T. C. Brock (Eds.), *Narrative impact: Social and cognitive foundations* (pp. 315-341). Mahwah, NJ: Erlbaum.

Green, M. C. & Brock, T. C. (2000). The role of transportation in the persuasiveness of public narratives. *Journal of Personality and Social Psychology, 79* (5), 701-721.

Higgins, E. (1997). Beyond pleasure and pain. *American Psychologist, 52*, 1280-1300.

Howison, D., Neidermyer, F., & Shortridge, R. (1988). Field testing a fifth-grade nutrition education program designed to change food-selection behavior. *Journal of Nutrition Education, 20*, 82-86.

Jago, R., Baranowski, T., Baranowski, J., Thompson, D., Cullen, K., Watson, K., et al. (2006). Fit For Life Boy Scout Badge: Outcome evaluation of a troop & internet intervention. *Preventive Medicine, 42* (3), 181-187.

Jentsch, F. & Bowers, C. (1998). Evidence for the falidity of PC-based simulations in studying aire crew coordination. *International Journal of Available Psychology, 8*, 243-260.

Kastorini, C. M. & Panagiotakos, D. B. (2009). Dietary Patterns and Prevention of Type 2 Diabetes: From Research to Clinical Practice; A Systematic Review. *Current Diabetes Review, 5* (4), 221-227.

Killen, J., Robinson, T., Telch, M., Saylor, K., Maron, D., Rich, T., et al. (1989). The Stanford Adolescent Heart Health Program. *Health Education Quarterly, 16*, 263-283.

Kreuter, M. et al. (2000). *Tailoring Health Messages: Customizing Communication With Computer Technology*. Mahway, NJ: Lawrence Erlbaum Associates.

Locke, E., Shaw, K., Saari, L., & Latham, G. (1981). Goal setting and task performance: 1969-1980. *Psychological Bulletin, 90*, 125-152.

Locke, E. & Latham, G. (1994). Goal setting theory. In H. O'Neil & M. Drillings (Eds.), *Motivation: Theory and Research*. Hillsdale, NJ: Lawrence Erlbaum Associates Publishers.

Ma, F. & Contento, I. (1997). Development and formative evaluation of a nutrition education curriculum aimed at reducing fat intake in Taiwan elementary students. *Journal of Nutrition Education, 29*, 237-243.

Maibach, E. & Cotton, D. (1995). Chapter 3: Moving People to Behavior Change: A Staged Social Cognitive Approach to Message Design. In E. a. P. Maibach, R (Ed.), *Designing Health Messages: Approaches From Communication Theory and Public Health Practice* (pp. 41-64). Thousand Oaks, CA: Sage Publications.

Michie, S. & Prestwich, A. (2009). Are interventions theory-based? Development of a theory coding scheme. *Health Psychology, 29* (1), 1-8.

Nader, P., Sallis, J., & Patterson, T. (1989). A family approach to cardiovascular risk reduction: results from the San Diego Family Health Project. *Health Education Quarterly, 16*, 229-244.

Ogden, C., Carroll, M., Curtin, L., McDowell, M., Tabak, C., & Flegal, K. (2006). Prevalence of overweight in the United States, 1999-2004. *Journal of American Medical Association, 295* (13), 1549-1555.

Paivio, A. (1991). Dual Coding Theory: retrospect and current status. *Canadian Journal of Psychology, 45* (3), 255-287.

Parcel, G., Simons-Morton, B., O'Hara, N., Baranowski, T., & Wilson, B. (1989). School promotion of healthful diet and physical activity: impact on learning outcomes and self-reported behavior. *Health Education Quarterly, 16* (2), 181-199.

Patrick, H. & Nicklas, T. A. (2005). A review of family and social determinants of children's eating patterns and diet quality. *Journal of American College Nutrition, 24* (2), 83-92.

Peng, W. (2009). Design and evaluation of a computer game to promote a healthy diet for young adults. *Health Communication, 24* (2), 115-127.

Perry, C., Mullis, R., & Maile, M. (1985). Modifying the eating behavior of children. *Journal of School Health, 10*, 399-402.

Perry, C., Stone, E., & Parcel, G. (1990). School-based cardiovascular health promotion: the child and adolescent trial for cardiovascular health (CATCH). *Journal of School Health, 60*, 406-413.

Perry, A., Tremblay, L., Signorile, J., Kaplan, T., & Miller, P. (1997). Fitness, diet, and coronary risk factors in a sample of southeastern US children. *Applied Human Science, 16*, 133-141.

Petty, R. E. & Cacioppo, J. T. (1986). Communication and persuasion: Central and peripheral routes to attitude change. In (pp. 34). New York, Inc: Springer-Vergal.

Resnicow, K., Davis, R. E., Zhang, G., Konkel, J., Strecher, V. J., Shaikh, A. R., et al. (2008). Tailoring a fruit and vegetable intervention on novel motivational constructs: results of a randomized study. *Annals of Behavioral Medicine, 35* (2), 159-169.

Rolls, B. J., Drewnowski, A., & Ledikwe, J. H. (2005). Changing the energy density of the diet as a strategy for weight management. *Journal of American Dietetic Association, 105* (Suppl 1), 98-103.

Rolls, B., Ello-Martins, J., & Tohill, B. (2004). What can intervention studies tell us about the relationship between fruit and vegetable consumption and weight management? *Nutrition Reviews, 62*, 1-17.

Ryan R. M. & Deci E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychology, 55*, 68-78.

Salas, E. & Cannon-Bowers, J. A. (2001). The science of training: a decade of progress. *Annual Review Psychology, 52*, 471-499.

Serdula, M. K., Ivery, D., Coates, R. J., Freedman, D. S., Williamson, D. F., & Byers, T. (1993). Do obese children become obese adults? a review of the literature. *Preventive Medicine, 22*, 167-177.

Simons-Morton, B., Coates, T., & Saylor, K. (1984). Great sensations: a program to encourage heart healthy snacking by high school students. *Journal of School Health, 54*, 288-291.

Stevens, V. J., Glasgow, R. E., Toobert, D. J., Karanja, N., & Smith, K. S. (2003). One-year results from a brief, computer-assisted intervention to decrease consumption of fat and increase consumption of fruits and vegetables. *Prev Med, 36* (5), 594-600.

Subar, A. F., Ziegler, R. G., Patterson, B. H., Ursin, G., & Graubard, B. (1994). US dietary patterns associated with fat intake: The 1987 National Health Interview Survey. *American Journal of Public Health, 84*, 359-366.

Terborg, J. (1976). The motivational components of goal-setting. *Journal of Applied Psychology, 61*, 613-621.

Thompson, D., Baranowski, T., Baranowski, J., Cullen, K., Jago, R., Watson, K., et al. (2009). Boy Scout 5-a-Day Badge: outcome results of a troop and Internet intervention. *Preventive Medicine, 49* (6), 518-526.

Thompson, D., Baranowski, T., Buday, R., Baranowski, J., Thompson, V., Jago, R., et al. (2010). Serious Video Games for Health: How Behavioral Science Guided the Development of a Serious Video Game. *Simulation & Gaming* (in press).

Thompson, D., Baranowski, J., Cullen, K., & Baranowski, T. (2007). Development of a theory-based internet program promoting maintenance of diet and physical activity change to 8 year old African American girls. *Computers & Education, 48* (3), 446-459.

Thompson, D., Baranowski, T., Cullen, K., Watson, K., Canada, A., Bhatt, R., et al. (2008). Food, Fun and Fitness Internet program for girls: influencing log-on rate. *Health Education Research, 23* (2), 228-237.

Thompson, D., Baranowski, T., Cullen, K., Watson, K., Liu, Y., Canada, A., et al. (2008). Food, fun, and fitness internet program for girls: pilot evaluation of an e-Health youth obesity prevention program examining predictors of obesity. *Preventive Medicine, 47* (5), 494-497.

Thompson, D., Canada, A., Bhatt, R., Davis, J., Plesko, L., Baranowski, T., et al. (2006). eHealth recruitment challenges. *Evaluate Program Planning, 29* (4), 433-440.

Thompson, V., Thompson, D., Baranowski, T., Creighton, D., Cullen, K., Baranowski, J., et al. (2010). Understanding "serious video game" storyline and genre preferences related to game immersion among low-income ethnically diverse urban and rural adolescents (in press). In *Internet Access and the Digital Divide*: Nova Publishers.

Tohill, B., Seymour, J., Serdula, M., Kettel-Khan, L., & Rolls, B. (2004). What epidemiologic studies tell us about the relationship between fruit and vegetable consumption and body weight. *Nutrition Reviews, 64*, 365-374.

Troiano, R. P., Berrigan, D., Dodd, K. W., Masse, L. C., Tilert, T., & McDowell, M. (2008). Physical activity in the United States measured by accelerometer. *Medical Science & Sports Exercise, 40* (1), 181-188.

Ursin, G., Ziegler, R. G., Subar, A. F., Graubard, B. I., Haile, R. W., & Hoover, R. (1993). Dietary patterns associated with a low-fat diet in the National Health Examination Follow-up Study: Identification of potential confounders in epidemiologic analyses. *American Journal of Epidemiology, 137*, 916-927.

Walter, H., & Wynder, E. (1989). The development, implementation, evaluation, and future directions of a chronic disease prevention program for children: The "Know Your Body" studies. *Preventive Medicine, 18*, 59-71.

Wardle, J., & Carnell, S. (2006). Parental feeding practices and child weight. *Acta Paediatricia, 96*, 5-11.

Webb, T. L., Joseph, J., Yardley, L., & Michie, S. (2010).Using the internet to promote health behavior change: a systematic review and meta-analysis of the impact of theoretical basis, use of behavior change techniques, and mode of delivery on efficacy. *Journal of Medical Internet Research, 12* (1), e4.

White, A. & Skinner, J. (1988). Can goal setting as a component of nutrition education effect behavior change among adolescents? *Journal of Nutrition Education, 20*, 327-335.

Physical activity and motor fitness of children and adolescents - Approaches for Serious Games

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Abstract

Physical activity is of inestimable value for health and the motoric development of young people. But in the course of late childhood and adolescence, it becomes less important compared to other leisure activities which do not contain any physical strain. The decrease of physical activity and the resulting decline of motor fitness are reflected in the outcomes of various studies. Hence, strategies are needed to maintain the children's motivation in physical activity. The enormous popularity of Serious Games could possibly be one strategy because Exergames give an access to sport or to a more active lifestyle.

As an isolated movement pattern, Serious Games are no alternative or even a surrogate for real physical exercise. It is difficult to enable a realistically social interaction during virtual sport which has a positive influence on social development. Furthermore indoor video gaming is not comparable to outdoor exercises due to the lack of external influences like wind or audience, which are important contributions to the "adventure" of sport. But in combination and addition to real sport, Serious Games can contribute to the preservation and increase of motor fitness and children's pleasure in motion.

PHYSICAL ACTIVITY, MOTOR FITNESS, SERIOUS GAMES

Introduction

Physical education, athletic activities in sports clubs or recreational exercise rank among the most popular activities in children and are of inestimable value for their motoric development, health and well-being. In the course of adolescence it is not the passion for physical exercise but the real exertion that becomes less important. Other leisure activities such as watching TV or listening to music which do not contain any physical strain and can be performed inside are preferred. The fact that 80% of all children and adolescents become a sports club member in the course of childhood and adolescence cannot belie the increasing lack of motion, as well (Woll & Bös, 2004).

In order to maintain the children's motivation in doing sports and to pique their interests in sport accordingly, it is important that they simply enjoy motion. The more fun children have in doing sports, the longer they will stick to it. But whereas climbing up trees or romping in the forest has received broad interest among children in former decades, such activities are not very popular with today's young generation. Motion culture has changed dramatically – activities which meant fun and pleasure in former times are nowadays boring and not interesting for children and adolescents any more.

Maybe, facilities and the use of modern communication and information technology could solve the problem?! In order to show possible approaches for Serious Games in the field of physical activity of children and adolescents, the current state and development of motor fitness and physical activity ought to be described first. Achieving sustained success with appropriate methods can only be realized based on the knowledge of strengths and weaknesses in the motor fitness of today's young people.

Motor fitness report

Nowadays the media often reflect badly on children's and adolescents' fitness level. Compared to former generations they are said to perform worse concerning motor fitness, extent of daily physical activity or other parameters like body mass which are related to health. But from a science standpoint, this question could not be clearly answered for a long time. There are indeed some national and international surveys published in the last 20 years that deal with this subject. However, the assessment of motor fitness and physical activity is not subject to standardized criteria; furthermore the investigated samples do not provide a representative image of the whole population. Hence, the existing data only allows very limited statements on the actual situation and development of motor fitness and physical activity.

Comprehensive reviews about motor fitness were published by Boes in the years 2003 and 2008 (Boes, 2003; Boes et al., 2008). The outcomes are based on the data analysis of thousands of children and adolescents aged 4 to 15 years. In eight research studies, motor fitness was assessed using a test profile commonly known as "Körperkoordinationstest für Kinder" (Kiphard & Schilling, 1970). The percentage of those children who need to be aided is 27% on average and ranges from 17% to 61% depending on the single studies. The BML test profile (commonly known as "Bestimmung der motorischen Leistungsfähigkeit"; Dordel, 1997), was used in four studies. The average percentage of children showing anomalies is 40% and ranges from 30% to 55%. The percentage in other test profiles used in studies such as "Allgemeiner Sportmotorischer Test 6-11", "MOT 4-6", "8-Minuten-Lauf", ergometry or orthopedic tests is generally higher than the expected value of 16% from the Gaussian distribution of the standardisation of test profiles.

Moreover, the German scientist Dordel (2000) concludes in a review comprising 13 studies of motor abilities in young children that primary-school pupils are worse grounded in motor coordination than in former times and that these differences occur more often among children living in cities than among those living in rural areas. Furthermore, the dimension of worse motor coordination increases as the children get older.

But there are also some existing research studies which contradict this adverse trend of deteriorated motor fitness. The outcomes of these studies show that there are no significant differences in motor fitness compared to standard values (Kretschmer und Giewald, 2001; Köster, 1997; Englicht, 1997).

Research studies dealing with secular trends are characterized by the fact that the motor performance abilities of children and adolescents are investigated with the same test profile over a period of many years. Those studies report an explicit loss of motor fitness compared to former generations (Klaes, Cosler, Rommel, & Zens, 2003; Klaes, Poddig, Wedekind, Rommel, & Zens, 2008; Raczek, 2002). During an observation period of 20 years, 10-year old boys were tested with ten identical motoric test profiles by Boes and Mechling. In the year 1976 the scientists had a sample of 342 boys and of 115 boys in the year 1996. In seven out of ten tests, the boys tested in 1996 showed a considerable loss of ability of 10% to 20% compared to those who were tested in 1976 (Schott, 2000).

Moreover, Boes (2003) tried to answer the question on historical changes of motor abilities in children and adolescents with a wide database. 54 meaningful studies from 43 scientific authors were comparatively analyzed and factored in his review based on a literature research, which dated from the year 1965 to the year 2002. The sample includes about 250.000 children and adolescents aged from 6 to 17 years. The data of five tests, endurance run (cardiorespiratory fitness), standing long jump (anaerobic strength), sit-ups (aerobic strength endurance), 20-meters run (speed) and forward trunk bending (flexibility) were statistically evaluated.
The outcomes of the different studies were statistically weighted and processed by regression analysis. Based on the outcomes, Boes (2003) states that motor fitness has shown a tendency to deteriorate by about 10% in the period from 1975 to 2002 in almost every test (see figures 1 to 5).

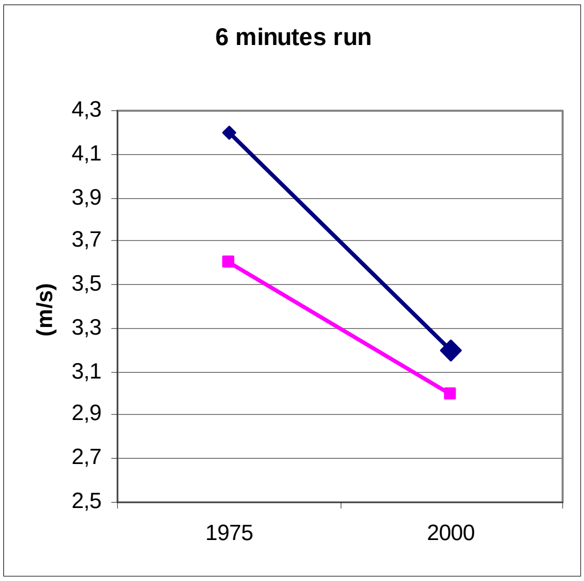

Fig. 1: 6 minutes run
(Boys: -24,7%, Girls: -15,8%)

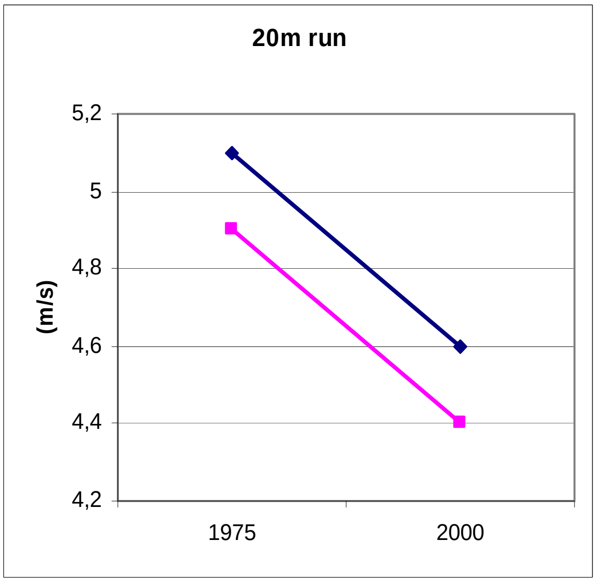

Fig. 2: 20m run
(Boys: -10,3%, Girls: -10,3%)

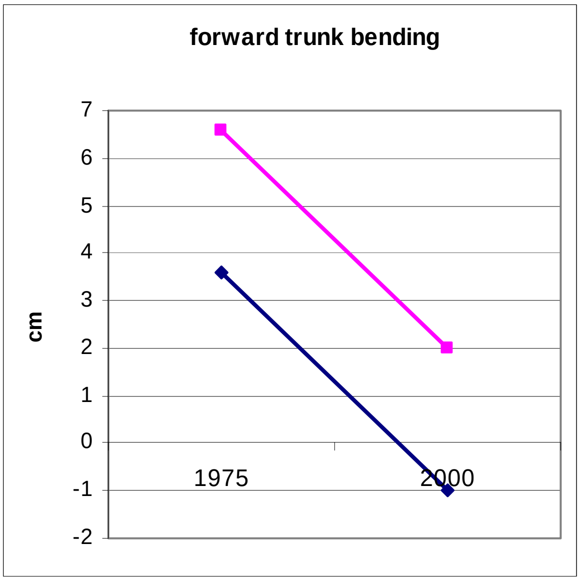

Fig. 3: forward trunk bending

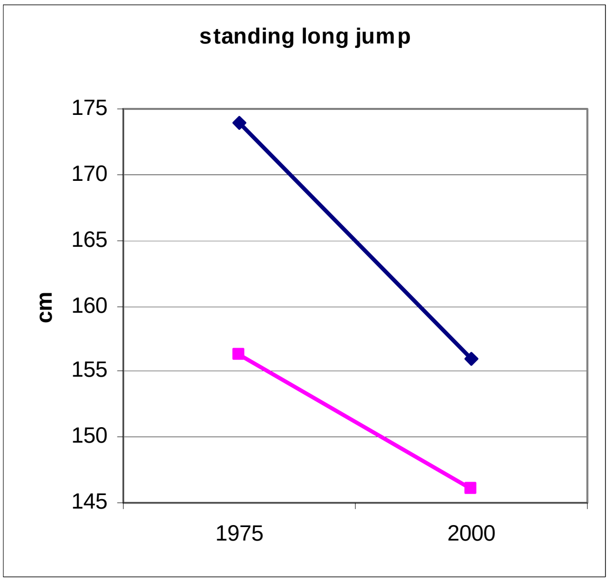

Fig.4: standing long jump
(Boys: -10,3%, Girls: -6,5%)

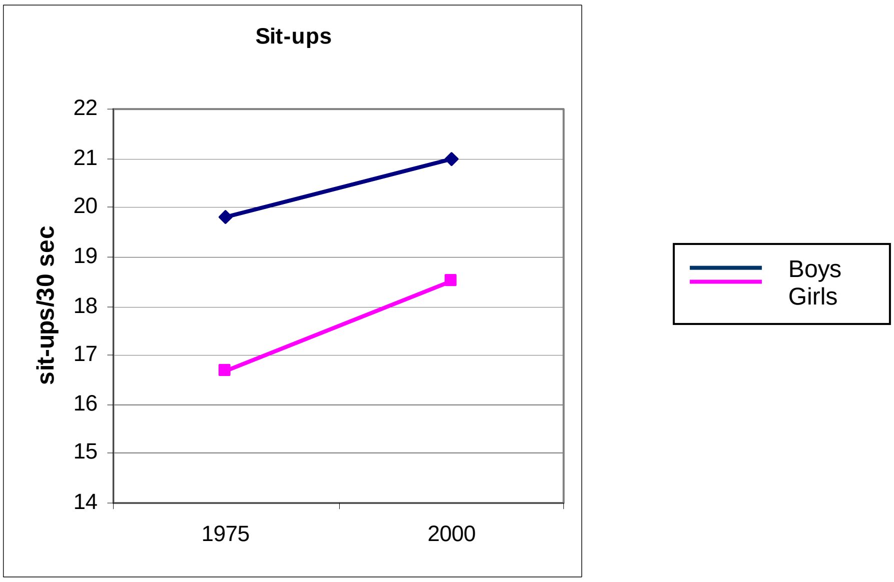

Fig. 5: sit-ups
(Boys: +6,1%, Girls: +11,2)

In the following review published in “Zweiter Kinder- und Jugendsportbericht”, Boes, Oberger, Laemmle, Opper, Romahn, Tittlbach, Wagner, Woll and Worth (2008) arrived at the differentiated conclusion that motor fitness deteriorated less in the age group of the 6 to 11 year olds (minus 6,7%) than in the older group aged between 12 and 17 years (minus 12,5%). This older group already seems to be under a stronger negative influence caused by the passive lifestyle than the younger group.

It is assumed that the reasons for the loss of motor fitness may be due to changes of body constitution (increase of body mass caused by imbalance of energy intake and energy expenditure) and increasing physical inactivity.

In summary it must be said, that there were neither any standardized, generally accepted tests for the assessment of motor fitness available nor any investigated samples which provide a representative image of the young population regarding motor fitness and physical activity. Hence, precise conclusions about motor fitness and the dimension of the loss of motor ability cannot be made based on the existing data. As a consequence, standardized test profiles for the assessment of motor fitness and for creating a representative baseline were postulated. This research gap was bridged by the "Motorik-Modul (MoMo)" as a part of the German Health Interview and Examination Survey for Children and Adolescents (KiGGS) initiated by the Robert-Koch-Institute in Berlin. In the years 2004 to 2006, the motor fitness and physical activity of more than 4,500 children and young people between the ages of 4 and 17 years was investigated in the context of this cross-sectional study. The test profile consists of 11 items measuring cardiorespiratory fitness, strength, coordination and flexibility. The test profile used is based on the "Deutscher Motorik Test", commonly known as "dmt 6-18" which was published in 2009 by Boes, Schlenker, Buesch, Laemmle, Mueller, Oberger, Seidel and Tittlbach (2009). The aim of the study is to investigate the current situation of motor fitness. The collected data on motor fitness moreover produce a representative database of Germany's young generation and will enable statements on current situation and development of motor fitness and physical activity in children and adolescents in the future.

Some fundamental outcomes of the "Motorik-Modul" are specifically mentioned below (Worth, Oberger, Wagner & Bös, 2008).
Performances in endurance, aerobic strength endurance and anaerobic strength increase in both sexes during childhood. Whereas boys can enhance their performances in the course of adolescence in nearly all condition-based abilities, the girls' performances in aerobic strength endurance and anaerobic strength (push-ups and standing long jump) stagnate after the 12th and 13th year of life (see figure 7). The girls increase their performances in late adolescence only in aerobic endurance (bicycle ergometer test), but the increment is considerably less than those of the boys (see figure 6).

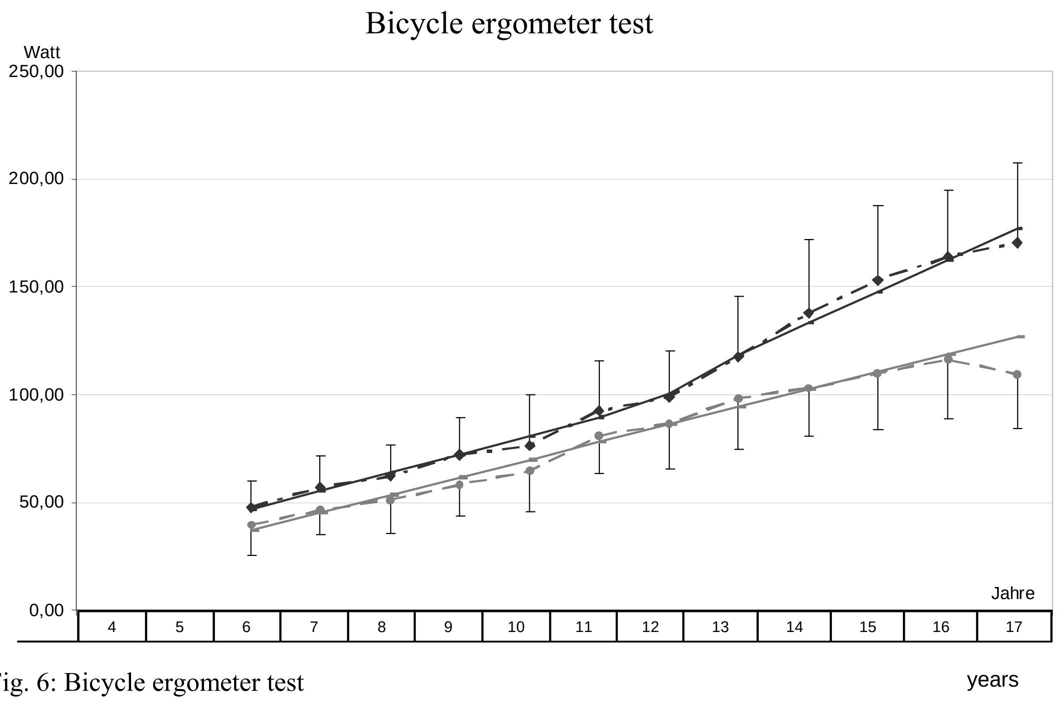

Fig. 6: Bicycle ergometer test

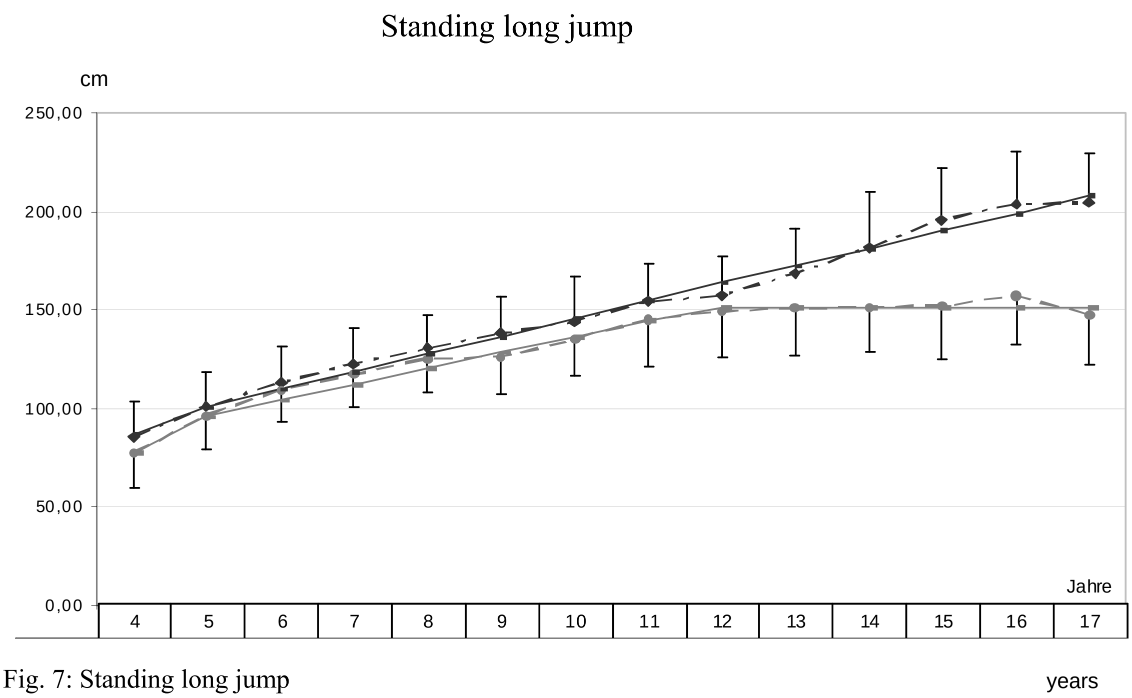

Fig. 7: Standing long jump

However, girls have a continuous advantage over the boys in gross motor coordination with static or dynamic precision such as standing on one leg or balancing backwards (see figure 8). There are no differences between boys and girls in gross motor skills coordination under time pressure (sideway jumping). In these three tests, an increment of performance from childhood to adolescence can be noticed, but it stagnates in the course of adolescence after the 11th and 12th year of life.

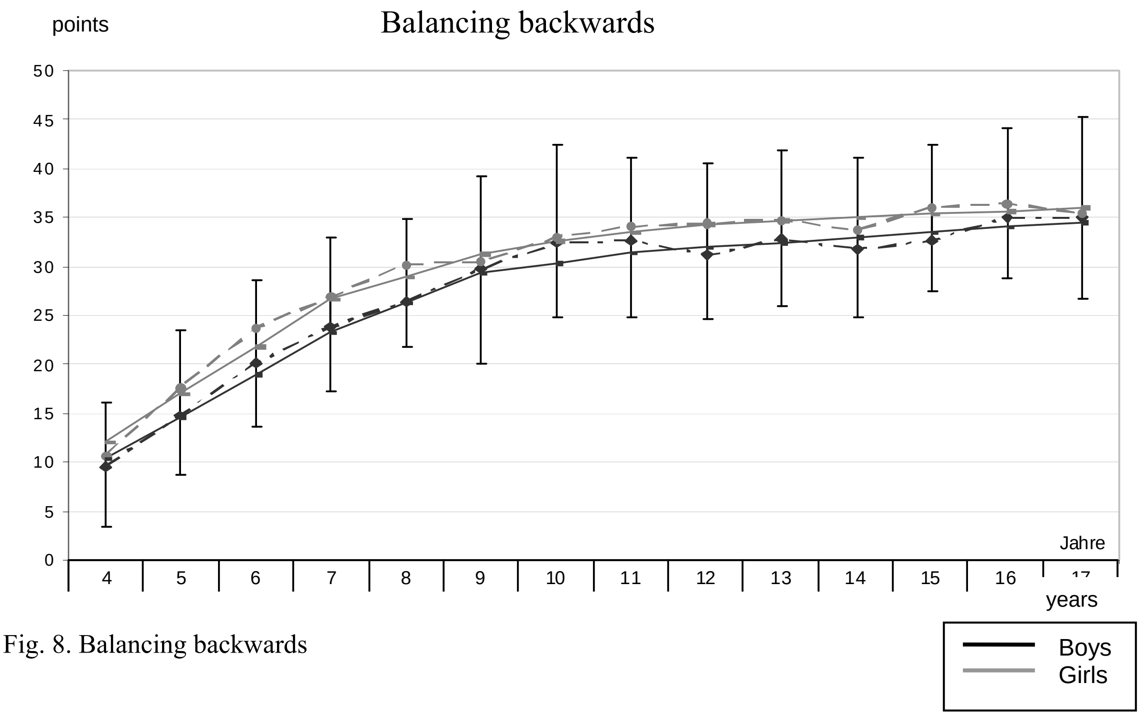

Fig. 8. Balancing backwards

The data analysis of development in fine motor coordination reveals a similar picture. While performance with precision (MLS line tracing) increases independent of gender with advancing age, it decreases continuously in the course of adolescence in the test of reaction time and fine motor coordination under time pressure (MLS inserting pins).

Gender-specific analysis shows better performances of girls in fine motor coordination with precision and under time pressure, but there is no difference between boys and girls in the test of reaction time.
The outcomes in the forward trunk bending test are gender-specific. As expected, girls are more flexible than boys over all age groups and the differences remain constant in the course of time.

With the “Motorik-Modul” it is possible for the first time to present representative data of motor fitness in German children and adolescents. The knowledge of the current situation may also be important for developing useful intervention programs.
The importance of wide motor advancement in childhood is demonstrated in published research in which the use of intervention programs was tested.
Over a research period of four years, Obst-Kitzmüller (2002) has investigated that motor fitness and social skills can be improved by daily physical education lessons. Similar effects can be achieved in projects called “active classroom” (in summary Laging, 2000). But the problem is, that intervention programs like those in schools are not transferable into the extracurricular life of today’s young generation and that it is impossible to reach intensities in physical education which are high enough yet to compensate for increasing physical inactivity in spare time.

Approaches for Serious Games

One possible and maybe decisive approach for Serious Games with regard to physical activity and motion is the interaction in childlike environment. Due to their fascinating animation effects, video game consoles like Nintendo Wii™ or Sony Playstation™ Eye Toy™, which offer interactive sport games (e.g. Wii Sports™ or EA Sports Active™), are getting more and more popular with children and adolescents. These interactive sport games are called Healthcare- or Exergames and represent a subgroup of Serious Games.
It is neither conceivable nor preferable that these kinds of exercises could completely substitute a real life sports activity. For instance the performances of the physical movement during a “virtual” and real-life sport activity are not even comparable. There are also serious doubts about the sustainability of virtual training. Due to the limited number of different games, a state of tedium could be reached after long duration of game play. Although technological improvement in the future is expected, it is hardly feasible to enable a realistically social interaction during sport. The contact with team members or one-to-one situations with an opponent especially show a tremendous and important influence of sport in the social development of children and adolescents.

Another positive aspect of the influence of sport during development of children and adolescents is being faced with new respectively different emotional situations, which is less pronounced in virtual games than in a real life activity. Furthermore an indoor video game is not really comparable to outdoor exercises due to the lack of external influences like wind, rain, sunlight and audience, which are important contributions to the “adventure” of sport. Hence Exergames are not at all an alternative to sport activities in real nature.
However they could promote the possibility to take an interest in exercise and give an access to sport or to a more active lifestyle for physically inactive or technically oriented children. Moreover such kind of games can be seen as a reasonable and beneficial addition to “real” sport because they are a further possibility for children and adolescents to keep themselves in motion and to be physically active in leisure time.

The phenomenon of Exergames has concerned kinesiology and sports science for some time now. If one is looking in a scientific data base for studies, which researches into the influence of video sport games in different samples to improve motor fitness, one will strike in rich very fast. Various reports can be found about children and adolescents but senior citizens are also a matter of interest for research projects with Serious Games. For elderly people Serious Games have successfully been tested as a helpful tool for remobilization of motor fitness or preservation of the current fitness level.

In our own pilot study from the year 2008, seven female and male pupils (mean age: 12.6 years) out of one class were performing different sports games on Nintendo Wii™ twice a week over a period of four weeks. The video game console was used with great enthusiasm. Due to the short intervention period there were no gender-specific differences in acceptance or positive effects on motor abilities observable (Futterer & Laupheimer, 2008).
However it is remarkable that a high level of intensity can be achieved during playing these games. Thus energy expenditure, determined by spiroergometry, is 320 kcal/hour during playing Wii Sports™ Tennis and Boxing. This equates to motion with moderate intensity such as fitness walking with an energy expenditure of 5 kcal/minute (Futterer & Laupheimer, 2008). Similar outcomes are also affirmed by other research studies (Graf, Pratt, Hester, & Short, 2009).

From our point of view it would be desirable that future Serious Games for children and adolescents will be designed and developed with a higher standard focusing on challenge and encourage gross motoric, e.g. endurance or coordination. A variation of relatively high or low intensity could possibly be realized by using a game play with different levels of difficulty. The enhancement of fine motor skills is also conceivable with Serious Games. However, this kind of motor skill is continuously trained in everyday situations such as typing a text on a keyboard.

Therefore a basic requirement is a further technical improvement of handling a paddle. In current available console models representation of the real motion sequence of the displayed sport is not satisfactory. The embedded motion sensors mainly react to an acceleration of the paddle and not to the correct execution of the motion in space. For instance some equipments just require a fast twist of the wrist to achieve the necessary points, so there is no need to imitate the real motion of whole arm or body. For this purpose players could tend to dose their activity down to a required minimum. In this case the sense of Exergames is definitely missed. Hence it must be the aim of the developers of Serious Games to record the player's motion true-to-life so that players are required to move as if they were doing real sports.

In summary it can be concluded that Serious Games as an isolated movement pattern are no alternative or even a surrogate for real physical exercise in nature or in a sports club. However in addition or combination to real sport they can contribute to the preservation and increase of motor fitness as well as to the pleasure in physical activity of children and adolescents.

References

Boes, K. (2003). Motorische Leistungsfähigkeit von Kindern und Jugendlichen. In W. Schmidt, I. Hartmann-Tews, & W.D. Brettschneider (Eds.), *Erster Deutscher Kinder- und Jugendsportbericht* (pp. 85-109). Schorndorf: Hofman.

Boes, K., Oberger, J., Lämmle, L., Opper, E., Romahn, N., Tittlbach, S., Wagner, M., Woll, A,. & Worth, A. (2008). Motorische Leistungsfähigkeit von Kindern. In W.

Schmidt (Eds.), *Zweiter Deutscher Kinder- und Jugendsportbericht. Schwerpunkt: Kindheit* (pp. 137-158). Schorndorf: Hofmann.

Boes, K., Schlenker, L., Buesch, D., Laemmle, L., Mueller, H., Oberger, J., Seidel, I. & Tittlbach, S. (2009). *Deutscher Motorik Test* (pp. 6-18). Hamburg: Czwalina.

Dordel, H.-J. (1997). Verfahren zur Bestimmung der motorischen Leistungsfähigkeit von Kindern (BML). In ADL (Eds.), *Sport, planen – durchführen – auswerten* (p. 263). Schorndorf: Hofmann.

Dordel, S. (2000). Kindheit heute: Veränderte Lebensbedingungen = reduzierte motorische Leistungsfähigkeit?. *Sportunterricht 49* (11), 340-349.

Englicht, C. (1997). *Die motorische Leistungsfähigkeit der 11- bis 15-jährigen im Zeitwandel von 25 Jahren*. Unveröffentlichte Diplomarbeit, Köln.

Futterer, V. & Laupheimer, M. (2008). *Training mit der Nintendo Wii – Auswirkungen auf die motorische Entwicklung bei Kindern*. Unveröffentlichte Examensarbeit, Universität Karlsruhe.

Graf, D. L., Pratt, L. V., Hester, C. N., & Short, K. R. (2009). Playing active video games increases energy expenditure in children. *Pediatrics, 124* (2), 534-540.

Kiphard, E. J. & Schilling, F. (1970). Der Hamm- Marburger Körperkoordinationstest für Kinder (HMKTK). *Kinderheilkunde, 118*, 473- 479.

Klaes, L., Cosler, D., Rommel, A., & Zens, Y. C. K. (2003). *Dritter Bericht zum Bewegungsstatus von Kindern und Jugendlichen in Deutschland. Ergebnisse des Bewegungs-Check-Ups im Rahmen der Gemeinschaftsaktion von AOK, DSB und WIAD „Fit sein macht Schule“*. Bonn: WIAD-AOK-DSB Studie II.

Klaes, L., Poddig, F., Wedekind, S., Zens, Y. C. K., & Rommel, A. (2008). *Fit sein macht Schule. Erfolgreiche Bewegungskonzepte für Kinder und Jugendliche*. Köln: Deutscher Ärzte-Verlag.

Koester, S. (1997). *Der Standweitsprung als sportmotorische Testaufgabe für Grundschüler – eine Revision.* Unveröffentlichte Diplomarbeit, Köln.

Kretschmer, J. & Giewald, C. (2001). Veränderte Kindheit – veränderter Schulsport?. *Sportunterricht, 50* (2), 36-42.

Laging, R. (Eds.). (2000). *Die Schule kommt in Bewegung*. Baltmannsweiler: Kongressbericht.

Obst-Kitzmueller, F. (2002). *Akzeptanz und Wirkung zusätzlicher Sportstunden in der Grundschule*. Berlin: dissertation.de.

Raczek, J. (2002). Entwicklungsveränderungen der motorischen Leistungsfähigkeit der Schuljugend in drei Jahrzehnten (1995-1995). *Sportwissenschaft 32* (2), 201-216.

Schott, N. (2000). *Prognostizierbarkeit und Stabilität von sportmotorischen Leistungen*. Unveröffentlichte Dissertation, Karlsruhe.

Woll, A. & Boes, K. (2004). Körperlich-sportliche Aktivität und Gesundheit von Kindern. In A. Woll & K. Boes (Eds.), *Kinder bewegen* (pp. 8-21). Forst: Hörner.

Worth, A., Oberger, J., Wagner, M. & Boes, K. (2008). Beschreibung der motorischen Leistungsfähigkeit nach Alter und Geschlecht. In K. Boes, A. Worth, E. Opper, J. Oberger, & A. Woll (Eds.), *Motorik Modul (MoMo). Eine Studie zur motorischen Leistungsfähigkeit und körperlich-sportlichen Aktivität von Kindern und Jugendlichen in Deutschland. Abschlussbericht zum Forschungsprojekt*. (pp. 21-31). Baden-Baden: Nomos Verlag.

Beauty and the Beast – Serious Games in Healthcare

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Abstract

True success of Serious Games depends on consumers' realization of the inherent value of those products for various self-efficacy applications in life. Additionally, there exist numerous challenges for Serious Games developers from a market perspective including smaller consumer audiences, higher development cost, the need for embedded evaluation and assessment functionality, as well as insufficient business models and distribution channels.
This article aims at giving an overview on the field of Serious Games from a healthcare industry perspective. In doing so it identifies challenges, opportunities and resulting requirements towards business viability. Finally, this paper further outlines requirements for Serious Games R&D towards effectiveness as well as consumer acceptance and adoption.
The article represents an extension of the keynote paper by the author (Encarnação, 2009) putting a special emphasis on discussing healthcare industry perspectives and requirements for Serious Games research and development.

SERIOUS GAMES, PERSUASIVE TECHNOLOGY, INDUSTRY VIEW, RESEARCH CHALLENGES, HEALTHCARE.

Introduction

The jury is still out on whether the current slowdown in hardware and software sales in the gaming industry is just a well-deserved rest after an impressive sprint in the fall of 2008 or a sign that the world-wide recession makes consumers focus more on life essentials than on dispensable luxury items like game consoles and entertainment.
However, the continuing success of the Nintendo Wii technology and market news about major non-obvious partnerships in the entertainment games market, seem to highlight a trend towards finally exploring more purposeful uses of game play in order to increase access to niche markets.
It is by far no longer a secret that the risk factors of many costly chronic diseases such as diabetes, coronary heart disease, chronic obstructive pulmonary disease (COPD) are significantly increased in audiences that exhibit prevalent behaviors of modern society such as mal-nutrition and lack of exercise – often leading to obesity – and smoking. (WHO, 2004). Similarly, the close relationship between cognitive decline and reduced physical activity in aging populations has been studied in depth.
It is, therefore, not surprising, that the healthcare industry has taken notice, due to increasing cost and public pressure to keep its audiences healthy rather than wait for treating their chronic diseases. Kaiser Permanente *Amazing Food Detective*, Cigna's free distribution of HopeLabs' *ReMission* Cancer Adherence game, and Humana's

Horsepower Challenge children pedometer program are early indications that healthcare providers are looking into new ways of motivating and inspiring healthy behaviors. Gaming technology with its proven potential to capture the attention of varying audience over extensive periods of time has been recognized to also hold the promise to also provide a platform for behavioral change – making it a truly serious proposition.

The Rise of Serious Games

In 2007, Eliane Alhadeff – a recognized Serious Games blogger and market observer (Alhadeff, 2007) – predicted the Serious Games market to grow to 2 billion dollars in revenues, initially based strongly on corporate training, healthcare simulation, and learning games, who she predicted to become mainstream by 2012. Whether these predictions still hold up in the current recession and with the increasing cost for game development is not clear, however recent announcements at least indicate that the entertainment market has taken notice of the growing potential of Serious Games as well as the increasing interest of casual gamers in games with a purpose. What the Wii success taught us is that in addition to traditional hardcore gamers, casual gamers are forcefully entering the game consumer market and they do not see their purpose in life sitting all day inactively in front of a console. Across all demographics, those casual gamers don't and might never see themselves as gamers and are attracted by activities that add additional value to the mental, physical, intellectual or social well-being. Furthermore, due to the social component of this game play – 59 percent of gamers play with other gamers in person – there is a unification happening between hardcore and casual gamers.

Consequently, a new type of game is evolving, which aims at seducing the new casual gamer generations through active, social, cognitive or educational play without requiring them to pass through a steep learning curve during seemingly endless hours of game play. Products like Wii, Wii FIT, eyeToy, Konami's DDR, and Microsoft Natal on the hardware and peripheral side, and WiiSports, Guitar Hero, RockBand, and EA Active's Virtual Trainer on the software side are clearly indicating a new direction for the entertainment games market.

Furthermore, trend-setting collaborations are emerging such as EA's partnership with toy manufacturer Hasbro to launch family classics, Hasbro's competitor Mattel closing an exclusivity deal with Neuorsky -- the leader in consumer brain computer technologies -- towards launching a new category of brain games and toys that operate using the power of concentration, Jerry Bruckheimer's opening of a games studio in partnership with MTV games, and Warner studios' purchase of midway games. All those developments show the convergence of the traditional entertainment video games markets with other entertainment genres, channels, and leisure offerings in response to having to serve a broader, more diverse, and more demanding gamer audience. Gaming is becoming a ubiquitous part of life and is in this sense providing new opportunities for Serious Games to evolve and being takes seriously.

What's in a Game, Seriously?!

Looking at the whole space currently referred to as Serious Games, it is clear that this term is being attributed to many different aspects of video game design, development, hardware and game play. Just considering the health and wellness space, a whole suite of Serious Games applications are being investigated in academia, government and by independent developers (see Table 1).

Table 1. Prelminary Games for Health taxonomy based on (Sawyer, 2007)

	Personal	Professional Practice	Research / Academia	Public Health
Preventative	Exergaming Stress Management	Patient Communication	Data Collection Persuasion	Public Health Messaging
Therapeutic	Rehabilitainment Disease Management	Pain Distraction CyberPsychology Disease Management	Virtual Humans	First Responders
Assessment	Self-Ranking	Measurement	Inducement	Interface/ Visualization
Educational	First Aid Medical Information	Skills / Training	Recruitment	Management Sims
Informatics	Personal Health Record (PHR)	Electronic Health Record (EMR)	Visualization	Epidemiology

Maybe this is just another indication for a widespread acceptance of the increasing awareness around Serious Games opportunities. However, it complicates attempts to look at it from a scientific perspective towards identifying needs, requirements, gaps and research potential in a multi-disciplinary environment.
While there have been efforts to take a structured look at the various application areas for Serious Games (Sawyer & Smith, 2008), identifying what differentiates a Serious Game from a game that is providing mere entertainment value seems daunting. What makes matters worse is that the aforementioned successes of recent activity games led to the adoption of the term Serious Games by marketers, attributing it to any possible positive impact the game play might have – whether intended or not.
The following section is, therefore, an attempt to separate Serious Games from other types of games as well as to delineate Serious Games design considerations from coincidental similar design outcomes.

Drivers and resulting design features

In general, there are two main purposes for Serious Games: skill augmentation and behavioral change (Lieberman, 1997). Both are equally valid, however create distinct requirements and approaches when it comes to design considerations and design features, especially due to the relative immaturity of the field.
Drivers for Serious Games targeting skills augmentation are the need for a more skilled workforce as well as safety improvements, thus addressing the weaknesses and shortcomings of a contemporary educational or training system and trying to exploit the strength of games for certain types of education and training. Consequently, design features include the manipulation of time, frequent repetition, the addressing of specific skills, and the gathering of related data towards proven mastery. Often the exposure to unacceptable risks or danger is an important design feature, introducing the stress, pressure and frustration required to make skills transfer effective.
Towards behavioral change, however, the drivers are the identification of needs not yet met by standard procedures or too costly to address by standard means. Consequently, other main drivers are peer-reviewed research as well as innovative and visionary individuals in academia, industry, government and non-governmental organizations, who are willing to take the risk to enter (and advocate) unchartered territory. While here

too, the manipulation of time, frequent repetition and gathering of data are core design features, it is the focus on improving and maximizing self-efficacy that fundamentally changes the experience and game play.

Educational Games

Despite the previous postulation of Serious Games as effective media for education and training, there is a fundamental difference between Serious Games that educate by experience and Educational Games that communicate educational content in a game-like manner. Serious Games in this context develop connections between contributing artifacts, raise awareness, and are immersive in nature, whereas Educational Games develop specific skills, address and test specific knowledge, and are repetitive in nature. Not surprisingly, the latter are mostly developed for the public sector spear-headed by companies like Leap Frog and Vtech, while Serious Games for education are advocated by public institutions, business colleges and other non-profit organizations that are striving for a compelling experience with potential educational value.

Virtual Worlds

The emergence of massively multi-user online worlds or MMOW has led to the confusion of those virtual worlds with massively multiplayer online games or MMOG, which have in recent years successfully provided compelling and immersive game experiences to its audiences. However, MMOW such a Linden Lab’s Second Life, Microsoft’s Club Penguin or Numedeon’s Whyville are platforms which certainly can be the interface to multiplayer distributed online Serious Games. With the freedom they are providing the user to interact, choose alternatives and provide input as well as their high level of instrumentation to give evaluation feedback to users and designers alike, they might actually be a reasonable basis for the earlier mentioned spectrum of life-related game activities that casual gamers are susceptible to. However, they shouldn’t be confused with the game-experience focused, highly scripted and thus from a Serious Games perspective somewhat limiting MMOG such a Blizzard Entertainment’s World of Warcraft, which trade participatory narrative for a better (mostly visual) experience. Whether such distinction will hold up in the future needs to be seen since increasing online provision of game play as well as consumer input to game design and game scenarios might eventually overcome these disparities.

Serious Games in the Context of Persuasive Technology

True Serious Games aim at having a measurable impact on the player without the player necessarily being aware of the intended impact. In fact, if the intended impact has not been established by the playing individual but by a higher authority such as a parent, physician, supervisor or educational institution, then there is a natural resistance or lack of buy-in, which will ultimately affect the game appreciation and thus experience. In recent years, the research field of persuasive technologies has emerged addressing particularly this challenge. How can technologies be designed that effectively change people’s thinking and behavior without explicitly requiring the user working towards such change? B. J. Fogg’s research (Fogg, 2003) is studying technology persuasion along a functional triad as depicted in Figure 1.

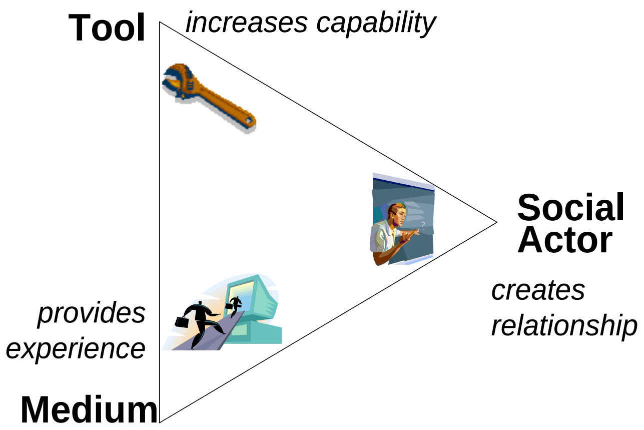

Figure 1. Functional triad of persuasive technology (Fogg, 2003).

Based on this research, technology can be persuasive by any combination of increasing capability, creating a relationship or providing an experience. For instance, a tool can be persuasive by

- making target behavior easier to do;
- leading people through a process;
- performing calculations or measurements that motivate;

a medium can be persuasive by

- allowing people to explore cause and effect relationships;
- providing people with vicarious experiences that motivate;
- helping people rehearse a behavior;

and a social actor can be persuasive by

- rewarding people with positive feedback;
- modeling/demonstrating a target behavior or attitude;
- providing social support.

Applying this 'lens' of persuasive technology, one can easily see the strength of Serious Games in covering all three bases. Currently they are, however, predominantly depicted through implementations which provide experiences in which individual players are represented by social actors in the form of avatars and interact with other social actors in the of non-player characters (NPC). A more thorough discussion of video games in the context of persuasion has been published by (Bogost, 2007).

Applying such methodology allows the evaluation of Serious Games in a way less tedious and restricted than trying to determine long-term behavioral change by means of short-term studies in controlled environments. While certainly less precise than through biometrical and physiological monitoring, such evaluations can be conducted before and throughout the design of the game rather than after its implementation.

Opportunities and challenges

Business processes in the traditional gaming industry follow business-to-consumer (B2C) models in the retail market or direct-to-consumer (D2C) models through emerging online distribution channels. In contrast, the significantly higher fragmentation of the Serious Games market requires the availability of very specialized distribution channels thus calling for business-to-business (B2B) models. Moreover, the traditional gaming industry's success is based on the common public recognition that games are entertaining. Therefore, development, marketing and distribution only need

to cater to the preferences of various demographics to target significant sales success with large audiences in the tenth and hundreds of millions.
Serious Games, on the other hand, lack both, the public acceptance of being generally a value-add as well as large audiences to design and market towards. The proof of value-add has so far been stifled by the need for scientific evidence that a Serious Game had a skill augmentation or behavior change impact on its players. Furthermore, there were less people with a particular self-motivated need for improvement or change than with the inherent desire to have fun. This required the availability of dedicated sales channels and organizations and therefore a B2B model. However, such model lacked so far the market size, on the one hand, and a robust and diversified value chain on the other to meet all audiences' needs and thus exploit all commercial opportunities.
Times might, however, be changing in favor of Serious Games. The financial, educational, and healthcare crises worldwide are affecting large audiences and are creating the public awareness that change is inevitable and must be a combination of public and individual effort and responsibility. Associated shortfalls in schools, the workplace, social communities and individual behavior such as poor education, mass layoffs, bankruptcy, physical inactivity, malnutrition, and drug-abuse are affecting large demographics. Ironically, those problems affecting the masses are taking the stigma of resulting individual problems such as depression, obesity, illiteracy, unemployment, and poverty. Simultaneously, the field of Serious Games research and development has matured and was able to produce some compelling highly publicized evidence on particular game interventions, which created public and individual awareness around the potential of Serious Games (Baranowski, Buday, Thompson, & Baranowski, 2008; Kato, Cole., Bradlyn, & Pollock, 2008). Consequently, several private and non-government organizations have invested in rapidly evolving the field of Serious Games from a mere academic field of study to a profitable industry. In anticipation, the established game industry has realized the trend and is beginning to start strategic directions as previously discussed in order not to be left out.
However, when it comes to business opportunities in healthcare, there is still a lack of understanding of the drivers as well as preconception that create barriers for even promising Serious Games to create value propositions.

Five Myths about the (US) Healthcare Industry

1. *Healthcare providers have significant profit margins that justify high-risk research investments*

   With increasing cost through medical advances, increase in chronic diseases based on unhealthy behaviors in modern society and an aging population, profit margins in the US have shrunk to between 2% and 5%. While premiums are collected at the beginning of a plan year and can – if managed wisely – create additional revenues through interest, much of the revenues are used towards paying for healthcare.
2. *Healthcare providers should be advocates of long-term research*

   Almost exclusively cost-oriented member and sponsor audiences as well as a strongly employer-based system lead to low retention rates due to frequent change of employment or cost-driven change of the healthcare provider. The resulting competitive landscape calls for short-term differentiators with immediate impact rather than long-term competitiveness, in order to increase member retention through cost avoidance and satisfaction.
3. *Healthcare providers have significant data assets that lend themselves to longitudinal research*

Due to the previously described significant fluctuation in member audiences as well as lack of centralized data repositories (electronic medical records; EMR) for patients, there is a significant lack of data continuity which renders claims-data driven longitudinal studies impractical. Additionally, the regulatory limitations on correlating members' claims data with lifestyle data also prevent contextual analysis of claims data with respect to health behaviors.

4. *Healthcare providers main focus is on sick members' care*

   The greatest profit of healthcare providers lays in the people that pay their premiums yet do not require medical treatment, i.e. the healthy people. Retaining, growing and using this audience as influencers of less healthy audiences has been a major focus in healthcare industry's quest for cost avoidance. Unfortunately, the fact that these audiences don't interact with the healthcare system also leads to a lack of data on them; understanding the behaviors of these so-called 'invisibles' is another interesting challenge for healthcare providers.

5. *Healthcare providers control members' cost and benefits*

   Healthcare providers determine the cost of benefits based on healthcare costs and risk assessments. It is, however the sponsors and members that decide which benefits to choose from and these decisions are more often than not solely based on cost considerations.

A remaining challenge for Serious Game development is related to the fact that purposeful play is something very personal and requires careful tailoring to individual needs, preferences and contexts. For it to have a measurable impact that translates well to real-world proficiency and behavioral change requires the experience to be very realistic. Game development over the years got away with fictional representations of a physical environment, approximations of physical behavior and crude as well as imprecise input devices. In contrast, many Serious Games applications might require a higher degree of visual, tactile, olfactory or other-sensory realism than commodity gaming hardware and software had to provide. Serious Games also might have to tie to existing real-world equipment in order to facilitate higher and quicker knowledge and experience transfer. At the same time, Serious Games have to still be able to compete with the appeal and experience of entertainment games which don't have those additional constraints.

Finally, Serious Games have the requirement to capture and measure the various facets of individual game play that document a player's progress towards the embedded purpose of the game. Availability of such data is not only crucial to integrate Serious Games seamlessly with other programs aimed at improving skills or self-efficacy. It is also a prerequisite towards improving the game itself and further document the business viability of Serious Games to various stakeholders. However, the fact that true Serious Games as defined above might not explicitly address these purposes but rather persuade players through the associated experience, functionality, or communication can make such data hard to capture. Such data is not directly tied to game design or game play but rather needs to be inferred from the player's reaction.

All these factors increase the cost of developing Serious Games, on the one hand, and are creating the risk for Serious Games to remain an academic field of study struggling to prove ultimate viability and consequently handicapped by lengthy, tedious and very narrowly focused scientific research endeavors resulting in mere proofs of concept.

A Healthcare Industry Perspective

Taking above business considerations into account and with a focus on demystifying healthcare industry attitudes towards viable Serious Games research and development, the following approaches to applied research offerings to healthcare are suggested. Those are complemented by the more generalized scientific challenges for Serious Games subsequently outlined which are naturally focused on the feasibility of the provisioned solutions.

All of the following suggestions are aimed at providing an industry – in this case healthcare – with enough information to make educated decisions on the risks and opportunities of any particular offering. Based on these risk and opportunities businesses need to develop business cases that scale with respect to consumer as well as business impact. They also must not be exclusively focused on a long-term potential but have short-term and mid-term return-of-investment prospects that provide low-risk assessment opportunities along the way.

In general, one has to consider that health insurers deal with large audiences – millions of people – that need to be helped. In providing solutions, resources and investments need to be prioritized based on members impacted (for member retention), cost avoided or saved, and brand impact (to attract more members and increase the standing in the public eye). The arguments required to inform these prioritizations require solid scientific evidence as well as broad applicability.

1. *Bigger is indeed better!*

   More often than not, the scientific community is focusing on very small groups of subjects and their specific needs, on rare diseases, or on scientific tasks that can only be accomplished with a unique infrastructure. While this approach warrants tenure eligibility, it does not provide broad impact and is not attractive to businesses in healthcare, since it provides only a high-risk, low-opportunity business proposition. In choosing and conducting research experiments, an additional focus should be put on studies that – while small and focused in nature – lend themselves to generalization to wider audiences beyond the test subjects. Interestingly enough, often this broad impact is postulated in justifying the particular research endeavor in the first place. However, in only few instances – once a particular research funding has been received – are research findings then tied back to the broader impact initially claimed.

2. *Connecting the dots, part I*

   One challenge that industry has is screening the vast amount of isolated research in different research communities in order to construct a business argument for innovative solutions. Lack of internal research resources often limit research to be focused on market opportunities rather than applicability of accepted scientific research. It is here, where the scientific community, which nowadays conducts many research projects in a multidisciplinary context, can help. Tying isolated research findings together to create a broad-impact argument would be sufficient for industry to then determine the corresponding market opportunity. For instance, combining studies on muscle-mass increase in seniors through dance games, studies on slowing down cognitive decline through physical activity, and studies on reducing incidents of falling in seniors by increasing muscle mass, might well provide a compelling case to the healthcare industry if tied together to the argument that dance games for seniors in general increase muscle mass and thus reduce incidents of falling, while slowing down mental decline.

3. *Why build when you can buy?*

   Far too often is much of Serious Games research effort spent on creating the game itself. This approach ignores several facts painfully apparent to industry: a) It takes a lot of experience and resources to create good games which creates an in itself expensive proposition. b) The likelihood that a game conceived by research can compete with the entertainment market is very small. c) The generally very short shelf-life of successful games titles does not justify large investments in applications aimed at long-term behavioral change. d) Consumers are first and foremost looking for the entertainment value of a game and then appreciate additional values. These facts favor a different approach to conducting Serious Games research focused on short- to mid-term impact, which admittedly is restricted by game companies' proprietary software and hardware platforms: Whenever possible research should be built around existing successful games titles, peripherals, engines and audiences. Since those have existing well understood business models attached to them, understanding and promoting healthcare applications of games as additional sales channels for the entertainment industry rather than a new product line for healthcare providers – with much smaller target audiences – provides a more reasonable business proposition.
4. *Scalability through personalization*

   Healthcare audiences are significantly more fragmented than entertainment audiences. While entertainment preferences vary mainly by age and gender, healthcare providers have to additionally consider the variety of different healthcare needs a person might have, the stage of a particular disease for disease management interventions, the socio-economic context for preventative propositions as well as many other factors. It is unrealistic to assume that reasonable business cases can be developed for applying games technology to any particular one of the resulting fragments. Consequently, the approach has to be to using common platforms that are customizable to a variety of healthcare needs and audiences, using different levels of difficulty, varying peripherals, and different rewards systems as a starting point. For instance, using a dance-mat game for preventative exergaming of the general population, adding, however, safety peripherals for social, cognitive and physical stimulation of mobile seniors, a higher contrast interface and senior-appropriate song choice, and adding for inclusion of wheel-chair bound audiences a hand-tapping peripheral, immediately scales up the opportunity space of the core health game proposition by several orders of magnitude.
5. *Connecting the dots, part II*

   As the previous recommendations indicate, there is a significant recognized need for multi-disciplinary research collaboration towards studying and developing effective games applications to health and wellness. The same need, however, applies to the rest of the innovation value chain from science and research to product development and delivery. Unfortunately, on the industry side, such collaborations are not common. Instead, vendor and customer relationships dictate the cross-industry interaction which is usually based on mature products and services and related well-understood and proven business models. As experience has shown, it is extremely hard to identify the admittedly existing pockets of innovative thinking and corresponding risk-taking research champions that would add perspective, credibility, and viability in identifying research opportunities. Even if such potential partnerships are being identified by coincidence, more often than not, a true collaboration is hampered by industry regulations tailored to vendor management or dictated by competitive thinking such as intellectual property protection, nondisclosure, and risk-averse master-services agreements. Science and research have the opportunity not only to identify the relevant industries for any particular Serious Games proposition and connect the corresponding thought leaders towards collaborative, mutually beneficial R&D undertakings, but also to provide the neutral ground for such collaborations to take place along the value chain. This would, however, require some additional understanding of and familiarization with this value chain in the first place.

Scientific and Research Considerations

Towards developing games into increasingly persuasive technologies that can be the catalyst for behavioral change, a variety of demands towards scientific research can be articulated, which seem crucial in order to advance the science in support of increasing health and wellness market momentum and discovering corresponding new application areas. The following list is certainly not exclusive and advancement in science and research in many other areas will be necessary to reach for the vision of life-accompanying Serious Game play for the benefit of individuals and their societal and environmental context.

Computer Graphics & Computer Vision

In order to provide truly compelling experiences, the need for increased realism and authenticity at reasonable cost requires new approaches that are able to rapidly capture and display existing environments and artifacts and integrate them with the game play. The field of Computational Photography (Tumblin & Raskar, 2006) has recently matured to a discipline that promises to provide inclusive photorealistic experiences from real-world imagery, while Google's Streetviewer has already begun to provide a glimpse at its commercial potential. At the same time camera technology has progressed to a point that the 3D reconstruction from cameras will soon become a commodity. Sony's eyeToy and Microsoft's Natal were just the beginning of exploring 3D camera recognition for interaction purposes but it can be expected that this progress will continue towards other areas of camera recognition applications. However, much research is needed on how such technology can be employed in mobile and outdoor environments, and can drive or integrate with games that run even on mobile and low-cost gaming devices.

Human-Computer Interaction

Toward providing interactive experiences as well as new capabilities to the end-users, an increased focus has to be put on the human-computer interaction aspects of Serious Games. Today's market penetration of commodity gaming platforms which exhibit much higher graphics and processing performance than their expensive special purpose predecessors makes scientific research in multimodal input and multisensory feedback again an academically worthy endeavor with significant commercialization potential. Controller-free input such as demonstrated by Sony's eyeToy, Microsoft's Natal, gesture recognition such as underlying the Wii input technology, and face and voice recognition such as also promised in Natal need to be combined with outcomes of the research fields of Affective Computing and Intelligent Interaction (Paiva, Prada, & Picard, 2007) capturing emotions, attitudes and unconscious behaviors by means of computer vision as well as different biometric and physiological sensors.
Similarly, multisensory feedback is needed for the player to receive realistic system response that corresponds with the game application as well as the underlying game

purpose of a Serious Game in order to have the potential to invoke success in skills augmentation or behavioral change. While aural feedback has reached especially through the introduction of spatial audio an acceptable level of maturity, other senses have continued to suffer from neglect. Tactile feedback so far is only available as rudimentary vibration of game controllers, haptic devices are only available for industrial or highly specialized applications (Bayonat, Garcia, Mendoza, & Fernindez,. 2006), olfactory displays are still very much limited to academic Virtual Reality applications (Yanagida, 2004), and so are other types of sensory renderings such as heat, wind, and humidity. Revisiting the research in those technologies in the context of Serious Games applications as well as developing a methodology on how to synchronize the various modalities appropriately in the context of game play and interaction seems to be an equally necessary and exciting challenge; not to mention the challenge of taking those modalities then to the low-cost and mobile applications space.

Modeling, Simulation, and Artificial Intelligence

In order to have an impact, Serious Games must be more concerned than traditional games with creating an accurate model of the player. For healthcare applications focused on behavioral change and motivation, such model is crucial. This is in order to better tailor the game experience to the player’s needs and preferences, including potential NPCs to accurately communicate with and hopefully persuade the player. Such player-adaptive experiences require a level of artificial intelligence to appropriately respond, anticipate and direct the human user’s actions that is not yet available in current systems. If, however, an additional goal of modeling the players is to reflect themselves in the game (such as in first-person genres and RPG’s) then we additionally need much more accurate simulations of human’s in the game. This statement does not only refer to the visual appearance, physical behavior or physiological composition of humans as being the focus of much computer graphics and medical simulations research these days. It moreover includes the aspect of personalities, social behaviors, emotions, attitudes and complex interactions of body, mind and spirit (van Lent & Swartout, 2007) which – in nature – have in return an influence on the visual and physiological representations of individuals. Only if such complex models of overall human existence can be established, can we target effectively the aforementioned societal problems through Serious Games such as health including obesity and depression.

Evaluation & Assessment

The increased demand for measurable impact in Serious Games in combination with an infinite number of applications and associated individualized goals and purposes make traditional effectiveness studies highly impractical beyond pioneering proofs of concept. In addition, the increasing ubiquity of game play makes it highly impracticable to conduct field studies for all possible game play contexts. Possibly the integration of emerging small, inexpensive and even disposable biometric sensors could provide the means for remote monitoring in context as well as in-situ adaptation of game play to player performance and behavior. In addition, advanced sensor technology to capture the corresponding context and circumstances as well as the networking and communication infrastructures to support such adaptive ubiquitous Serious Game play provide further challenges for science and engineering worth addressing.

Conclusions

The emergence of social gaming and the corresponding increasing number of casual gamers entering the market for gaming purposes beyond mere entertainment is providing new opportunities to Serious Game development. By addressing global and societal relevant problems like education, health, employment and politics, the field of Serious Games will not only be able to overcome its cost and market size challenges but provide attractive market potential for the traditional game industry which is at the mercy of fluctuations in the economic wellbeing of its player constituents. Health and wellness seems to be a promising and underexplored application field. Understanding the value systems of the involved producing as well as delivering industries – from game development to healthcare providers, healthcare payors and disease management organizations, is crucial towards feasible as well as viable solutions. Along the way are a variety of scientific and research challenges that need to be addressed, yet by themselves can already contribute to solving those societal problems through economic and educational stimulation. One prerequisite is, however, a new type of transdisciplinary partnership between academic disciplines and application industries leading to a whole new intellectual and practitioner workforce as well as market-stimulating products and services in Serious Games.

References

Alhadeff, E. (2007). Serious Games – A sizeable market. *Blog Future-making Serious Games.* Retrieved March 6, 2010 from http://futuremakingseriousgames.blogspot.com/

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for real: Video games and stories for health-related behavior change. *American Journal of Preventative Medicine, 34* (1), 74-82.

Bayonat, S., Garcia, M., Mendoza, C., & Fernindez, J. (2006). Shoulder Arthroscopy Training System with Force Feedback. In *MEDVIS Proc. of the Intl. Conf. on Medical Information Visualization, Biomedical Visualization* (pp. 71-76).

Bogost, I. (2007). *Persuasive Games: the Expressive Power of Videogames.* The MIT Press.

Encarnação, L. M. (2009). On the Future of Serious Games in Science and Industry. In The Universityof Wolverhampton, School of Computing an Information Technology. (Eds.), *Proc. 14th International Conference on Computer Games: AI, Animation, Mobile, Interactive Multimedia, Educational & Serious Games 200,* (pp. 9-12). Louisville, KY, USA.

Fogg, B. J. (2003). *Persuasive Technology: Using computers to change what we think and do.* Amsterdam, Boston: Morgan Kaufmann Publishers.

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), 305-317.

Lieberman, D. (1997). Interactive Video Games for Health Promotion: Effects on Knowledge, Self-Efficacy, Social Support and Health. In R. L. Street, W. R. Gold, & T. R. Manning (Eds.), *Health promotion and interactive technology* (pp. 103-119). Mahwah, NJ: Lawrence Erlbaum Associates.

Paiva, A., Prada, R., & Picard, R. W. (Eds.) (2007). Affective Computing and Intelligent Interaction. In *Proc. of the Second International Conference, ACII 2007*. Lisbon, Portugal.

Sawyer, B. & Smith, P. (2008). *Serious Games taxonomy*. Retrieved March 6, 2010 from http://www.seriousgames.org/presentations/serious-games-taxonomy2008_web.pdf

Sawyer, B. (2007). Games for Health taxonomy. Presentation at *Connected Health.* Retrieved March 5, 2010 from http://www.connected-health.org/media/262821/sawyer%20games%20-for%20health.pdf

Tumblin, J. & Raskar, R. (2006). Computational Photography. State of The Art Report (STAR) in *ACM/Eurographics 2006*. Vienna, Austria.

Van Lent, M & Swartout, W. (2007). Games: Once More with Feeling. *Computer, IEEE Computer Society, 40* (8), 98-100.

Yanagida, Y., Kawato, S., Noma, H., Tomono, A. & Tesutani, N. (2004). Projection based olfactory display with nose tracking. *Virtual Reality 2004*, *Proc. IEEE,* 43-50.

WHO (2004). Diet, nutrition and the prevention of chronic diseases: scientific background papers of the joint WHO/FAO expert consultation. *Public Health Nutrition*, *Special Issue, 7* (1) (A). Retrieved March 5, 2010 from http://www.who.int/nutrition/publications/obesity/-PHNvol7no1afeb2004/en/index.html

Methods for Evaluating Gameplay Experience in a Serious Gaming Context

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Abstract

Gameplay experience (GX) is created during the process of player-game interaction, where this interaction has the goal to provide a motivating, fun experience for the player. Since GX is an important factor for the success of failure of a game, a formal classification of how to design for and evaluate GX is necessary. Using appropriate mechanisms for evaluation and measurement of GX allows the validation of good gameplay experiences. This paper presents an approach to formalize such evaluative methods and a roadmap for applying these mechanisms in the context of serious games. We first discuss related work of user experience (UX) and player experience models, based on which we propose a three-layer framework of GX. For each layer, a number of measurement methodologies are listed and our focus is put on physiological and technical metrics for game evaluation. Finally, we point out the potential use of this framework within the field of game-based learning and serious gaming for sports and health.

GAMEPLAY, AFFECT, PSYCHOPHYSIOLOGY, USER EXPERIENCE (UX), SERIOUS GAMING

Introduction

Over the past decade, an increasing amount of research interest has been directed toward the emotional and affective aspects of user experience (UX) that digital games provide. The evaluation of digital games has been a largely informal process in the past. However, the gaming industry is starting to adopt more formal techniques from human-computer interaction (HCI), especially UX, to evaluate their products. The caveat is that for game testing classic usability testing does not suffice, since its standard metrics (e.g., effectiveness in task completion or efficiency in error rate) are not directly applicable to all aspects of digital games (Pagulayan, Keeker, Wixon, Romero, & Fuller, 2003). Traditional usability metrics are still relevant, but they need to be adapted to digital games and supplemented with physiological and metrical assessment of gameplay experience (Mandryk, Atkins, & Inkpen, 2006; Nacke, 2009a; Nacke, Lindley, & Stellmach, 2008; Tychsen & Canossa, 2008). In the area of serious gaming (Gee, 2003; Michael & Chen, 2005; Prensky, 2000), a further extension is necessary to include *serious* aspects (advanced goals, such as training in a certain knowledge domain, apart from pure entertainment). For example, in the field of game-based learning, approaches such as evaluation schemes of computer-based learning arrangements have been developed (Bruder, Offenbartl, Oswald, & Sauer, 2004; Bruder, Offenbartl, Oswald, Sauer, & Sonnenberger, 2005) although they lack the inclusion of UX factors (and appropriate measurement methodologies) described in this paper.

Since recently much effort has been put into broadening usability concepts to investigate UX in terms of underlying principles and action plans for improving design, similar actions are now being taken to formalize playtesting methodology during game development (Nacke, 2009b; Pagulayan, et al., 2003; Sánchez, Zea, & Gutiérrez, 2009). However, there is still a lack of concrete advice for game industry and research practice about the taxonomical relationship of different methodologies for gameplay experience assessment.

We aim here at incorporating different measurements in a broad and simplistic framework, which should include methods already in use for game evaluation. We also want to focus on presenting emerging methodologies that combine physiological and technological metrics in the different layers of our framework that provide a technology-based, but user-centered approach to evaluating games during the development process. It is our hope that by establishing emerging game evaluation methodologies and framing them, this research will be useful for game developers and researchers alike.

Models of User Experience

UX has formed one of the cornerstones of HCI research in order of a decade (Law, Vermeeren, Hassenzahl, & Blythe, 2007). Thus, a variety of (A) *models* of UX and (B) considerations of *design principles* for UX, have emerged in this period of time with different foci, such as emotion, affect, experience, pleasure, hedonic qualities, and the like (Law, Roto, Hassenzahl, Vermeeren, & Kort, 2009). In this section, we show how this previous work forms the foundation for the framework that is presented here.

Aimed toward design practices, the fundamental work of Malone (1980) described what makes things fun to learn and presented a model of intrinsically motivating instruction. This has been influential in game design and game-based learning. It contains three categories of design guidelines: challenge, fantasy, and curiosity. The model is useful for the generation of design principles, but does not provide methods for evaluating UX.

Hassenzahl (2004) introduced a model (supplementing simpler and older models, e.g. Logan (1994), which views UX from a designer and a user perspective making a distinction between the intended and apparent character of a product. Thus, he emphasizes the fact that there is no guarantee for designers to ensure their products are used or perceived as intended. The emotional personal response to a product is based on the situational context. Experience in his model is formed from the iconic value and prior memories the product triggers. Following his argumentation, a product can have pragmatic (e.g., utilitarian value) and hedonic (e.g., knowledge/skill stimulation, communication of identity, memory evocation) attributes. This model extends to games as well, since they also provide challenges, stimulation, and novelty to create personal value. However, games are primarily played for their hedonic value so that pragmatic use of play – which could be relevant for serious gaming – is often hidden underneath the pleasurable experience.

Garrett (2003) proposed a design model of UX for the web, with UX elements clustered on different layers of abstraction during the web development process. The core of the model consists of integrating UX considerations as the product development process moves from an abstract synergy to a concrete aesthetic surface. This notion of abstraction in modeling experience can be adapted to a game development context and inspired the abstraction dimension in the GX model that we will present in the next section.

Based on Maslow's motivational model of human needs (Maslow, 1943), Jordan (1999) proposed a hierarchical pleasure model of needs oriented toward design practices. In this model, pleasure follows from usability (which depends on functionality). He distinguishes four types of pleasure: physio-pleasure (e.g., evoked tactile and olfactory stimuli), socio-pleasure (e.g., evoked by relationships, society, personal status, or indicative of social identity), psycho-pleasure (e.g., cognitive and emotional reactions), and ideo-pleasure (e.g., aesthetics and ideological value).

Few researchers have tried to explicitly model GX or in a similar vein, *playability*. The latter is a somewhat nebulous concept, which is inconsistently used in the literature (Fabricatore, Nussbaum, & Rosas, 2002; Järvinen, Helioe, & Mäyrä, 2002; Sánchez, et al., 2009) although most sources utilize the term to refer to usability testing that is not focused on interface design, but for example game pacing, difficulty balancing, game mechanics and game story.

Arhippainen and Tähti (2003) described UX as being formed via user-product interaction only. However, they included considerations of the influence of social and cultural factors on UX. The interaction of these factors was viewed as contributing to UX. A primary drawback of the model is that it lacks reflection about UX in terms of systems design. This is a subject included by Kankainen (2003), who discusses user-centered methodologies for concept-level product design. UX is defined as a result of motivated action in specific contexts. Motivation, action, and content all form the vertices of a triangle that subsumes present experience. Thereby, he adds temporality to the UX debate, indicating that previous experiences shape present experiences, which will affect future experiences. The model focuses on informing content creation by evaluating users' motivational needs and action needs. Motivational needs are hard to assess with any kind of methodology, while action needs can be evaluated during gameplay if behavior and emotional responses of players are recorded.

Fernandez (2008) also worked with the temporal dimension of UX, proposing a model of GX which is built around temporal influences *before* (i.e., antecedents), *during* (i.e., processing) and *after* (i.e., consequences) the GX occurring during player-game interaction. The model considers "fun" to be the chief component of GX, which is constructed from emotional and cognitive player responses. Game evaluation should concentrate on evaluating these. The model is too specific to account for all instances of GX and playtesting in games, thus it is a good starting point for a broader, more inclusive GX model that has a development-centric perspective on evaluation and classification of GX.

A mapping of usability to playability to evaluate UX in entertainment systems by Sánchez et al. (2009) deconstructed playability, integrating methodological considerations from the game development process. They propose six "facets of playability": Intrinsic, mechanical, interactive, artistic, intrapersonal/personal, and interpersonal/social playability. However, this model has two major limitations: 1) It is not described what process that was used to derive the game playability concepts from desktop usability definitions; 2) The model introduces unclear concepts of playability that are in turn defined using other conceptual descriptions, which are empirically unsupported.

Qualitative playability evaluation in other research studies provides criteria with which a product's gameplay or interaction can be evaluated. Järvinen et al. (2002) proposed four components of playability each relating to formal aspects (i.e., functional) and informal aspects (i.e., experiential) of games. The challenge for qualitative playability evaluation is that most of them rely on expert evaluations.

One of the few practical approaches to playability evaluation is the use of sets of design heuristics. A few sets have been proposed for digital games. For example, Desurvire, Caplan, and Toth (2004) discussed four game heuristic categories: game play, game story, game mechanics, game usability. Korhonen and Koivisto (2006) presented playability heuristics modules for game usability, mobility and gameplay. Heuristics-based evaluation permits the development of a detailed understanding of the conceptual and individual factors determining gameplay, with the limitation that the approach relies on experience of the evaluator.

Fabricatore et al. (2002) used grounded theory to create a qualitative model of GX, which focuses on utilizing the opinions of players to develop design guidelines, which conceptualize individual playing preferences. A substantial body of work within the game studies field has been focused on conceptualizing and analyzing theoretical constructs, which are likely part the gameplay experience, such as flow (Cowley, Charles, Black, & Hickey, 2008; Sweetser & Wyeth, 2005), immersion (Ermi & Mäyrä, 2005; Jennett, et al., 2008), frustration (Gilleade & Dix, 2004), enjoyment (Gajadhar, de Kort, & IJsselsteijn, 2008; Klimmt, 2003), presence (Slater, 2002) and spatial presence (Wirth, Hartmann, Böcking, Vorderer, Klimmt, Schramm, et al 2007), and so forth. The focus of this article is on providing a broad categorical model of GX, so that a detailed discussion of all these experiential constructs is beyond its scope.

Nacke (2009b) proposed a practice-oriented model that focused on describing playtesting in game development, classifying game usability into evaluations of technology (i.e., system quality), player (i.e., gameplay quality), and community (i.e., social quality). Analysis of the technology is handled by quality assurance team, player analysis by a UX team, and community analysis is done in sociological studies. The model comes close to Garret’s (2003) description of UX design for the web, and is organized in layers similarly to the approaches in UX that are described above. It provides a starting point for the abstraction dimension of the model proposed in the next section.

Three important threads of UX research are apparent in the currently available literature: 1) The requirement for addressing human needs beyond the instrumental; 2) Affective and emotional aspects of interaction, and 3) The nature of UX itself (Hassenzahl & Tractinsky, 2006).

This provides two motivations for the framework presented here: (1) Providing a frame for technological methods that enable behavioral modeling of player-game interaction and (2) Providing a frame for evaluation of affect and cognition of player-game interaction. Different UX models and approaches for projecting UX in games have been discussed. However, none of these has taken an *inclusive* theoretical stance with focus on the game system, the player, and the context of play – especially in serious gaming environments such as game-based learning or games for sports and health, where the context is key to the training experience. Similar to product experience in general, GX is very complex, since player personas and profiling (also including individual background knowledge for educational games or the health and fitness status of a player being relevant for sports and health games); individual expectations based on past experiences are all factors contributing to it. Existing models also do not include recommendations about which methods are useful for measuring within different frames of UX or GX. Our model provides such recommendations within classifying frames of GX.

Measuring Gameplay Experiences

The digital game development process is usually interative and product-focused. Thus, testing of game systems has classically been carried out by quality assurance groups with a focus on finding bugs in the software and has been synonymous with assuring technical quality of the digital game. Playtesting with user-focus on the player has long been performed with a high degree of informalism (e.g. recruiting testers from within the game development studio). Today we see playtesting adopt strategies from HCI and usability for developing inclusive player-game evaluation instrumentation (Isbister & Schaffer, 2008; Kim, Gunn, Schuh, Phillips, Pagulayan, & Wixon, 2008; Pagulayan, et al., 2003).

There are three methodological categories for experiences that surround digital games: the quality of the product (game system experience), the quality of human-product interaction (individual player experience), and the quality of this interaction in a given social, temporal, spatial or other context. All of these qualities will determine different layers of gameplay experience over time (since time is an important influence factor, which is subsumed in all the frames) and all of them can be assessed during the game development process. Figure 1 shows how these methodological gameplay experience layers interact in game development. For example, what the developer implements in the game system affects player experience. The contextual effects on player experience are diverse, such as presence of other players, physical health conditions, time of day, and many others.

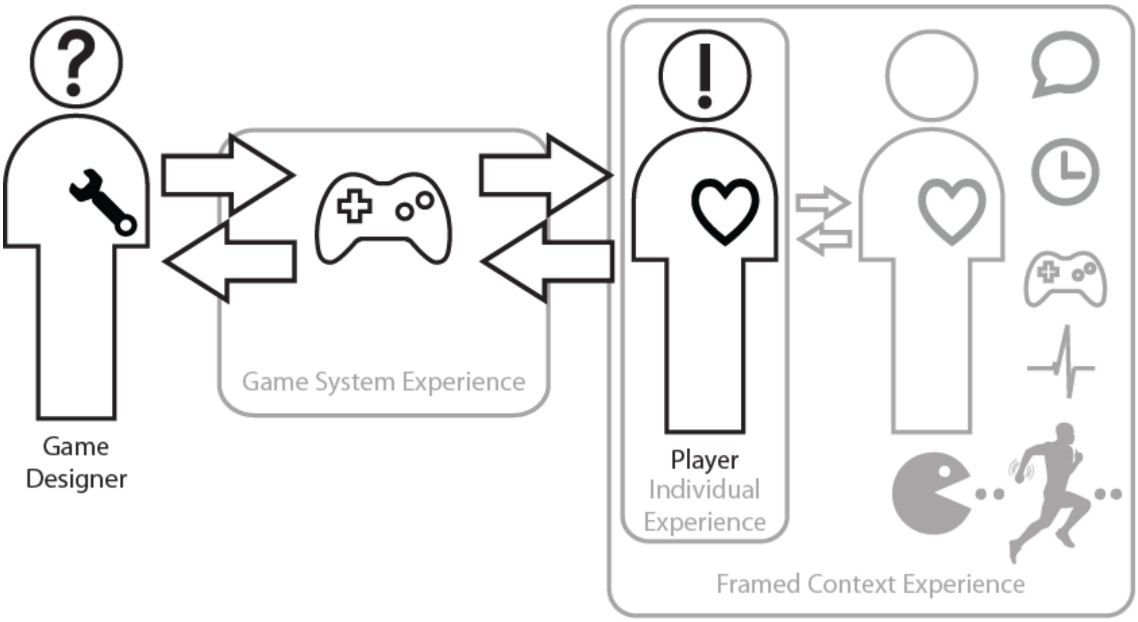

Figure 1. Three methodological frames of gameplay experience in the game development process. For example, game system experience methods are concerned with functional testing of the game; player experience methods ideally use sensor technology (or usability and playtesting) to assess emotion and enable player-game interaction, and finally logging metrics methods (among others) enable assessing game context experience.

Game developers currently have primarily influence on game system experience by refining and testing the game software and by balancing the game system variables. Systematic balancing of gameplay requires either a very good knowledge of the preferences of a targeted user base or the application of scientific methods to evaluate user preferences, emotions, and behavior. This affects the layer of individual player experience, which models the reception and effects, the game mechanics, dynamics, and aesthetics have on a player. Thus, game developers can only indirectly influence this layer of game experience, for example by player modeling in the game system (Drachen, Canossa, & Yannakakis, 2009) or by providing adaptive technologies (e.g., macro and micro adaptation) in digital educational games (Goebel, Mehm, Radke, & Steinmetz, 2009; Peirce, Conlan, & Wade, 2008). This is also the layer where affective studies allow a prominent assessment of player emotion and cognition using psychophysiological methodology. Finally, the individual experience is also affected by the context in which playing happens. This can for example relate to playing in a social context that might amplify emotions (e.g., playing a party/exergame such as *Wii Sports* in a competitive multi-player scenario vs. playing a health game such as *Wii Fit* in a stand-alone mode), it might also relate to the temporal change of experience if a game is played more than one time and affection becomes intertwined with the experiential memory of playing a certain part or sequence in the game and the actual experience, which is elicited when the game is played again. The experience is then framed in a context. This context can only be marginally influenced by game developers through providing additional tie-in experiences[1]. In the following sections, we will look at methodologies that operate on the three different levels of the framework.

Assessing Game System Experience

Methodologies for assessing game system experience come from regular software and traditional game testing. They are often explicitly included in the game development process (at least by larger companies) and make sure the functional level on which the game system operates is correct. We will only briefly review these. Unit testing (i.e., automated testing of the program code), stress testing (i.e., testing of software or hardware limitations), soak testing, compatibility testing, regression testing, bug tracking, localization testing, open beta-testing, gameplay metrics (i.e., event- and location-based metrics allow the tracking of user behavior in the game, which can then feedback into the design process to balance out a certain level based on statistical data).

Assessing Individual Player Experience

An important issue preventing successful evaluation of digital games is the inability to successfully cater to individual emotions. New sensor technology and behavioral tracking enable us to model and assess player cognition and emotion during gameplay. Some examples of novel methodologies used here include:

- **Psychophysiological player testing**. These are controlled measures of gameplay experience usually deployed in a laboratory with the benefit of covertly assessing physical reactions of players.
    - Electromyography (**EMG**) is a measurement technology for recording the electrical activation of muscles. Basic emotions are well reflected in facial expressions. This allows a mapping of emotions in the valence dimensions of the circumplex model of affect (Russell, 1980).
    - Measurement of electrodermal activity (**EDA**) is one of the easiest and therefore most commonly used psychophysiological methods. The

[1] For example, the Xbox Live Pub Games of Fable II are a tie-in to the full game. They provide people that like the casual experiences of these games with a different experience than playing the full game, potentially evoking curiosity for the full game.

measured increased sweat gland activity is directly related to physical arousal.

- Electroencephalography (**EEG**) requires the participant to wear scalp electrodes. Brain waves are usually described in terms of frequency bands, such as alpha (e.g., 8-14 Hz).
- Functional magnetic resonance imaging (**fMRI**), positron emission tomography (**PET**) and functional near-infrared spectroscopy (**fNIR**) are other non-invasive techniques for measuring brain activation. The former two have major limitations in deployment and are hardly used in UX research, while fNIR has recently received more attention from the HCI community.

- **Eye Tracking**. Eye Trackers measure the saccades (fast movements) and fixations (dwell times) of human gaze. Due to the relationship between eye fixations and attentional focus, we are able to infer and visualize cognitive and attentional processes in virtual environment exploration (Stellmach, Nacke, & Dachselt, 2010)
- **Persona Modeling**. "Play-personas" are partly data-driven and constructed. Persona models can be compared with user behavior metrics and prompt changes in the game design (Drachen, et al., 2009; Tychsen & Canossa, 2008).
- **Game Metrics Behavior Assessment**. Instrumentation data ideally log any action the player takes while playing, such as input commands, location, events, or interaction with in-game entities. As an analysis tool, metrics supplement existing methods of game user research by offering insights into how people are actually playing the games under examination (Tychsen & Canossa, 2008).
- **Player Modeling**. Research based on AI is using neural networks and cognitive theories to model and react to player behavior, with the goal to develop adaptive games. Models of players based on behavior and responses to different in-game situations, form the basis for how the game should adapt in real time (Drachen et al., 2009).
- **Qualitative interviews and questionnaires**. Semi-quantitative and qualitative approaches traditionally form the basis for user-feedback gathering in game development. Surveys have been focused on the enjoyment-aspects of UX in games, but recent developments have included dimensions such as tension, frustration, or negative affect. Using surveys during natural breaks in the gameplay action is usually the preferred method of deployment.
- **RITE Testing**. Rapid Iterative Testing and Evaluation was developed by Microsoft Game User Research (Medlock, Wixon, Terrano, Romero, & Fulton, 2002). The approach specifies data analysis after each participant or at the end of the testing day with changes to the interface or the game design being made rapidly after a solution is found. This allows iterative improvement of game designs during the development process.

Assessing Player Context Experience

Playing context is not often evaluated by game development studios, but has been the focus of research efforts, mainly from empirical and sociological perspectives. This is especially common in testing mobile games, where the context of the game has a large influence on how the game is perceived (Korhonen & Koivisto, 2006). Examples of methodologies used here include:

- **Ethnography**. Ethnographic methods attempt to record practices of a certain population acknowledging the impossibility for the researcher to be a transparent observer but instead treasure the impact that the act of observing has on the studied population.
- **Cultural debugging**: Testing conducted to assess how and if culturally arbitrary conventions are understood in different contexts. For example in Deus Ex 3, a receptionist was not perceived as such outside of the US because of cultural conventions.
- **Playability Heuristics**. Playability heuristics can be implemented quickly and cheaply into the game development process. There a few sets of specialized heuristics for use in game development (Desurvire, et al., 2004; Korhonen & Koivisto, 2006). Expert reviews with heuristics have been presented for action games, based on technical game review scores, and for game-based learning applications. The main benefits of heuristic methods are that they are time and cost efficient.
- **Qualitative interviews and questionnaires**. Used to assess context and social impact on individual player experience in a similar capacity as in the UX assessment at the individual player experience level.
- **Multiplayer game metrics.** Similar as for player experience, the social experience can be modeled using gameplay metrics to study the interaction of several players depicted the interaction log.

Applying the Framework to Serious Games

Serious games have been used before as motivators for learning (Gee, 2003; Prensky, 2000) and for healthy, sportive activity (Baranowski, Buday, Thompson, & Baranowski, 2008; Wiemeyer, 2009). The sensor technology and the psychophysiological (measurement) methods discussed within our proposed framework provide great possibilities in such application scenarios, both (1) to enhance adaptation and personalization of existing games and systems during play and (2) to evaluate the effectiveness of serious games in general. The following two examples come from ongoing research activities of the serious gaming group at TU Darmstadt and we will apply our framework to these examples.

- In *80Days*[2] different game modes (relaxed, driven and hectic version) are used to match player characteristics (taken from a player questionnaire administered before the educational game starts) as good as possible. For example, players familiar with action games receive the arousing or hectic version with exciting music, (artificial) time pressure and alien opponents chasing them by default, whilst casual gamers without an affinity for (action) gaming and interactive media play a relaxed version at first. Then, during gameplay, individual player experience is evaluated by classical event logging mechanisms and user interactions with the system. By using the GX framework from this paper, we can decide to add some of the above methods for evaluating individual player experience. For example, we will check the emotional state of players and the appropriateness of particular game modes or of switching modes during play.

[2] For more information about the game see http://www.eightydays.eu

Similar, the assessed player experience might be considered in real time during gameplay to determine how an educational game continues during play (i.e., macro adaptation; sequencing of learning objects and learning units/game levels) or how a learning unit/object is presented (i.e., level of interactivity, use of digital media; interaction templates, more specifically micro adaptation).

- In *motivation60+*[3] the overall aim is to provide and to combine sensor technology and game-based concepts in order not only to monitor the health status of (elderly) users, but also to motivate the *silver generation* to do sports regularly, in a sustainable manner. Here, in addition to sensor technology for the measurement of vital parameters such as the heart rate and other psychophysiological methods would provide a motivating insight into the affective player experience and "soft factors" such as emotion, fun, arousal, stress, and others. These GX parameters are highly relevant for the success or failure of game design and subsequently for a long-term, sustainable motivation and effectiveness of sports/health games.

The individual player experience is important in serious gaming, since this frame is where an effect of the serious game on behavioral change in the player can be witnessed. It depends on the kind of serious game that should be tested, which evaluative UX measure is preferred, but our recommendation is that affective measures should be used when probing for effectiveness of game-based learning applications for example.

Conclusion and Future Work

In brief, UX evaluation of gameplay can be categorized in three GX frames. Game system experience methods work on the functional level of assessing the functional capacity of the game system, game engine, or level data to balance the game design. Player experience methods evaluate the emotional or cognitive impact that a game or certain events or entities in a game have on a player, ideally by using quantifiable, objective, and physiological methods. Finally, context experience methods are suited for studying the interaction of player in a co-located or co-present game environment, taking into account the sociological impact of game mechanics and player behavior. Ideally, those methods allow balancing and tuning of the game during and after game development to improve the experience and contextual or personal value that a game can provide to its players.

The individual player experience is especially important in serious gaming, since this frame is where we want to use a serious game to foster learning and behavioral changes. It depends on the kind of serious game that should be tested, which evaluative UX measure is chosen, but our recommendation is that affective measures are ideal for evaluating the effectiveness of motivation to play game-based learning applications or games for sports and health. While these measures might focus on emotional assessment, we assume that a link between positive emotion and long-term storage and recall of information in the brain exists, which future studies will investigate using the methods presented in this framework.

Further research will be investigating qualitative and quantitative evaluation studies for serious games domains. In a first step, comparative studies of *80Days* with different game modes and classical evaluation mechanisms (questionnaires, interviews, assessment) will be carried out to receive valid feedback about usage effects of different

[3] For more information about the project see http://www.motivotion.org

game modes and the overall effectiveness of learning. Finally, another goal is to find a correlation between fun, identification in games and (successful) learning. Similar, in *motivotion60+*, the aim is to correlate the intensity and duration of movements in exergaming with the attractiveness and fun of a sports or health game.

References

Arhippainen, L. & Tähti, M. (2003). *Empirical Evaluation of User Experience in Two Adaptive Mobile Application Prototypes* MUM 2003. Proc. of the 2nd Int. Conf. on Mobile and Ubiquitous Multimedia, Norrköping, Sweden.

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for real. Video games and stories for health-related behavior change. *American Journal of Preventive Medicine, 34* (1), 74–82.

Bruder, R., Offenbartl, S., Oswald, K., & Sauer, S. (2004). *Third party certification of computer-based learning environments.* EISTA: Int. Conf. on Education and Information Systems: Technologies and Applications, Orlando, Florida.

Bruder, R., Offenbartl, S., Oswald, K., Sauer, S., & Sonnenberger, J. (2005). Qualität von computergestützten Lernumgebungen beurteilen: ein ganzheitliches Konzept [Judging the quality of computer-based learning environments: a wholistic concept]. *Thema Forschung: E-Learning, 1* (2005), 62-65.

Cowley, B., Charles, D., Black, M., & Hickey, R. (2008). Toward an understanding of flow in video games. *Computers in Entertainment, 6* (2), 1-27.

Desurvire, H., Caplan, M., & Toth, J. A. (2004). Using heuristics to evaluate the playability of games. In *CHI '04 extended abstracts.* Vienna, Austria.

Drachen, A., Canossa, A., & Yannakakis, G. N. (2009). Player Modeling using Self-Organization in Tomb Raider: Underworld. In *Proc. of IEEE CIG 2009*. Milano, Italy.

Ermi, L. & Mäyrä, F. (2005). Fundamental Components of the Gameplay Experience: Analysing Immersion. In *Proc. of DiGRA.*Vancouver, BC, Canada.

Fabricatore, C., Nussbaum, M., & Rosas, R. (2002). Playability in video games: a qualitative design model. *Human-Computer Interaction, 17* (4), 311-368.

Fernandez, A. (2008). Fun Experience with Digital Games: A Model Proposition. In O. Leino, H. Wirman & A. Fernandez (Eds.), *Extending Experiences: Structure, Analysis and Design of Computer Game Player Experience* (pp. 181-190). Rovaniemi, Finland: Lapland University Press.

Gajadhar, B. J., de Kort, Y. A. W., & IJsselsteijn, W. A. (2008). Shared Fun Is Doubled Fun: Player Enjoyment as a Function of Social Setting. In *Proc. of Fun and Games 2008.* Eindhoven, The Netherlands.

Garrett, J. J. (2003). *The Elements of User Experience: User-Centered Design for the Web*. Berkeley, CA, USA: New Riders.

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

Gilleade, K. M., & Dix, A. (2004). *Using frustration in the design of adaptive videogames.* Proc. of ACE 2004, Singapore.

Goebel, S., Mehm, F., Radke, S., & Steinmetz, R. (2009). 80days: Adaptive Digital Storytelling for Digital Educational Games. In *Proc. of 2nd Int. Workshop on Story-Telling and Educational Games (STEG'09)*. Aachen, Germany.

Hassenzahl, M. (2004). The thing and I: understanding the relationship between user and product. In M. Blythe, C. Overbeeke, A. F. Monk & P. C. Wright (Eds.), *Funology: From Usability to Enjoyment* (pp. 31-42). Norwell, MA, USA: Kluwer Academic Publishers.

Hassenzahl, M. & Tractinsky, N. (2006). User experience - a research agenda. *Behaviour & Information Technology, 25* (2), 91-97.

Isbister, K. & Schaffer, N. (2008). *Game Usability: Advice from the experts for advancing the player experience*. Burlington, MA: Morgan Kaufmann.

Järvinen, A., Helioe, S., & Mäyrä, F. (2002). *Communication and Community in Digital Entertainment Services* (Prestudy Research Report). Hypermedia Laboratory, University of Tampere.

Jennett, C., Cox, A. L., Cairns, P., Dhoparee, S., Epps, A., Tijs, T., et al. (2008). Measuring and defining the experience of immersion in games. *International Journal of Human-Computer Studies, 66*, 641-661.

Jordan, P. W. (1999). Pleasure with Products: Human Factors for Body, Mind and Soul. In W. S. Green & P. W. Jordan (Eds.), *Human Factors in Product Design: Current Practise and Future Trends* (pp. 206-217). UK: Taylor & Francis.

Kankainen, A. (2003). *UCPCD:* User-centered product concept design. In *Proc. of Conf. on Designing for User Experiences*. San Francisco, CA, USA.

Kim, J. H., Gunn, D. V., Schuh, E., Phillips, B., Pagulayan, R. J., & Wixon, D. (2008). Tracking real-time user experience (TRUE): a comprehensive instrumentation solution for complex systems. In *Proc. of CHI 2008*. Florence, Italy.

Klimmt, C. (2003). Dimensions and determinants of the enjoyment of playing digital games: A three-level model. In M. Copier & J. Raessens (Eds.), *Level Up: Digital Games Research Conference* (pp. 246-257). Utrecht: Faculty of Arts, Utrecht University.

Korhonen, H., & Koivisto, E. M. I. (2006). Playability heuristics for mobile games. In *Proc. of 8th conf. on HCI with Mobile Devices and Services*. Espoo, Finland.

Law, E., Vermeeren, A. P. O. S., Hassenzahl, M., & Blythe, M. (2007). Towards a UX manifesto. In *Proc. of HCI 2008: People and Computers XXI: HCI...but not as we know it - Volume 2*. Swinton, UK.

Law, E. L.-C., Roto, V., Hassenzahl, M., Vermeeren, A. P. O. S., & Kort, J. (2009). Understanding, scoping and defining user experience: a survey approach. In *Proc. of CHI 2009.* Boston, MA, USA.

Logan, R. J. (1994). Behavioral and Emotional Usability: Thomson Consumer Electronics. In M. Wiklund (Eds.), *Usability in practice: how companies develop user-friendly products* (pp. 59-82). San Diego, CA, USA: Academic Press.

Malone, T. W. (1980). What makes things fun to learn? heuristics for designing instructional computer games. In *Proceedings of the 3rd ACM SIGSMALL Symposium*. Palo Alto, CA, United States.

Mandryk, R. L., Atkins, M. S., & Inkpen, K. M. (2006). A Continuous and Objective Evaluation of Emotional Experience with Interactive Play Environments. In *Proc. of CHI 2006.* Montréal, Québec, Canada.

Maslow, A. H. (1943). A Theory of Human Motivation. *Psychological Review, 50* (4), 370-396.

Medlock, M. C., Wixon, D., Terrano, M., Romero, R. L., & Fulton, B. (2002). Using the RITE method to improve products: A definition and a case study. In *Proc. of UPA 2002*. Orlando, Florida, USA.

Michael, D. R., & Chen, S. L. (2005). *Serious games: Games that educate, train, and inform*. Boston, MA: Thomson Course Technology.

Nacke, L. (2009a). *Affective Ludology: Scientific Measurement of User Experience in Interactive Entertainment.* Ph.D. Thesis, Blekinge Institute of Technology, Karlskrona. Available online at: http://affectiveludology.acagamic.com

Nacke, L. (2009b). From Playability to a Hierarchical Game Usability Model. In *Proc. of Future Play @ GDC*. Canada, Vancouver, BC, Canada.

Nacke, L., Lindley, C., & Stellmach, S. (2008). Log who's playing: psychophysiological game analysis made easy through event logging. In *Proceedings of Fun and Games 2008*. Eindhoven, The Netherlands.

Pagulayan, R., Keeker, K., Wixon, D., Romero, R. L., & Fuller, T. (2003). User-centered design in games. In J. A. Jacko & A. Sears (Eds.), *The Human-Computer Interaction Handbook: Fundamentals, Evolving Technologies, and Emerging Applications* (pp. 883-906). New York, NY, USA: L. Erlbaum Associates Inc.

Peirce, N., Conlan, O., & Wade, V. (2008). *Adaptive Educational Games: Providing Non-invasive Personalised Learning Experiences.* 2nd IEEE Int. Conf. on Digital Games and Intelligent Toys Based Education, Banff, Canada.

Prensky, M. (2000). *Digital Game-Based Learning*. New York, NY, USA: McGraw-Hill.

Russell, J. A. (1980). A Circumplex Model of Affect. *Journal of Personality and Social Psychology, 39* (6), 1161-1178.

Sánchez, J. L. G., Zea, N. P., & Gutiérrez, F. L. (2009). From Usability to Playability: Introduction to Player-Centred Video Game Development Process. In *Proc. of 1st Int. Conf. HCD 2009*. San Diego, CA, USA.

Slater, M. (2002). Presence and the sixth sense. *Presence: Teleoperators and Virtual Environments, 11* (4), 435-439.

Stellmach, S., Nacke, L., & Dachselt, R. (2010). Advanced Gaze Visualizations for Three-dimensional Virtual Environments. In *Proc. of ETRA 2010*. Austin, TX.

Sweetser, P., & Wyeth, P. (2005). GameFlow: a model for evaluating player enjoyment in games. *Computers in Entertainment (CIE), 3* (3), 3-3.

Tychsen, A., & Canossa, A. (2008). *Defining personas in games using metrics.* Proceedings of the 2008 Conference on Future Play: Research, Play, Share, Toronto, Ontario, Canada.

Wiemeyer, J. (2009). *Serious games in prevention and rehabilitation.* International conference „Physical education and sport in research 2009 – Aging and physical activity", Rydzyna, Poland.

Wirth, W., Hartmann, T., Böcking, S., Vorderer, P., Klimmt, C., Schramm, H., et al. (2007). A Process Model of the Formation of Spatial Presence Experiences. *Media Psychology, 9* (3), 493-493.

Serious Games for Rehabilitation of stroke patients with Vibrotactile feedback

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Abstract

In this paper, we present a set of serious games with vibrotactile feedback developed for upper extremity motor function rehabilitation. These games are part of a framework called SIERRA that stands for Post-Stroke Interactive and Entertaining Rehabilitation with ReActive objects. The framework uses Augmented Reality technology to provide natural exercise environment and motivating virtual objects at the same time. It adopts serious games concept to provide patients with a more entertaining environment for treatments. We seamlessly superimpose virtual objects onto a real environment and patients can interact with them in a motivating game scenario. Since vibrotactile actuators are attached to the real objects, patient can experience haptic feedback as well as audiovisual feedback. Usability results show that the serious games with vibortactile feedback offers significant advantages both in terms of improving interests of the subjects for the game and in dealing with the realism of the games.

SERIOUS GAME, STROKE REHABILITATION, VIBROTACTILE ACTUATORS, AUGMENTED REALITY

Introduction

Stroke depicts the sudden neurological deficits caused by brain vascular injury that include a range of medical problems (Radomski & Trombly, 2007). Hemiplegia is a medical condition that follows stroke attack, and typically results in a decreased ability to perform activities of daily living, due to the resulting cognitive and motor deficits (Foulkes et al., 1988). An essential part of the rehabilitation process is a remediation of these deficits in order to improve the functional ability of patients, and to enable the patients to achieve greater independence. Patients are usually seen in rehabilitation centres for half-hour sessions, once or twice a day in order to be treated. In general, during traditional stroke rehabilitation, therapists conduct special types of exercises to teach patients to recover their basic motor skills, e. g. how to handle a cup and move it to a shelf. Since these types of treatments concentrate on patient body motor functionality, their exercises comprise trivial and boring tasks that need to be repeated such as moving a hand back and forth. Most of the stroke patients who are undergoing some traditional therapies lose their interest in the program shortly (Burdea, 2003). Therefore motivating patients to continue the exercises is important to accomplish successful treatment.

Computer-based rehabilitation applications, which have emerged in response to the above problem, have been actively designed and developed. There has been much work done both in the industry and academia on developing new approaches to the rehabilitation applications. The interest in this area still remains high because it constitutes extremely complex area in healthcare that is marred by poor efficiencies and high cost. One of the earliest and popular approaches is virtual reality-based rehabilitation system (Holden, 2005). Virtual Reality (VR) technologies can change the boring exercises into more entertaining ones carrying out enough visual and auditory motivation components. However, despite its popularity, VR-based systems encounter several limitations. Patients are unable not only to feel natural reality but also to touch virtual objects. This makes the patient feel uncomfortable during her/his rehabilitation process. Although, VR rehabilitation systems have recently taken haptic technologies to enable patients to feel and touch the virtual objects, the complexity and bulkiness of haptic devices have limited the usage of this technology especially for stroke patients (Kayyali et al., 2007). Therefore, the current generation of the rehabilitation systems still requires further improvements to make stroke rehabilitation more natural, interactive, and applicable to a broader range of real-life treatments.

To deal with this issue, in this paper, we use SIERRA (Post-Stroke Interactive and Entertaining Rehabilitation with ReActive objects) (Alhamid et al., 2010) as a platform to design a set of serious games developed for rehabilitation of stroke patients. The framework uses Augmented Reality (AR) technology and serious games concept to provide patients with an entertaining environment for treatments (Alhamid et al., 2010). We superimpose virtual objects in motivating scenarios designed to consider the use of real environment setup. In addition, we incorporate reactive objects with the serious games to improve the realism of the games scenarios. By embedding vibrotactile actuators into the real objects, the system allows patients to feel interactive contacts between virtual objects through vibration or to be rewarded with a cheering vibration patterns when patients accomplish a certain objective. The main contributions of this study toward the rehabilitation systems can be summarized as follows: 1) We design and develop serious games for stroke rehabilitation in dealing with the issues of encouragement of patients' treatment process with some interests. 2) We present vibrotactile feedback in serious games without wearing special devices on users' impaired hands.

The rest of this paper is organized as follows: The next section review previous studies related to stroke rehabilitation systems. We also present a detailed scenario of the serious games with vibrotactile feedback for stroke rehabilitation. We then show the result of the usability study. Finally, conclusions are presented and future work is discussed.

Related Work

Computer-based rehabilitation systems are largely classified into the following categories based on what technologies are used: VR-based rehabilitation systems, Haptic-based rehabilitation systems, and AR-based rehabilitation system

Holden et al. (1999) developed a virtual reality system that consists of 20 different exercises for motor training of stroke patients. As a result, they are the first to prove that motor knowledge obtained in VR learning environment can be used in the real physical world (Rose et al., 2000). Then, many studies followed after to explore the consistency and feasibility of VR systems as rehabilitation tools for the measurement of motor performance in motivating and safe environment (Kizony et al., 2004; Chen et al., 2008; Piron et al., 2001; Hilton et al., 2002). However, in VR-based systems, patients are unable to feel or touch virtual objects.

In order to provide feeling of virtual objects, haptic-based systems for rehabilitation have been developed. Haptic-based rehabilitation inherits the advantages of VR-based rehabilitation because most of haptic systems are incorporated with VR environment. In addition, the patient is able to touch the virtual objects presented to him/her using such systems. Therefore, this approach can enhance the feedback of the virtual environment and provide the patients with more natural interaction mode. Consequently, the natural interaction can give a chance to improve users' motor strength. Different studies on haptic rehabilitation systems have shown its potential to continue to improve recovery of stroke patients with disability in upper extremity (Adamovich et al., 2005; Loureiro et al., 2004; Broeren et al., 2002; Rizzo et al., 2005; Alamri et al., 2008), and/or in lower extremity (Boian et al., 2002; Boian et al., 2003). These systems help stroke patients mainly to gain strength and knowledge of perceptual and physical daily activity. However, the haptic systems are limited by the bulkiness of some haptic devices, e.g., CyberForce (Virtual Realities Inc., 2010), which cannot be properly used with stroke patients (Kayyali et al., 2007).

Similar to our study, fewer attempts were made to use AR in the rehabilitation process of stroke patients. Researchers in Luo et al. (2005a) developed an augmented reality framework to train a stroke patient for Grasp-and-Release tasks. The system renders the patients real hand inside a virtual environment using a Head Mounted Display (HMD). In addition, this framework is equipped with an assistive glove to help the patient extend their fingers during the Grasp-and-Release task. Using a Joystick, a therapist can modify positions, orientations, and sizes of virtual objects in the virtual environment to best fit the patient's needs (Luo et al., 2005b). The authors in Lozano et al. (2005) developed a custom-design (fully immersive) tool called the VR-mirror that utilizes overhead projection technology to make the surface of a table as a display screen. This tool allows the patient to relearn hand flexion/extension movement from their unaffected (healthy) hand by asking the patient to rehearse that movement throw a constructed 3D model presented by a custom display (Gaggioli et al., 2007). Although these studies give promise of patients' interaction intuitively and naturally, they do not take the effects of tactile interactions into consideration. Differing from these works, our goal is to motivate patients to complete their rehabilitation process, as well as, to interact with them and receive a variety of feedback modalities (visual, audio, and haptic). Besides, we provide patients with games exercises that are designed specifically to enhance cognitive and/or motor skill. We believe that motor knowledge obtained from such exercises enhanced with vibortactile feedback can be helpful to improve users's motor strength.

Serious Games with Vibrotactile Feedback

Serious games are kind of games designed mainly to serve objective(s) other than entertainment, such as education and training (Zyda, 2005). Besides entertainment, games, in this context, are mostly designed to train patients on motor movements for daily life activities, e. g. handling a cup and moving it into a kitchen cupboard (Radomski & Trombly 2007). Furthermore, motor skills learning in rehabilitation becomes better when the attention of the subject is shifted from their own movement to external effects within the space used for rehabilitation (Wulf & Prinz 2001). Through competition with computer, serious games help distance the patient from the actual task of reaching to focus in performing games scenarios.

Game are developed to enhance the motor function capability of the patient's hand, as well as, monitor her/his treatment progress by evaluating one more of the following parameters:

- Task Completion Time (TCT): the time that it takes the patient to finish a specific task.
- Eye-Hand Coordination: the ability of the patient to move his/her hand precisely following a prescribed visual cue.
- Motion Smoothness: of hand moving toward a target is defined as the measure of abrupt changes in hand movement acceleration.
- Hand Steadiness: the level to which the hand movement of the subject is tremor free.
- Hand Motion Curvature: the measure of the curve created by the hand motion when reaching an object.
- Hand Range of Motion: the spatial workspace used by the subject.
- Hand Strength: The total power spent by the hand and arm muscles of the subject.

In the following, we describe two games to highlight advantages of serious game in rehabilitation: Cannon-ball and Air-Hockey games.

Cannon-ball Game

We developed an augmented-reality game called "cannon-ball", where a patient sees a virtual cannon that blows virtual cannon balls (Figure 1). This game was developed to increase the level of entertainment the patient is experiencing in her/his treatment. In addition, by repeatedly performing this game for a long period of time, we expect the patient to gain increased ability in three important hand motor function aspects: hand motion smoothness, range of hand-arm motion, and Eye-hand coordination. Moreover, it supports the eye-hand coordination capability of the patient by instructing her/him to catch the fired cannon balls. This game scenario is summarized in the following step:

1. The patient sees a regular table where a virtual cannon is displayed in the left-far corner of the table.
2. A message (for ten seconds) is displayed to ask the patient to grab a real cup and try to move on the table.
3. A five second countdown is displayed (before the cannon blows).
4. The virtual cannon blows out a virtual cannon ball when the countdown reaches zero.
5. The patient tries to receive the virtual ball with the cup by moving it on the table.
6. Blowing a cannon ball is repeated ten times (default trials times).

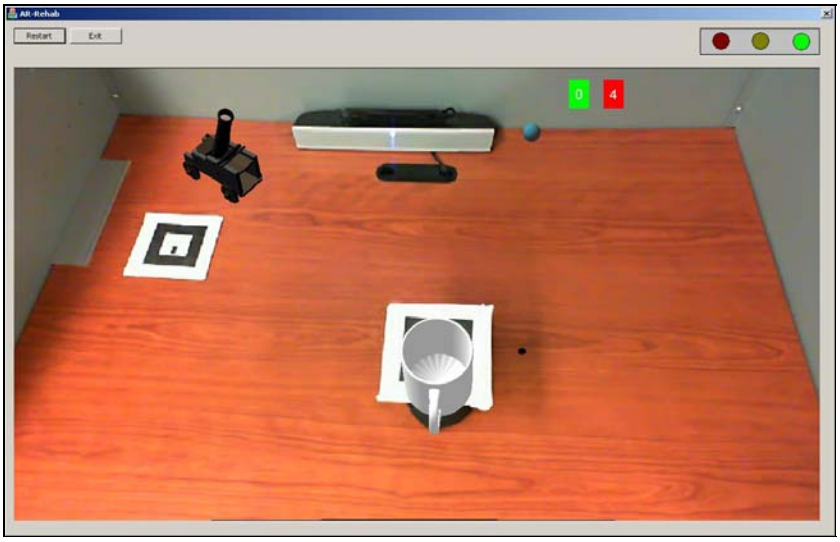

Figure 1. Cannon Ball Game: The subject is trying to catch the virtual ball in the Cup.

While the patient is playing the game, we display the number of received balls in a green box and the number of missed balls in a red box, both of them are rendered in the top-right corner of the screen.

The game has different levels of difficulties. The therapist defines these levels of difficulties through the therapist interface in the framework. Every level of the game is defined by assigning a value to the following parameters:

- *Firing force:* The force that the cannon uses to throw the ball. This force controls the height that the ball reaches before it starts descending toward the table surface. It has three values: low, medium, and high.
- *Ball falling target:* The target position on the table that the ball should reach. It has the following self-described values:
  - *Random*: the ball is allowed to fall at any place on the table.
  - *Fixed-left:* the ball falls only in he left area of the table, to train the patient to reach and catch dynamic falling objects in the left side of the table only.
  - *Fixed-middle:* the ball falls only in the middle area of the table, to train the patient to reach and catch things thrown in front of her/him.
  - *Fixed-right-far:* the ball falls only in the right-far corner area of the table, to train the patient to reach and catch the ball at far right side of the table.
  - *Fixed-right-near*: the ball falls in the right-near corner area of the table, to train the patient to reach and catch objects in the near right area.
- *Falling speed:* The falling speed of the cannon ball. In other words, this parameter defines the time given to the patient to move her/his hand to the place where the ball is falling to. It has three pre-configured values: slow, medium, and fast.

Air-Hockey Game

The objective of the Air-Hockey game (Figure 2) is to help the patient learn a smooth reach motion. In addition, it supports the patient's range of motions by forcing her/him to extend her/his arm in the (XY) plane. Thus, it helps the patient to accumulatively strengthen her/his hand-arm.

In the Air-Hockey game the patient tries to hit the puck into the goal of the opponent (the computer in our case) and vice-versa. The game continues until either the patient or the computer scores a specific number of points pre-configured by the therapist. The scenario of the game can be summarized in the following steps:

1. At the beginning, the puck is placed at the centre of the air hockey rink.
2. The game begins by attempting to recognize the cup marker.
3. Once it does, the traffic light in the top right corner will turn from yellow to green and the game starts.
4. Once the game begins the puck starts to move. The puck has a minimum speed limit, which is what it starts at.
5. Whenever a mallet (patient's or computer's mallet) collides with the puck it transfers its speed in the direction it was moving to the puck.
6. The game continues until either user hase accumulated specific number of points.
7. After that the puck remains motionless in the middle and a label reading "Game Over" will appear.

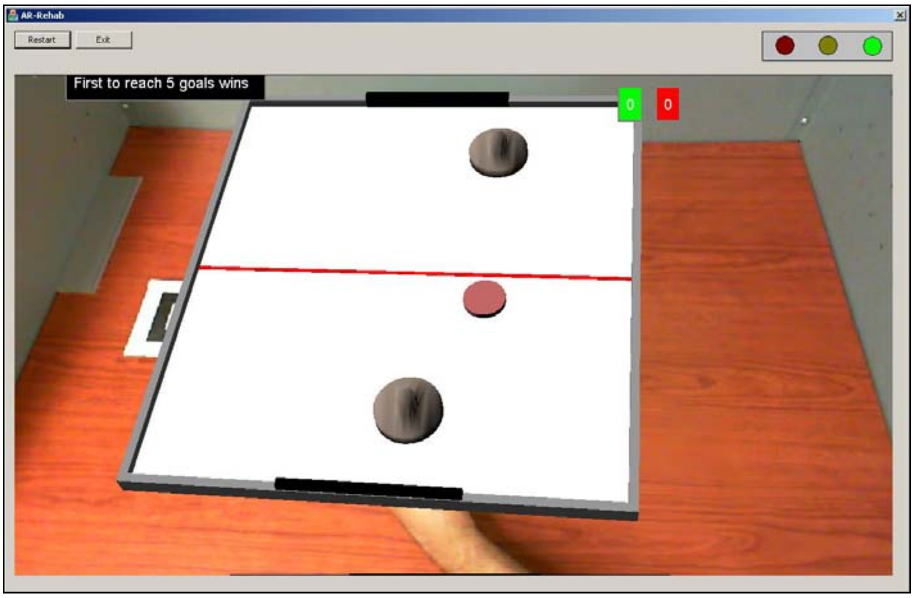

Figure 2. The Air Hockey Game: The subject is competing with the computer opponent in the game.

The computer mallet remains at a set y-plane and moves only on the x-axis. The patient mallet is placed on the cup marker. The mallet object will follow the marker on the x and y-axis, but will not rise off the set z-plane. Usually, the friction will cause the puck to slow down, but to avoid having the puck stopping entirely it is not allowed to drop below a certain speed in both x and y directions. The friction will begin to come into effect when either the patient or computer mallet collides with the puck up to slow it down.

The game has levels of difficulties. These levels are defined by the following parameters:

- *Opponent response speed:* The speed of the computer-controlled opponent. It has three values:

  - *Easy:* the opponent mallet will simply move back and forth at a constant speed.
  - *Normal:* the opponent mallet will chase the puck. It will move towards the x position of the puck at a speed relative to the speed of the puck.
  - *Hard:* The only difference between the Normal and Hard level is that in the later one the opponent mallet moves faster.
- *Playing field width:* the width of the air hockey rink. It helps to calibrate the game to better support the patient practices her/his hand range of motion. This parameter has three predefined values: narrow, regular, and wide.
- *Wining score:* Number of goals needed to win and finish the game. The minimum value for the parameters is at least three goals, and the default is ten goals.

Vibrotactile Feedback in Serious Games

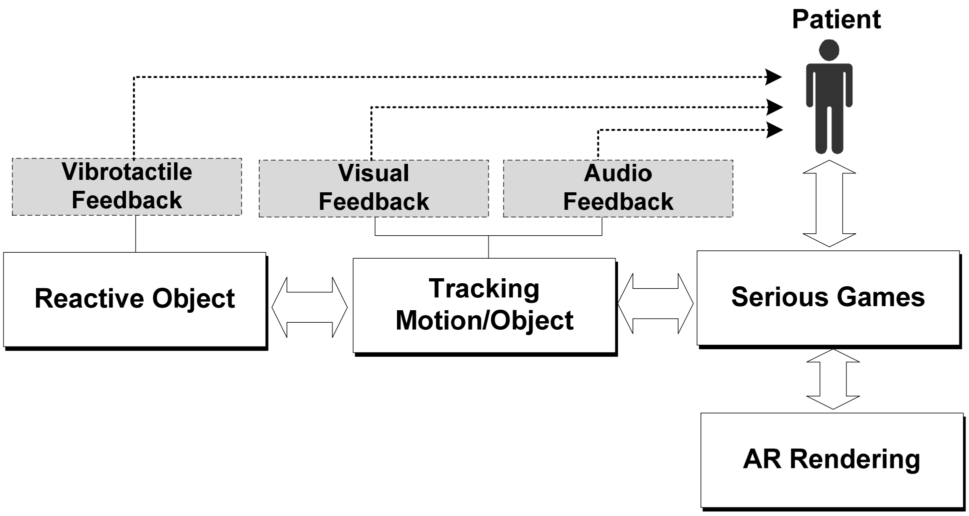

Figure 3. An interaction of a patient with audio, visual, and vibrotactile feedback during playing a game

Real-time feedback is important for a successful stroke patients' rehabilitation because immediate performance notification is beneficial for motor learning or skill acquisition (Vliet & Wulf 2006). Moreover, multimodal (audio, visual, and haptic) feedback is helpful in rehabilitation because it presents feedback to stroke patients using multiple senses, and thus, simplifies user's reception (Riva, 2002). Touch interaction plays an important role in creating more realistic virtual experiences (Reiner, 2004). In addition, multimodal feedback can enhance the ecological validity and the credibility of virtual rehabilitation scenarios (Rizzo et al., 2004). Therefore, our rehabilitation framework encourages patients to accomplish successful treatments through tree types of feedback: audio, visual, and vibrotactile feedback as illustrated in Figure 3.

An actuator controller, a 9V battery and a bluetooth module are embedded in the real object as shown in Figure 4. This real object is lightweight and portable and provides vibrotactile feedback to the patient. The actuators are arranged to cover a whole hand when grabbing the object. We called these objects "Reactive Objects" as they can react with vibration to inform the subject of being interacted with. For example, in the air-hockey game, when the puck hits user's mullet, the vibrotactile actuator around the collided site is activated. In another mode, pre-recorded vibration patterns are presented on patient's hand when the patient accomplishes an objective such as scoring a goal in the air-hockey game.

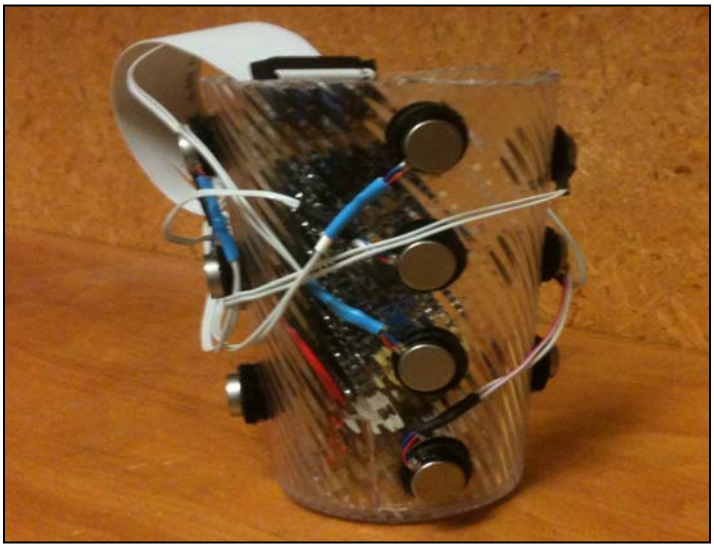

Figure 4. A Reactive object used in our games; a kitchen Cup that covered with vibrotactile actuators.

Usability Study

In this section we present the result of a usability study we conducted. Since we tested the framework with normal subjects, we consider the result as preliminary. However, we assume that if the framework is motivating to normal subjects, then it will be motivating for patients. This is because we considered simplicity in games design while generating motivating feedback to patients (audio, visual, and haptic).

Experiment Setup

Eleven subjects (average age of 30, age range from 22 to 37 years; all males), who are all students at the University of Ottawa, participated in the experiment. All subjects have self-reported a normal or corrected-to-normal vision and a normal sense of touch. All participants were first time to use the designed games environment and scenarios; however, some of them have tried Augmented Reality application before.

To perform the experiment, every subject was asked to perform the above-mentioned games two times (four consequent sessions of treatments). The first time the subject played the game while holding the real object (i.e., mug), where in the second time the subject played the game while holding the Reactive Object (i.e., mug with actuators). In both setups, we collected results to measure the performance of the subjects with and without vibrotactile feedback. At the end of the experiment session, every subject was requested to fill-up a questionnaire to evaluate her/his experience of games.

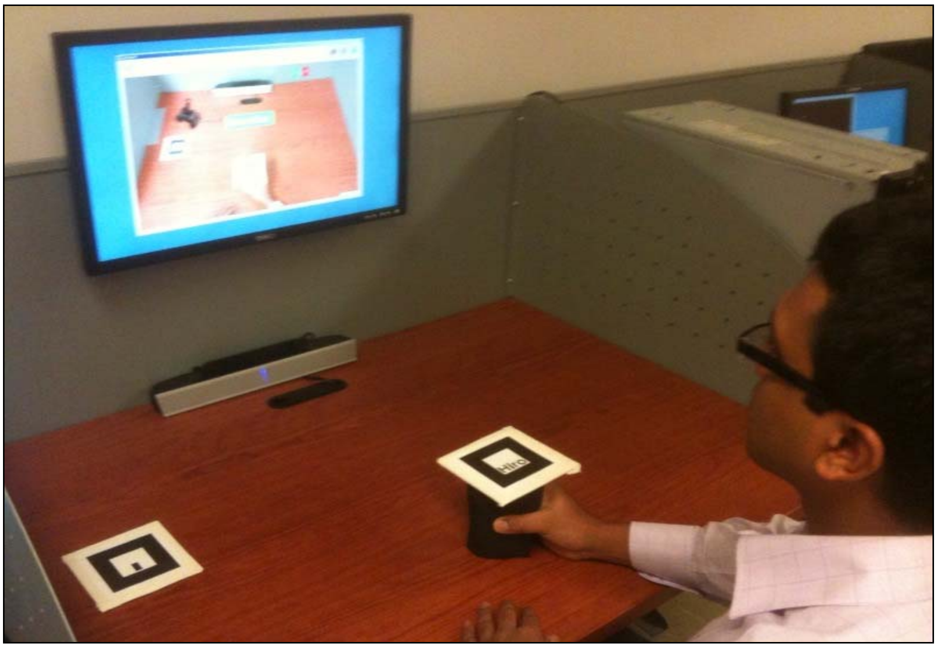

Figure 5. One subject is performing the Cannon-ball game.

As shown in Figure 5, we asked the subjects to sit in front of a regular computer desk facing an 24 inch LCD screen and grabbing a real cup or the designed reactive object (mug with vibrotactile actuators). We used The Microsoft LifeCam 3.0 high definition camera to capture the scene. In the mean time, a custom made armature attached to the desk was used to hold the camera for better viewing angle. We projected the augmented scene on the LCD screen in from of the user.

Result Discussion

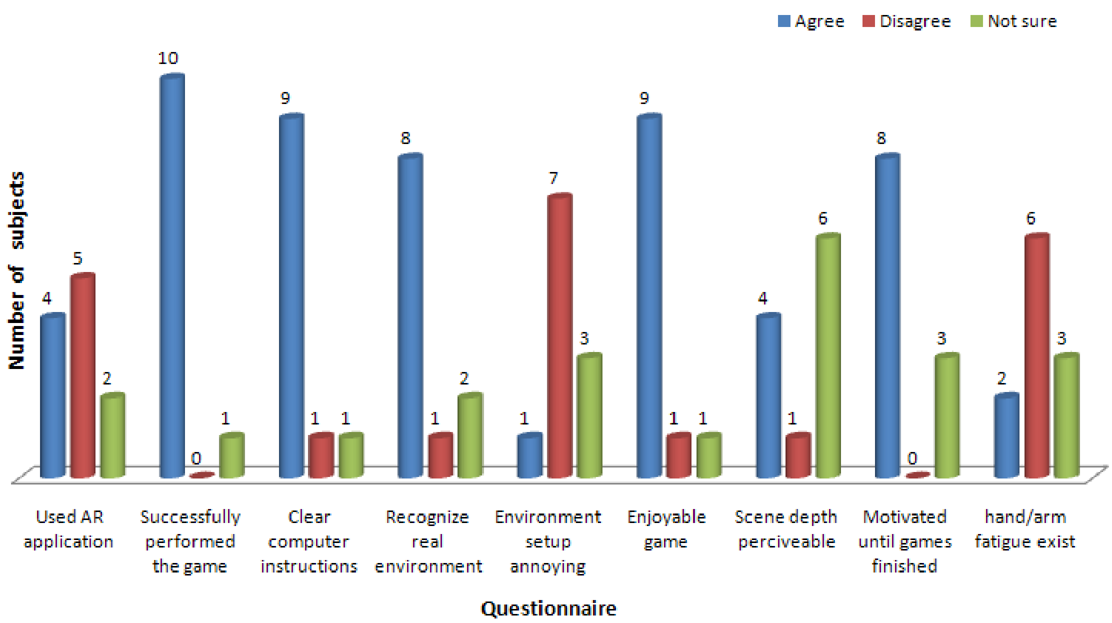

Figure 6. Result of evaluating the proposed games.

From the analysis of the questionnaire, we found that most of the subjects were motivated to play the games (see Fig. 6). In addition, nearly all subjects perceived the environment as a real environment not as a virtual environment. Generally, subjects found that the computer instruction produced by the framework were useful and clear except one subject who suggested to replace the textual instruction with a verbal one. Furthermore, we noticed that only four subjects were able to comfortably perceive well the depth of the augmented video, while three were not sure. However, most of the subjects agreed when we asked them whether they were able to play the game successfully. Thus, we can conclude that most of them were able to perceive the depth of the scene properly. Finally, only two subjects complained of hand and arm fatigue while others finished the task of the game without any noticeable fatigue.

Figure 7 shows the subjects' experience when played and interacted with real object compared with reactive object. Most of the subjects enjoyed it better when they played with reactive object (Only subject three had an opposite opinion). In addition, we found that the subjects reported an enhancement of the perception of the environment depth. Regarding hand/arm fatigue, only one subject complained suffering from it.

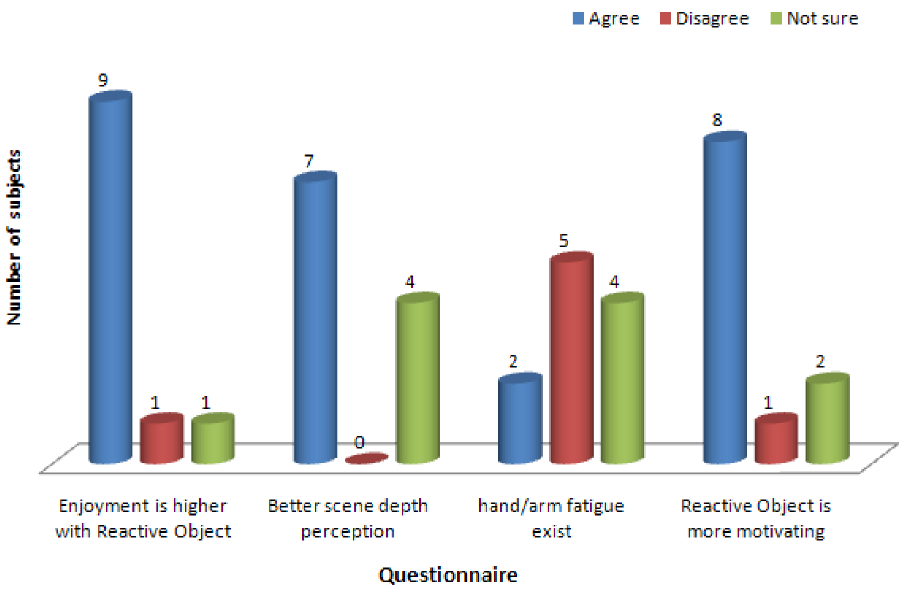

Figure 7. Subject evaluation of Reactive Object trial compared with real object trial of both games.

Table 1 shows the scores of all subjects for both games. We found that almost all subjects achieved better performance when using reactive objects compared real objects. It is worth mentioning that subject number two was not much interested in the version of the games when real objects were used. However, he was more interested in playing the games games when he tested them with Reactive Object. He stated that the vibrotactile actuators (reactive object) increased the level of entertainment in the games.

Subject number three was not interested in playing the "Cannon-ball" game with reactive object because the tactile feedback was limited to vibration only when the ball falls inside the cup. A possible enhancement would be to render tactile forces incrementally as the subject is moving her/his hand to catch the ball. This will guide him/her toward the correct falling position of the ball. The closer the subject's hand is in regard to the falling position, the higher the tactile feedback is.

Table 2. The scores of all subjects for both games.

Games	Cannon-ball Game				Air-Hockey Game			
	With real object		with reactive object		With real object		with reactive object	
Subjects	Catched	Missed	Catched	Missed	Subject Score	Comp Score	Subject Score	Computer Score
Subj-1	5	5	6	4	5	3	5	2
Subj-2	2	8	4	6	3	5	5	4
Subj-3	3	7	4	6	1	5	1	5
Subj-4	3	6	4	6	5	4	5	3
Subj-5	1	9	2	8	2	5	3	5
Subj-6	5	5	7	3	5	4	5	2
Subj-7	2	8	5	5	5	3	5	1
Subj-8	3	7	5	5	3	5	5	2
Subj-9	1	9	1	9	3	5	4	5
Subj-10	6	4	4	6	5	4	5	1
Subj-11	0	10	2	8	5	4	5	1

Conclusion and Future Work

In this paper, we have presented two serious games developed for rehabilitation of stroke patients. The serious games exploit augmented reality technology to provide virtual objects seamlessly blended into real objects. We attached vibrotactile actuators on the real objects, and thus, our games allowed subjects to interact with virtual objects not only through audio/visual feedback but also through the engaging vibrotactile feedback. Usability results demonstrated that the serious games with vibrotactile feedback offers advantages in terms of increasing the interests of the users while playing.

Our study opens several tasks for future work. First, to deal with different scenarios in stroke rehabilitation, we plan to extend the serious games and design other possible games. Second, since the current usability tests were conducted with normal subjects, it is worthwhile observing the usage of stroke patients. In this regard, we plan to conduct further usability tests with real stroke patients.

References

Adamovich, S., Merians, A., Boian, R., Lewis, J., Tremaine, M., Burdea, G., Recce, M., & Poizner, H. (2005). A virtual reality-based exercise system for hand rehabilitation post-stroke. *Presence: Teleoper. Virtual Environ*, *14* (2), 161-174.

Alamri, A., Eid, M., Iglesias, R., Shirmohammadi, S., & El Saddik, S. (2008). Haptic Virtual Rehabilitation Exercises for Poststroke Diagnosis. IEEE *Transaction on Instrumentation and Measurement, 57* (9), 1876–1883.

Alhamid, M., Alamri, A., & El Saddik, A. (2010). Measuring Hand-Arm Steadiness for Post-Stroke and Parkinson's Disease Patients Using Sierra Framework. Accepted in *the International Workshop on Medical Measurement and Applications (2010).*

Boian, R., Lee, C., Deutsch, J., & Burdea, G. (2002). Virtual reality-based system for ankle rehabilitation post stroke. In *Proceedings of the 1st International Workshop on Virtual Reality Rehabilitation (Mental Health, Neurological, Physical, Vocational) VRMHR 2002.*

Boian, R., Deutsch, J., Lee, C., Burdea, G., & Lewis, J. (2003). Haptic effects for virtual reality-based post-stroke rehabilitation. In *Proceedings of the 11th Symposium* *on Haptic Interfaces for Virtual Environment and Teleoperator Systems* (pp. 247-253).

Broeren, J., Björkdahl, A., Pascher, R., & Rydmark, M. (2002). Virtual Reality and Haptics as an Assessment Device in the Postacute Phase after Stroke. *CyberPsychology and Behavior*, *5* (3), 207-211.

Burdea, G. (2003). Review Paper - Virtual Rehabilitation- Benefits and Challenges. In *Proceedings of the 2003 International Medical Informatics Association Yearbook of Medical Informatics* (pp. 170-176). Heidelberg, Germany.

Chen, Y., Xu, W., Sundaram, H., Rikakis, T., & Liu, S. (2008). A dynamic decision network framework for online media adaptation in stroke rehabilitation. *ACM Transactions on Multimedia Computing, Communications and Applications*, *5* (1), 1-38.

Foulkes, M., Wolf, P., Price, T., Mohr, J., & Hier, D. (1988). The Stroke Data Bank: Design, methods, and baseline characteristics. *Stroke*, *19*, 547-554.

Gaggioli, A., Meneghini, A., Pigatto, M., Pozzato, I., Greggio, G., Morganti, F., & Riva. G. (2007). Computer-enhanced mental practice in upper-limb rehabilitation after cerebrovascular accident: a case series study. In *Proceedings of the 2007 International Conference of Virtual Rehabilitation* (pp. 151-154).

Hilton, D., Cobb, S., Pridmore, T., & Gladman, J. (2002). Virtual reality and stroke rehabilitation: a tangible interface to an every day task. In *Proceedings of the 4th International Conference Disability, Virtual Reality & Associated Technologies* (pp. 63-70).

Holden. M. (2005). Virtual environments for motor rehabilitation: review. *Cyberpsychology & behavior*, *8* (3), 187-211.

Holden, M., Todorov, E., Callahan, J., & Bizzi, E. (1999). Virtual Environment Training Improves Motor Performance in Two Patients with Stroke: Case Report. *Journal of Neurologic Physical Therapy*, *23* (2), 57-67.

Virtual Realities Inc. (n. d.) *CyberForce haptic device*. Retrieved 2010 from http://www.vrealities.com/cyberforcehi.html

Kayyali, R. (2007). Occupational therapists' evaluation of haptic motor rehabilitation. In *Proceedings of the 29th IEEE Annual International Conference of Engineering in Medicine and Biology Society* (*EMBS 2007*) (pp. 4763–4766).

Kizony, R., Katz, N., & Weiss, P. (2004). Virtual reality based intervention in rehabilitation: relationship between motor and cognitive abilities and performance within virtual environments for patients with stroke. In *Proceedings of the 5th International Conference Disability, Virtual Reality & Associated Technologies* (pp. 19-26).

Loureiro, R., Collin, C., & Harwin, W. (2004). Robot Aided Therapy: Challenges Ahead for Upper Limb Stroke Rehabilitation. In *Proceedings of the 5th International Conference on Disability, Virtual Reality and Associated Technologies* (pp. 33-39).

Lozano, J., Montesa, J., Juan, M., Alcañiz, M., Rey, B., Gil, J., Martinez, J., Gaggioli, A., & Morganti. F. (2005). VR-Mirror: A Virtual Reality System for Mental Practice in Post-Stroke Rehabilitation. *Lecture Notes in Computer Science*, *3638*, 241-251.

Luo, X., Kenyon, R., Kline, T., Waldinger, H., & Kamper, D. (2005a). An augmented reality training environment for post-stroke finger extension rehabilitation. In *Proceedings of the 9th International Conference on Rehabilitation Robotics (ICORR 2005)* (pp. 329-332).

Luo, X., Kline, T., Fischer, H., Stubblefield, K., Kenyon, R., & Kamper, D. (2005b). An augmented reality training environment for post-stroke finger extension rehabilitation. In *Proceedings of the 9th International Conference on Rehabilitation Robotics (ICORR 2005).*

Piron, L., Cenni, F., Tonin, P., & Dam, M. (2001). Virtual reality as an assessment tool for arm motor deficits after brain lesions. In J. Westwood (Eds.), *Studies in Health Technology and Infomatics, 81*, 386–392.

Radomski, M., & Trombly, C. (2007). *Occupational therapy for physical dysfunction: Comprehensive atlas*, (6th Edition). Lippincott: Williams & Wilkins.

Reiner, M. (2004). The role of haptics in immersive telecommunication environments. *IEEE Trans. Circuits and Systems for Video Technology*, *14* (3), 392-401.

Rizzo, A., Mclaughlin, M., Jung, Y., Peng, W., Yeh, S., & Zhu., W. (2005). Virtual therapeutic environments with haptics: An interdisciplinary approach for developing post-stroke rehabilitation systems. In *Proceedings of the 2005 International Conference on Computers for People with Special Needs*.

Rizzo, A. Schultheis, M., Kerns, K., & Mateer, C. (2004). Analysis of assets for virtual reality applications in neuropsychology. *Journal of Neuropsychological Rehabilitation, 14* (1), 207-239.

Riva, G. (2002). Virtual reality for health care: the status of research. *Cyberpsychology & Behavior*, *5* (3), 219-225.

Rose, F., Attree, E., Brooks, B., Parslow, D., & Penn, P. (2000). Training in virtual environments: transfer to real world tasks and equivalence to real task training. *Ergonomics*. *43* (4), 494-511.

Vliet, P. & Wulf. G. (2006). Extrinsic feedback for motor learning after stroke: What is the evidence?. *Disability & Rehabilitation*, *28* (13-14), 831-840.

Wulf, G. & Prinz, W. (2001). Directing attention to movement effects enhances learning: A review. *Psychonomic Bulletin and Review*, *8* (4), 648-660.

Zyda, M. (2005). From visual simulation to virtual reality to games. *Computer*, *38* (9), 25-32.

Serious Games – The challenges for computer science in sport

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Abstract

Digital games can be used not only for fun and entertainment. The term 'serious games' denotes digital games serving serious purposes like education, training, advertising, research, and health. In the contribution the chances and challenges of serious games for computer science in sport will be discussed.

Serious games, particularly adventure and shooter games, already play an important role in health education and rehabilitation, e.g., to enhance health-related physical activity, prevent asthma, change nutrition behavior and alleviate diabetes, prevent smoking or HIV.

Serious games also offer new options for training in sport. In our laboratory, we developed a prototype for application in volleyball training.

Education in sport and sport science is another promising application field of serious games. Particularly the natural sciences offer the opportunity to combine simulations and gaming in order to learn about the basics of movement.

The effects of Serious Games depend on the specific game genre. They can be described and explained by different mechanisms including social, psychological, and motor processes.

Despite first promising results the sustainability is a critical factor. In this regard, computer science in sport can help to develop and implement serious games and test appropriate settings that ensure sustainable use of serious games.

SERIOUS GAMES, REHABILITATION, PREVENTION, HEALTH, EDUCATION

Introduction

Playing games is a fundamental human activity. Engaging in playing means to pursue a purposeless activity (i.e., driven by intrinsic motivation) that is free of external restraints, experiencing inner infinity (e.g., flow), and acting within an illusionary (symbolic) 'quasi-reality'. Games are ambivalent and open concerning both process and outcome. On the other hand, games are subject to closed rules defining goals, allowed and forbidden actions etc. Games normally have simple goal structures. Because of immediate feedback, players experience presence and directness. Games can be repeated over and over like rituals. Because of all these features games in general have a positive connotation, particularly concerning human development. Particularly children and young adults can act in fictional or 'virtual' contexts, test different roles and experience different behaviour without the danger of causing 'real' consequences.

Concerning digital games, i.e., games that are played on electronic devices working with microprocessors, this positive connotation seems to be not valid. On the one hand, digital games (i.e., video games, computer games, and mobile games) are considered appropriate options to enhance cognitive, perceptual-motor, emotional, personal and social competencies (see figure 1; Gebel, Gurt, & Wagner, 2005; Wiemeyer, 2009). On the other hand, digital gaming is considered to cause addiction, obesity and other social, psychological or physical hazards (Griffiths, 2005; Mitchell & Savill-Smith, 2004, p.25).

Cognition:
Perception
Attention
Understanding structures and meanings
Strategic thinking
Problem solving
Planning, management
Memory

Emotions & volition:
Emotional control
Stress control
Endurance

Personal competencies:
Self-observation
Self-critics
Identity
Emotional control

Motor control:
Eye-hand coordination
Eye-foot coordination
Reaction time
Sensory-motor abilities
Operating mouse and keyboard
Endurance, strength, flexibility

Social competencies:
Cooperation
Mutual support
Empathy
Interaction and communication skills
Moral judgements

Media competency:
Media knowledge
Self-regulated use
Active communication
Media design

Figure 1. Competencies that can be enhanced by playing digital games (adopted with modifications from Gebel, Gurt, & Wagner, 2005, p.262)

Recently an area of digital games emerged termed ‘serious games’. The idea of ‘serious games’ is to integrate playing games, simulation, and learning or training for serious purposes like education, exercising, health, prevention, rehabilitation, and advertisement (for a review cf. Sawyer & Smith 2008). This combination of gaming and serious application purposes on the one hand offers new fascinating options and on the other hand raises critical questions. The purpose of this contribution is to address this ambivalence of ‘serious games’ and to discuss the specific chances and challenges for computer science in sport. Three application areas will be discussed: prevention, rehabilitation, and learning.

Serious games for prevention – exergames and games for health

Physical inactivity and its consequences (e.g., obesity, hypertony, and metabolic syndrome) are among the most serious threats to health and well-being. Preventing accidents and falling is another important area of prevention, particularly for elder people. Besides control of nutrition and drug consumption, performing an adequate, continuous, and enduring physical activity or sport program is an important issue.
One goal of these activities is to raise the energy expenditure above a minimum 600 to 800 kcal per week, with on optimum of about 3,000 kcal per week (Sygusch, Wagner, Janke & Brehm, 2005). There have been many attempts to motivate and encourage people to engage in health-enhancing physical activities (HEPA). One key issue is to establish a sustainable modification of behaviour. In this regard, psychological aspects like motivation, volition, self-determination and self-efficacy play an important role (Godin & Kok; 1996, Hagger, Chatzisarantis & Biddle, 2002; Hausenblas, Carron & Mack, 1997; Sheeran, Conner & Norman, 2001: Theodorakis, 1994; Theodorakis, Doganis, Bagiatis & Gouthas 1991; Ryan & Deci, 2000). Furthermore, the structure of factors contributing to engagement in HEPA may change over time (e.g., Wagner, 2000). According to the proposed theory of planned behaviour and its extensions, digital games may offer a good option for HEPA because of their positive effects on attitude, emotions, motivation, intention, and self-efficacy.
The new generation of digital games, especially video games, works on interfaces that demand whole-body movements to control the game, like Sony eye-toy kinetics and Nintendo Wii sport. Specific sensors like cameras, motion sensors and force sensors register the movements of the players and integrate this information into the control of the respective game.
Numerous studies have been published showing great differences concerning the applied research methods (Baranowski et al., 2008; Lager & Bremberg, 2005; Lieberman, 2001; Papastergiou, 2009 for recent reviews). Concerning the rise of energy expenditure, figure 2 shows the results of the available studies. The impact of playing games on energy expenditure is highly depending on gaming device, game and intensity of gaming. Energy expenditure in ‘virtual’ sport games is always below the respective ‘real’ sports activity. At best an energy expenditure of above 400 kcal per hour can be achieved. This means that in order to meet the minimum requirements for HEPA, one has to play at least two hours per week; for the optimum at least 7.5 hours are required. From long-term studies we know that this demand has never been met by the subjects.
Other application fields are perception, motor control, asthma prevention, prevention of drug abuse, smoking prevention, HIV prevention, prevention of violence, and nutrition. Most of the studies find positive short-term effects of serious gaming on attitude, knowledge, motivation, volition, and behaviour. Almost nothing is known about long-term effects.
Summing up the existing evidence, the following effects can be expected from health games:

- Improvement of simple reactions
- Improvement of simple perceptual skills (e.g., spatial resolution)
- Improvement of basic motor control (e.g., balance)
- Improvement of knowledge concerning HEPA
- Improvement of self-efficacy and other motivational, emotional, and volitional components

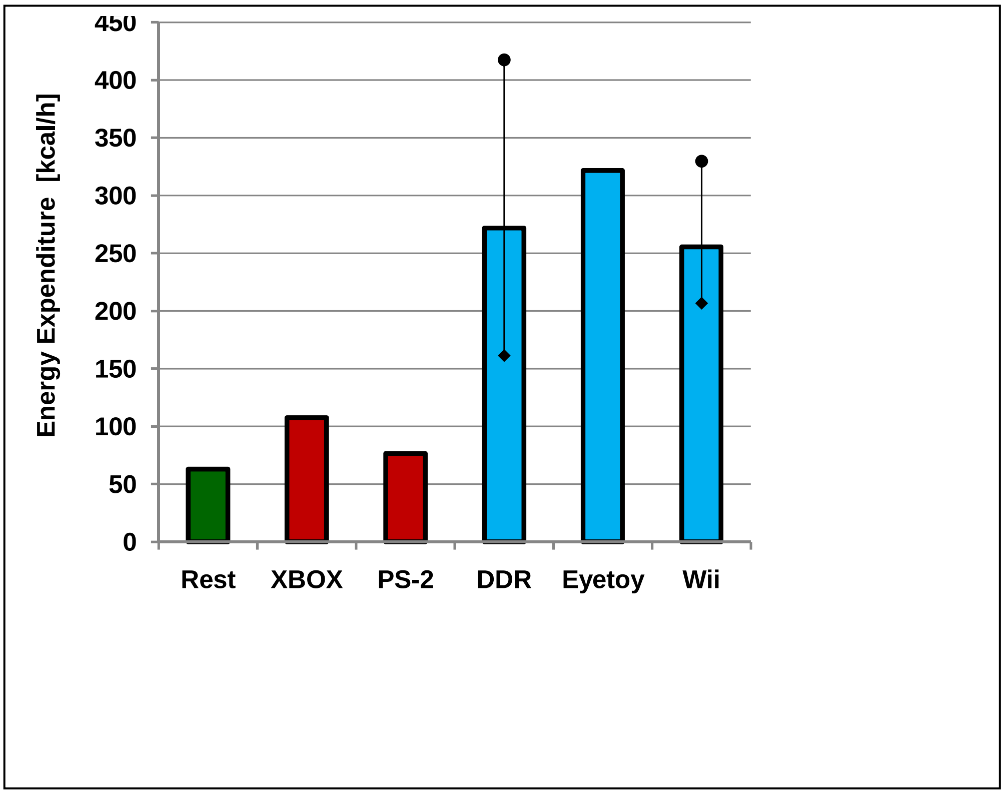

Figure 2. Results of games studies trying to raise energy expenditure (from Wiemeyer, under review) (Legend: PS-2 – Playstation 2; DDR – Dance Dance Revolution; • - maximum; ◆ - minimum)

Which are the particular challenges for computer science in sport?
Computer Science in Sport as an interdisciplinary scientific area has to deal with the following questions:

- Development of appropriate sensor systems being able to measure sport performance
- Development of appropriate algorithms for real-time recognition of sport activities and action parameters
- Development of appropriate game concepts for effective and enduring enhancement of all components of health behaviour
- Evaluation of health games in order to identify the appropriate learning and training settings.

Serious games for rehabilitation – Rehagames

In rehabilitation numerous applications have been reported (see Wiemeyer, under review). Many of them are just case reports or qualitative studies based on small samples of patients. The following applications fields of therapy and rehabilitation are covered:

- Asthma
- Diabetes
- Cancer
- Respiratory diseases
- Neurological therapy after stroke and other brain injuries
- Burns

The first applications date back to the 1980s, where specific interfaces were developed and the motivational impact of games was exploited. In modern medical therapy, analogous to prevention, the effect models comprise all relevant aspects of human action and perception, ranging from knowledge to actual behaviour. One important result of these studies is that therapy has to employ meaningful movements, i.e. movement embedded into a context that makes sense to the patients. Using movements to control a game instead of rote movements had a significant positive effect on therapeutic results.

Again, in the area of rehabilitation some specific challenges exist for computer science in sport:

- Selection of appropriate sport or sport-like movements in order to offer meaningful contexts
- Construction of appropriate training devices (including sensors and interfaces) to enhance motor control
- Development and evaluation of adequate training settings.

Serious games for learning – Edugames

A third application field of serious games is education. According to Mitchell and Savill-Smith (2004) there are many reasons to apply digital games to education and learning:

- Digital games enhance individual engagement and active involvement in learning by increased motivation.
- Digital games deliver fast, individualized and immediate feedback.
- Digital games increase learning efficiency.
- Digital games individualize learning by means of numerous options for interaction, adaptation and communication.
- Particularly simulation games offer unique opportunity to learn without having to face real consequences like injuries (Lee, 1999). Particularly the natural sciences like maths, physics, and chemistry offer good options for simulation games because a high level of formalization exists that can easily be transformed into game scenarios with clearly defined tasks and feedback options.

In general digital games have been used predominantly in the following application fields:

- Clinics – diagnostics, training, and therapy
- Language education (reading, writing)
- Physics, mathematics
- Psychology
- Civil engineering, military
- Basic perceptual and sensory-motor skills and abilities
- Problem solving

In sport and sport science only few reports have been published so far using digital games for learning motor skills or enhancing motor abilities. The results show that digital games have a great potential for learning.

Fery and Ponserre (2001) showed that using a golf video game could enhance putting accuracy. The players had to control a virtual player’s putt. However, only the game group who could watch a symbolic representation of the putting force (gauge on a scale) showed enhanced learning.

Hebbel-Seeger (2008) adopted a simulative sailing game to enhance sailing skills. In a preliminary study, he found positive transfer effects to real sailing. He assumes that cognitive transfer was supported by the training environment.

In three consecutive experiments on learning table tennis skills, Sohnsmeyer (2009) found effects on both knowledge and reaction in table tennis.

Brumels et al. (2008) applied the video games 'Dance Dance Revolution' and 'Wii fit' to the training of balance skills. They found differential effects of video gaming compared to a traditional balance program: Whereas the traditional group performed better at the Star Excursion Balance Test, the two game groups outperformed the traditional group at the postural sway task. Furthermore, the game groups reported that the training program was less strenuous and more enjoyable compared to the traditional group.

In general, applying digital games to education in sport seems to support at least two components: knowledge about movements and basic perceptual-motor skills. There is some evidence that sports-specific motor control may also be improved.

In our lab a volleyball prototype was developed (in cooperation with the research group of Dr. Stefan Göbel) in order to improve tactical knowledge and behaviour (see figure 3). The player has to solve typical tactic tasks of increasing difficulty. She has to proceed in different steps:

1. She has to choose three options from a menu of suggested actions: ideal, sub-optimal, and emergency option. Depending on the quality of reception one of these options are chosen by the program.
2. She has to control the receiving player. First, she has to place the player at the correct location to receive the ball and second she has to initiate the receiving action at the correct time.
3. She has to control the attacking player. She has to decide on attacking technique, direction and speed of the attacking action.
4. Finally the quality of the three steps is recorded and a final score is displayed. Then the sequence starts again with the first step.

Figure 3. Screenshot of the volleyball prototype

Which are the challenges for computer science in sport?

- First of all, appropriate application to learning needs to establish a perfect fit of didactics, learning theory, and the respective digital game system.
- Appropriate interfaces and sensors have to be developed which allow a realistic transformation of players' actions to sensor signals.
- To identify action types and parameters in real-time appropriate and fast algorithms have to be developed.
- One important challenge is to determine the adequate level of transfer. The transfer problem is one of the crucial issues for learning (Hossner, 2003; Smyth, 2003).
- The key issue is to establish an appropriate balance of gaming and learning (Ang & Rao, 2008). This is not at all trivial. In this regard, Ang and Rao (2008) have identified three main reasons why educational games may not be as attractive as commercial digital games: lack of a narration that addresses phantasy and curiosity, lack of semantic rules that address education and learning, and lack of explicit ludus rules that demand solving challenging tasks of adequate difficulty.

How do Serious Games work?

This issue has already been addressed in the previous sections. Applying digital games to serious purposes like prevention, rehabilitation, and education is far away from a naive expectation of just enhancing fun and activation. Most of the studies are based on a detailed model of effects. To sum it up, the following levels can be distinguished (see also figure 1):

- Motivation, emotion, and volition
  Positive effects on intrinsic motivation, attitude, self-concept, perceived control, and self-efficacy are expected and have been confirmed by research.
- Cognitive learning
  Serious games support a specific way of cognitive learning. By focussing on and solving attractive tasks, pursuing clear goals, repeating the attempts to solve the problems, getting immediate feedback and background information a deeper information processing becomes possible. Transfer may be enhanced by more authentic and variable contexts or the appropriate symbolic representation of transfer-relevant information.
- Perceptual-motor learning
  Depending on the quality of the (wo)man-game interface basic or specific perceptual-motor skills and abilities can be acquired and transferred.
- Social interaction and communication
  Constructivist approaches emphasize the importance of social interaction and communication for learning. This component can be addressed by a specific genre of digital games: massive(ly) multi-player online games (MMOG). Mobile devices like cell phones and PDAs (personal digital assistants) can also be used to support interaction and communication.

As a result, the surplus value of serious games must not be reduced to the simple formula ‘serious purpose + motivation’. Rather, serious games offer options for a new kind of prevention, rehabilitation, and education.

Conclusion – Chances and challenges

In this contribution three application fields of serious games have been discussed. Existing studies clearly show that serious games have much to offer to the fields of prevention, rehabilitation, and education. On the other hand, to avoid a new ‘hype’ overestimating the potentials of serious games, the new options of serious games can only take effect if serious games are developed and designed based on an interdisciplinary understanding of the respective application field. The requirements of the field have to match the options of digital games. Successful applications show that this synthesis is possible and can produce substantial benefits of serious games.

One key problem to be solved is sustainability. Serious games have been proved to produce short-term effects. This effect may be due to initial increase of motivation. But prevention, rehabilitation, and education aim at enduring effects. Few studies investigating long-term effects are much less promising. In order to ensure sustainability, research has to evaluate which settings support long-term motivation and engagement in serious games.

Furthermore, there are great challenges for computer science in sport concerning development of appropriate sensor and interface technology, real-time activity recognition, and establishing a balance of narration, rules, and application purposes. To achieve high quality of serious games there is a strong demand for truly interdisciplinary cooperation. The future will show whether computer science in sport is willing and ready to meet these ambitious demands.

References

Ang, C. S. & Rao, R. K. (2008). Computer Game Theories for Designing Motivating Educational Software: A Survey Study. *International Journal on E-Learning, 7* (2), 181-199.

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for real. Video games and stories for health-related behavior change. *American Journal of Preventive Medicine, 34* (1), 74–82.

Brumels, K. A., Blasius, T., Cortright, T., Oumedian, D., & Solberg, B. (2008). Comparison of efficacy between traditional and video game based balance programs. *Clinical Kinesiology: Journal of the American Kinesiotherapy Association*, *62* (4), 26-31.

Fery, Y.-A. & Ponserre, S. (2001). Enhancing the control of force in putting by video game training. *Ergonomics, 44* (12), 1025–1037.

Godin, G. & Kok, G. (1996). The theory of planned behavior: A review of its applications to health-related behaviors. *American Journal of Health Promotion, 11* (2), 87-97.

Gebel, C., Gurt, M,. & Wagner, U. (2005). Kompetenzförderliche Potenziale populärer Computerspiele. In Arbeitsgemeinschaft betriebliche Weiterbildungsforschung (Eds.), *E-Lernen: Hybride Lernformen, Online-Communities, Spiele* (pp. 241-376). QEM-Report, Heft 92. Berlin: Arbeitsgemeinschaft betriebliche Weiterbildungsforschung.

Griffiths, M. (2005). Video games and health. Video gaming is safe for most players and can be useful in health care. *British Medical Journal, 331,* 122-123.

Hagger, M. S., Chatzisarantis, M. L. D., & Biddle, S. J. H. (2002). A meta-analytic review of the theories of reasoned action and planned behavior in physical activity: Predictive validity and the contribution of additional variables. *Journal of Sport and Exercise Psychology, 24,* 3-32.

Hausenblas, H. A., Carron, A. V., & Mack, D. E. (1997). Application of the theories of reasoned action and planned behavior to exercise behavior: A meta-analysis. *Journal of Sport and Exercise Psychology, 19,* 36-51.

Hebbel-Seeger, A. (2008). Videospiel und Sportpraxis - (k)ein Widerspruch. *Zeitschrift für e-learning*, *3* (4), 9-20.

Hossner, E.-J. (2003). Transfer described – Transfer interpreted – Transfer explained. *E-Journal Bewegung und Training, Suppl.,* 39-40.

Lager, A. & Bremberg, S. (2005). *Health effects of video and computer game playing. A systematic review*. Stockholm: Swedish National Institute of Public Health. [Online-Version]

Lee, J. (1999). Effectiveness of computer-based instructional simulation: A meta analysis. *International Journal of Instructional Media 26* (1), 71-85.

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.

Mitchell, A. & Savill-Smith, C. (2004). *The use of computer and video games for learning. A Review of the literature.* London: Learning and Skills Development Agency.

Papastergiou, M. (2009). Exploring the potential of computer and video games for health and physical education: A literature review. *Computers & Education, 53*, 603–622.

Ryan, R. M. & Deci, E. L. (2000). Self-Determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-Being. *American Psychologist, 55* (1), 68-78.

Sawyer, B. & Smith, P. (2008). *Serious Games Taxonomy*. Retrieved May 30, 2008 from http://www.dmill.com/presentations/serious-games-taxonomy-2008.pdf

Sheeran, P., Conner, M., & Norman, P. (2001). Can the theory of planned behavior explain patterns of health behavior change? *Health Psychology, 20* (1), 12-19.

Smyth, P. J. (2003). Gaining insight to what is transferred between motor skills. *E-Journal Bewegung und Training, Suppl.*, 45-46.

Sohnsmeyer, J. (2009). Virtuelles Spiel und realer Sport – Nutzungspotenziale digitaler Sportspiele. In S. Baumgärtner, F. Hänsel & J. Wiemeyer (Eds.), *Informations- und Kommunikationstechnologien in der Sportmotorik* (pp. 141-143). Hamburg: TK.

Sygusch, R., Wagner, P., Janke, A., & Brehm, W. (2005). Gesundheitssport – Effekte und deren Nachhaltigkeit bei unterschiedlichem Energieverbrauch. *Deutsche Zeitschrift für Sportmedizin, 56* (9), 318-326.

Theodorakis, Y. (1994). Planned behavior, attitude strength, role identity, and the prediction of exercise behavior. *The Sport Psychologist, 8,* 149-165.

Theodorakis, Y., Doganis, G., Bagiatis, K., & Gouthas, M. (1991). Preliminary study of the ability of reasoned action model in predicting exercise behavior of young children. *Perceptual and Motor Skills, 72,* 51-58.

Wagner, P. (2000). *Aussteigen oder Dabeibleiben?* Darmstadt: WBG.

Wiemeyer, J. (2009). Digitale Spiele – (k)ein Thema für die Sportwissenschaft?! *Sportwissenschaft, 39* (2), 120-128.

Wiemeyer, J. (under revision). Gesundheit auf dem Spiel? – Serious Games in Prävention und Rehabilitation. *Deutsche Zeitschrift für Sportmedizin*.

Effect of a six-week-intervention with an activity-promoting video game on isometric muscle strength in elderly subjects

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Abstract

In order to analyze the effect of a six-week intervention with an activity-promoting video game on muscle strength in elderly subjects (> 60 years) a controlled pretest-posttest study was conducted. The intervention group performed a 20-minutes session playing Wii bowling, twice a week for a total of six weeks. Data was analyzed by use of an ANCOVA. When comparing the results with the control group findings, the isometric muscle strength of the m. quadriceps increased significantly. Thus, an activity-promoting video game such as bowling with a Wii leads to functional improvement and might have positive health implications for elderly people.

ACTIVITY-PROMOTING, VIDEO GAME, WII, MUSCLE STRENGTH, ELDERLY SUBJECTS

Introduction

Physical activity is inversely associated with morbidity and mortality from chronic diseases such as cardiovascular diseases and cancer. Twenty years ago Blair et al. (1989) demonstrated that in addition to the volume of physical activity (behaviour) physical fitness (attribute) is a more powerful prognostic health factor. Fitness was at least as important as classical risk factors such as arterial hypertension, high blood lipids or obesity (Blair et al., 1989). Improvement of fitness by exercise training reduced mortality as shown in a further study (Blair et al., 1995).

Growing evidence shows that not only endurance capacity but also strength is a predictor of health especially in elderly people. Several studies have indicated a correlation between muscle strength and future morbidity, disability and mortality in elderly subjects. Although the trainability of both endurance and strength has been documented even in nonagenarians (Fiatarone et al., 1990) many elderly are subjected to steady decline in muscle strength, because the vast majority are physically inactive. This decline in fitness is associated with deterioration in health.

“The Nintendo Wii console is one example of a commercially available games system that integrates hand and, in some cases, whole body movements in a range of simulated environments. Games systems provide opportunities to improve motor skills” (Hill, 2009, p. 1169). For adolescents, Graves, Stratton, Ridgers, & Cable (2007; 2008) compared the energy expenditure when playing sedentary and activity-promoting video games (Wii) and found that activity-promoting video games produced significantly greater energy expenditures than playing sedentary games. Nitz, Kuys, Isles, & Fu (2009) revealed in a pilot study significant improvements on balance and lower limb

muscle strength in ten women aged 30–58 years. Currently, there is no study published supporting evidence for an effect on muscle strength in subjects elder than 60 years.
In the present study, the effect of a six-week intervention with an activity-promoting video game on muscle strength of the m. quadriceps in 20 subjects older than 60 years was investigated. The aim was to find out, whether there were positive effects of the video game on an important health predictor in elderly persons.

Methods

Study population

There were a total of 40 volunteers (36 female, 4 male) recruited from assisted living facilities of the German Red Cross (GRC) and the deaconship Kiel who participated in the study. The demographic information collected included age and self-reported information that related to habitual physical activity and well-being. Volunteers were allocated into two groups: 20 persons (age 76.95 ± 4.84 years) undertook a continuous six-week-intervention with an activity-promoting video game and 20 persons (age 77.75 ± 8.69 years) served as the control group in which all testings were conducted but no intervention exercises were attended.

Training program and Testing

Prior to the training period, maximal isometric muscle strength (m. quadriceps) was tested. After the participants familiarized themselves with the Wii Sports video game (bowling) a 20-minutes session was performed twice a week for six weeks in total. The Wii is operated by moving a handheld controller, which can detect acceleration in three dimensions. The controller communicates with the base unit using Bluetooth and the player receives control of the game through movements of the whole body. So when playing Wii bowling, the player executes the same movements as in real bowling.
Following to the training period the subjects performed the strength test again.
A force transducer was used to determine maximal isometric strength of both legs (m. quadriceps). During testing the subjects were sitting on a chair with the knee flexed at 90°. A non-elastic strap was placed around the leg just above the ankle. The strap was attached to a digital dynamometer (Digimax - mechaTronic, Hamm, Germany) which was connected to a personal computer. The subjects were instructed to perform a maximal isometric contraction. The test was repeated within 30 seconds, taking the highest value of three tests for the analysis. The values obtained by the Digimax were converted from N to kg.

Statistical analysis

A one-way analysis of covariance (ANCOVA) was conducted. The independent variable ‘group’ involved two levels: intervention and control group. The dependent variables were posttest muscle strength of the left and right m. quadriceps. The covariates were pretest muscle strength of the left and right m. quadriceps.
The assumptions for ANCOVA were met. In particular, the homogeneity of the regression slopes was evident for the covariates and the covariates were significantly related to the dependent variables. SPSS (version 17.0) was used for statistical analyses and level of statistical significance was established a priori at $p < .05$.

Results

After the six-week training program, there were significant changes in the maximum isometric strength of the m. quadriceps for the intervention group. Maximum isometric strength for the intervention group increased by an average of 38.71% for the left leg (from 17.54 kg before to 24.33 kg after the training period), and 36.91% for the right leg (from 19.48 kg to 26.67 kg). Data on muscle strength are shown in Table 1.

Table 1: Age and muscle strength (pre- and posttest scores) for intervention group and control group

	Intervention group (M ± SD)	Control group (M ± SD)
Age (years)	76.95 ± 4.84	77.75 ± 8.69
Strength left pre (kg)	17.54 ± 4.70	18.86 ± 6.40
Strength right pre (kg)	19.48 ± 5.92	20.70 ± 6.93
Strength left post (kg)	24.33 ± 4.73	21.98 ± 8.35
Strength right post (kg)	26.67 ± 5.98	22.00 ± 8.60

The arithmetic mean (M) with standard deviation (SD)

The means of muscle strength adjusted for initial differences were ordered as expected across the two groups. For muscle strength of the m. quadriceps the intervention group had the largest adjusted means (M_{left} = 24.97, M_{right} = 27.27) and the control group had the smallest adjusted means (M_{left} = 21.33, M_{right} = 22.40). Figure 1 shows the maximal isometric muscle strength of the two groups (adjusted posttest means).

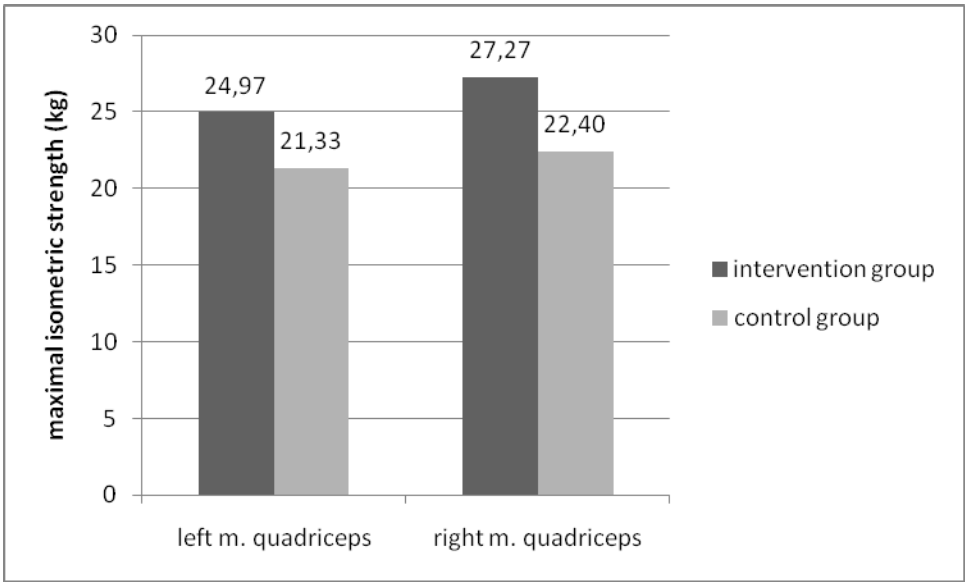

Figure 1: Group profiles of posttest means adjusted by pretest scores on maximal isometric strength

There was a significant effect of playing the activity-promoting video game on posttest muscle strength of the left ($F(1, 37) = 8.059$, $p = .007$, $\eta^2 = .179$) and right ($F(1, 37) = 13.354$, $p = .001$, $\eta^2 = .265$) m. quadriceps after controlling for the effect of pretest muscle strength. Evidently there is a strong relationship between group and the dependent variables, as assessed by η^2.

Discussion

The results of the present study support the concept of a sustained trainability of muscle strength in an elderly population. There was a significant increase in isometric strength of the m. quadriceps in the intervention group as compared with the control group. While this finding has been revealed using conventional training programs in several other studies, we investigated the effect of an activity-promoting video game (bowling) on muscle strength. The acceptance of this type of training was high among the elderly subjects (data not shown) and the interactive character of the video game may contribute to a long-term effect on muscle strength. In addition, other skills such as balance and coordination might also be improved by this intervention. Further studies are necessary to assess these effects. It is unclear whether this training may indeed reduce future morbidity in our study group. But increased muscle strength has been linked to reduced disability, decreased number of falls and even increased life expectancy (Rantanen, 2003; Rantanen et al., 2003). There are even data suggesting that strength training might be more effective than endurance training in chronic disease such as type 2 diabetes mellitus (Cauza et al., 2005).

Thus, involving elderly subjects in activity-promoting video games such as bowling with a Wii may lead to functional improvement and might have positive health implications. Motivation for physical activity may not only increase in younger but also in elderly subjects (Baranowski, Buday, Thompson, & Baranowski, 2008; Lin, Mamykina, Lindtner, Delajoux, & Strub, 2006).

Playing Wii has shown to expend more energy than traditional computer games, "but not to the same extent as the authentic sports" (Graves et al., 2008, p. 1284). For elderly subjects this lower level of extent might be sufficiently dimensioned.

However, some hazards with activity-promoting video games have to be mentioned.

Lately some injuries have been reported that are associated with playing activity-promoting video games. There are injuries described involving shoulder (Bonis, 2007; Cowley & Minnaar, 2008) or knee (Robinson, Barron, Grainger, & Venkatesh, 2008) but also a traumatic haemothorax (Peek, Ibrahim, Abunasra, Waller, & Natarajan, 2008). According to these findings one can say that playing Wii is quite demanding, especially for elderly subjects.When using Wii for rehabilitation (Deutsch, Borbely, Filler, Huhn, & Guarrera-Bowlby, 2008) we therefore suggest that these intensive training sessions are being conducted under the guidance of fully qualified trainers.

Given the current level of engagement of elderly subjects with interactive video games further research is required to: (a) examine usability and acceptance parameters, (b) inspect improvements on balance, coordination, and energy expenditure versus traditional physical activities, (c) determine sex differences, and (d) analyse the long term effect of interactive video games.

References

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for Real: Video Games and Stories for Health-Related Behavior Change. *American Journal of Preventive Medicine, 34* (1), 74-82.

Blair, S. N., Kohl, H. W., Barlow, C. E., Paffenbarger, R. S., Gibbons, L. W., & Macera, C. A. (1995). Changes in physical fitness and all-cause mortality. A prospective study of healthy and unhealthy men. *Journal of the American Medical Association, 273* (14), 1093-1098.

Blair, S. N., Kohl, H. W., Paffenbarger, R. S., Clark, D. G., Cooper, K. H., & Gibbons, L. W. (1989). Physical Fitness and All-Cause Mortality: A Prospective Study of Healthy Men and Women. *Journal of the American Medical Association, 262* (17), 2395-2401.

Bonis, J. (2007). Acute Wiiitis. *New England Journal of Medicine, 356* (23), 2431-2432.

Cauza, E., Hanusch-Enserer, U., Strasser, B., Ludvik, B., Metz-Schimmerl, S., Pacini, G., et al. (2005). The Relative Benefits of Endurance and Strength Training on the Metabolic Factors and Muscle Function of People With Type 2 Diabetes Mellitus. *Archives of Physical Medicine and Rehabilitation, 86* (8), 1527-1533.

Cowley, A. D. & Minnaar, G. (2008). New Generation Computer Games: Watch out for Wii shoulder. *BMJ, 336* (7636), 110.

Deutsch, J. E., Borbely, M., Filler, J., Huhn, K., & Guarrera-Bowlby, P. (2008). Use of a Low-Cost, Commercially Available Gaming Console (Wii) for Rehabilitation of an Adolescent With Cerebral Palsy. *Physical Therapy, 88* (10), 1196-1207.

Fiatarone, M. A., Marks, E. C., Ryan, N. D., Meredith, C. N., Lipsitz, L. A., & Evans, W. J. (1990). High-Intensity Strength Training in Nonagenarians: Effects on Skeletal Muscle. *Journal of the American Medical Association, 263* (22), 3029-3034.

Graves, L., Stratton, G., Ridgers, N. D., & Cable, N. T. (2007). Comparison of energy expenditure in adolescents when playing new generation and sedentary computer games: Cross sectional study. *British Medical Journal, 335* (12), 1282-1284.

Graves, L., Stratton, G., Ridgers, N. D., & Cable, N. T. (2008). Energy expenditure in adolescents playing new generation computer games. *British Journal of Sports Medicine, 42* (7), 592-594.

Hill, C. S. (2009). Developing psychomotor skills the Wii way. *Science, 27* (323), 1169.

Lin, J. J., Mamykina, L., Lindtner, S., Delajoux, G., & Strub, H. B. (2006). Fish'n'Steps: Encouraging Physical Activity with an Interactive Computer Game. In P. Dourish & A. Friday (Eds.), *UbiComp 2006: Ubiquitous Computing* (pp. 261-278). Berlin: Springer.

Nitz, J. C., Kuys, S., Isles, R., & Fu, S. (2009). Is the Wii Fit™ a new-generation tool for improving balance, health and well-being? A pilot study. *Climacteric, 12*, 1-6.

Peek, A. C., Ibrahim, T., Abunasra, H., Waller, D., & Natarajan, R. (2008). White-out from a Wii: traumatic haemothorax sustained playing Nintendo Wii. *Annals of The Royal College of Surgeons of England, 90*, W9-W10.

Rantanen, T. (2003). Muscle strength, disability and mortality. *Scandinavian Journal of Medicine & Science in Sports, 13*, 3-8.

Rantanen, T., Volpato, S., Ferrucci, M. D. L., Heikkinen, M. D. E., Fried, L. P., & Guralnik, J. M. (2003). Handgrip Strength and Cause-Specific and Total Mortality in Older Disabled Women: Exploring the Mechanism. *Journal of the American Geriatrics Society, 51* (5), 636-641.

Robinson, R. J., Barron, D. A., Grainger, A. J., & Venkatesh, R. (2008). Wii knee. *Emergency Radiology, 15* (4), 255-257.

Comparison of a Traditional and a Video Game Based Balance Training Program

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Abstract

The aim of the present study is to compare the efficiency of traditional and video game based balance training programs. 22 customers of a health care centre (age: *M* = 47.6 yrs; *SD* = 13.1) volunteered to participate in the experiment. They were randomly assigned to two experimental groups. One group underwent a traditional training program, while the other group trained using the Nintendo Wii Fit ™ Balance Board. Between pre and post test procedures, training sessions were performed three times a week for three weeks. In addition to five balance tests (SEBT, ball-handling, two video games, dynamic balance), a questionnaire was applied concerning mood state, self-efficacy, physical activity enjoyment, flow and subjective experience in order to evaluate psychological effects of the interventions.

Two-factor analyses of variance showed both general and differential improvements of the two groups for pre and post test measures. Both groups improved their balance performance in 4 of five tests. The traditional group showed a significantly greater improvement in two tests (SEBT: $F_{(1,20)}$ = 8.907, p = .007, η^2 = .308; ball-handling: $F_{(1,20)}$ = 13.578, p = .001, η^2 = .404), whereas the Wii group showed a significantly greater improvement in one test (Ski Slalom ($F_{(1,20)}$ = 5.101, p = .035, η^2 = .203). Psychological questionnaires revealed neither significant pre-post effects nor differences between the groups for pre and post test measurements.

The results confirm that the Nintendo Wii Fit ™ may be a suitable medium of training balance in prevention and rehabilitation of adults. Specific effects of training are more pronounced than transfer between virtual and real performance.

BALANCE, VIDEO GAMES, NINTENDO Wii Fit ™, REHABILITATION, PREVENTION

Introduction

Body balance is a basic skill and a very important sensorimotor ability of human beings. Without the ability to keep balance a person could not stand, walk or sit upright without tools for more than a few seconds. Therefore, balance has a great importance in daily life (Wydra, 1993). Balance performance decreases continuously in life, starting from age 45 (Teipel, 1995). As a consequence, the risk of getting injured by falling is high in elder people. To avoid this, it is important to exercise balance performance. However, sometimes traditional training programs are not attractive to participants for several reasons (e.g., rote, mechanic movements and exposure to group training). In this regard, the new exergames offer attractive options for exercising, even for seniors (Parker, 2007). Thus, the goal of the present study was to compare a traditional and a video game based training program.

Exergames have been very successful in the recent years. Besides the fact that playing exergames can be funny, enjoyable, and entertaining, this activity can improve physical abilities in subjects of all ages. There is a number of studies concerning the relationship between digital games and overweight or energy expenditure, especially with regard to prevention of overweight and obesity (Bausch, Beran, Cahanes, & Krug, 2008; Boehm, Hartmann, & Boehm, 2008; Graves, Stratton, Ridgers, & Cableon, 2007; Hagger, Chatzisarantis, & Biddle, 2002; Lanningham-Foster, Jensen, Foster, Redmond, Walker, Heinz & Levine, 2006; Marshall, Biddle, Gorely, Cameron & Murdey,. 2004; Saelens & Epstein, 1998). Furthermore, there are studies and meta-analyses about the impact of Serious Games on a healthy lifestyle and health-related activities (Baranowski, Buday, Thompson. & Baranowski, 2008; Kato, Cole, Bradlyn & Pollock, 2008; Lager & Bremberg, 2005; Lieberman, 2001). A study by Brumels, Basius, Cortright, Oumedian, & Brent (2008) deals with the impact of video games on balance performance. Brumels et al. (2008) compared three training programs: Konami's Dance Dance Revolution (DDR), the Wii Fit ™ game collection including the Wii Fit ™ Balance Board and a traditional balance training program. Before and after the treatments the balance performance of subjects was assessed using the Star Excursion Balance Test (SEBT) and a single leg stance on a force plate (AMTI AccuSwayPLUS Balance Platform). Participants exercised three days a week for four weeks. The results showed on the one hand a significant reduction of postural sway for average displacement and average deviation on the y-axis in the DDR® group, while only significant average deviation improvements were observed in the Wii group. On the other hand, the traditional group improved significantly in the SEBT. No pre to post test improvements were observed in postural sway for the traditional balance group. Furthermore, "Statistical evaluation of perceived difficulty and enjoyment of the programs obtained data showing the video based games to be perceived as less strenuous (DDR®, $p = 0.073$, Wii Fit™, $p = 0.014$) and more enjoyable (DDR®, $p = 0.007$, Wii Fit™, $p = 0.006$) than the traditional balance program" (Brumels et al., 2008, p. 26).
Besides the question how such exergames can be used in medicine, in sports science the question arises, whether transfer effects exist from the virtual game to real world, and vice versa, and how exergames can be used for learning and training. More specifically, the question is: How are, for example, the movements in Wii Sports ™ Bowling transferable to the real bowling or, referring to the present study, is it possible to transfer video game training of balance to real balance performance and vice versa?
The aim of this study is to determine whether there is a difference between a game-based and a traditional training program, and whether transfer effects can be found. In contrast to Brumels et al. (2008), who examined younger adults (*M* age = 19.56 years, *SD* = 1.69), in this study older patients attending rehabilitation and prevention were also included.

Methods

Participants

All participants were recruited from a health care centre, the Gesundheitszentrum Rehaktiv, Großostheim in Germany, which specializes in prevention and rehabilitation. Twenty-two participants, 5 men and 17 women between the ages of 18 and 67 years (*M* = 47.36 years, *SD* = 13.14) participated voluntarily.

All participants were regularly engaged in sports and were enrolled in a structured strength and cardiovascular training program before the study started.
Only two participants had experience with video games, whereas none had any experience with the Nintendo Wii Fit ™.

Study design

The study was performed based on an experimental two-factor design with repeated measures. Pre and post measurements were performed before and after the treatment. Dependent variables comprised the Star Excursion Balance Test (SEBT), a single-leg balance test on the Posturomed device (ball-handling), a dynamic balance test (DBT), published by Wydra (1993) and Boes (2001), and two game tests on the Wii Fit ™ (Ski Slalom and Balance Bubble). Participants were randomly assigned to one of two treatment groups based on their pretest scores (Wii, *n* = 11 and traditional, *n* = 11). Both exercise groups participated in balance training exercises three days a week for three weeks. Each training session lasted about 10 to 12 minutes and included game-based or traditional balance exercises.
Table 1 shows the design of pretest and posttest measurements and questionnaires.

Table 3. Structure of the experimental study

	t1 (Pretest)		Treatment	t2 (Posttest)		
	Questionnaire	Balance Tests		Questionnaire	Balance Tests	Retest
Group 1: Wii	Mood State Self-efficacy	SEBT Ball-handling Ski Slalom Balance Bubble DBT	Treatment 1: Wii	Mood State Self-efficacy PAES Flow Subjective experience	SEBT Ball-handling Ski Slalom Balance Bubble DBT	Ball-handling Ski Slalom Balance Bubble
Group 2: Traditional	Mood State Self-efficacy	SEBT Ball-handling Ski Slalom Balance Bubble DBT	Treatment 2: Traditional	Mood State Self-efficacy PAES Flow Subjective experience	SEBT Ball-handling Ski Slalom Balance Bubble DBT	Ball-handling Ski Slalom Balance Bubble

Pre and Post Measurements

Tests

Before the tests started, the subjects were asked to take off their shoes. The order of the tests was as follows: SEBT, ball handling, Ski Slalom, Balance Bubble and finally DBT. The first two tests are static, non-game-based balance tests, the second two tests are also static, game-based balance tests on the Wii Fit ™ and the final test is a dynamic balance test executed on a small beam. The tests were chosen to analyze two types of transfer: transfer between virtual and real movements, and transfer from exercised to non-exercised tests.
After the post measurement, a retest of ball-handling, Ski Slalom, and Balance Bubble has been performed for a test of reliability. The respective correlation coefficients were 0.880, 0.678, and 0.567, respectively.

SEBT

SEBT required the participant to balance on one leg in the centre of an eight-directional SEBT Star with their hands placed on their hips. Subjects reached out as far as they could with their free leg in each direction, starting with the anterior direction by gently touching the ground with their toe without shifting weight. After each tap they returned to the starting position and proceeded to the next direction. This exercise was continued in all eight directions in a clockwise manner. Because the achieved absolute width depends on the leg length (Gribble & Hertel, 2003), the individual distances were divided by the leg length of the respective subjects. The leg length was measured as the distance between the anterior superior iliac spine (ASIS) and the middle of the lateral malleolus.

Ball-handling

In the ball-handling test subjects balanced on one leg on the Posturomed, i.e., a therapeutic device associated with a mobile platform, and passed a small ball around their body with their hands. Standing on the right leg, the subject had to move the ball around first clockwise and then counter-clockwise. The procedure was repeated on the left leg. The number of turns in one direction was limited to eight. The participant was awarded one point per cycle. When a subject could not keep his or her balance and stepped down, only the circles already completed were counted. Therefore, a subject could achieve a maximum score of 32 points.

Ski Slalom

In this game the player took the role of a skier and raced against time. By leaning to the right or left, the skier controlled the direction of his movement. By leaning forward or backward, the player controlled her speed. As in the real sports the skier had to clear the gates as fast as possible. For the test the beginner level was chosen. By default of the Wii Fit ™ system, seven seconds were added to the total time for each missed gate. The game was played three times in succession. The mean time of the three trials was calculated for further analysis.

Balance Bubble

The player was placed in a small soap bubble and had to float down a river. By leaning forward and backward the player controlled both forward and backward direction and speed of his movement. By leaning to the right and left, the player controlled the lateral direction. If the bubble touched the walls of the river, the bubble burst and the player fell down. In this game, the distance (unit: metres) was measured, which each player could reach without falling down. Each subject played the game three times. The mean time of the three trials was calculated for further analysis.

Dynamic balance (DBT)

The dynamic balance performance was tested using a variety of exercises of the balance test ('Gleichgewichtstest') published by Wydra (1993; see also Boes, 2001). Four exercises on a beam were selected (length of the beam: 300 cm; width: 10 cm; height: 15 cm above the ground).

The first task was to walk forward over the beam with eyes open and the hands resting on the hips, to turn around at the end and walk back to the starting point.

Second task: Walk backward with eyes open and the hands resting on the hips, to turn around at the end and walk backward to the beginning point.

Third task: Walk forward with eyes closed. Arms were allowed to be used for balance.

Fourth task: Walk backward with eyes closed. Arms were allowed to be used for balance.
If a participant completed the track without touching the ground he got two points. If he touched the ground once with one foot he got one point. If he fell off the beam or touched the ground two times or more he got zero points. The maximum score was eight points.

Questionnaires
Before the tests started, the participants were asked to complete a questionnaire. The pretest questionnaire consisted of 8 questions about the participants' mood state and 5 items concerning their self-efficacy. The subjects had to answer the following question: *How confident are you to accomplish the following tasks, without trying? One leg stand without falling over for 30 (45 / 60 / 75 / 90) seconds.* The subjects had to mark each of the five statements on a six-digit scale, ranging from 'very unsure' (1) to 'very sure' (6)
In the posttest condition, the items of the pre-questionnaires were applied again. Additional questions were asked regarding the completed treatments, i.e., about the pleasure of the treatment using the physical activity enjoyment scale (PAES) by Kendzierski and DeCarlo (1991). Regarding 'flow', questions were derived from the game flow model of Sweetser and Wyeth (2005). The questions referred to the dimensions of *concentration, challenge, skill, control, clear goal, feedback, immersion, and social interaction*. The questions concerning subjective experiences were adopted from Brumels et al. (2008, p. 29):
1) How difficult was your program?
2) How engaged were you during your program?
3) How enjoyable was your program?
Whereas Brumels et al. (2008) applied a 5-grade scale, a 6-grade scale was used in this study.

Interventions
Treatment of the Wii group
The treatment of the Wii Fit TM exercise group (Wii group) consisted of playing games selected by the authors from the balance training exercises offered by the Nintendo Corporation. The Wii Fit TM Balance Board was placed about two meters from the television in front of the screen. During each training session, the subjects were instructed to play the same three games on the balance board, each for about three minutes. The participants were allowed to choose their own difficulty level. Furthermore, they were asked not to perform any other balance exercises during the intervention period.
The training protocol consisted of *Ski Slalom*, *Table Tilt*, and *Tightrope Walk*. *Ski Slalom* is the same game used during the tests. In the game *Table Tilt* balls have to be guided into one or more holes of a virtual tabletop. By shifting the center of gravity the player tilts the table. In the game *Tightrope Walk,* the player simulates a walk on a tightrope. The player has to perform steps on the board to get from one end of the rope to the other and to keep balance. The rope is fixed between two skyscrapers. Here, the player's center of gravity must always be kept exactly in the middle, so that the tightrope walker does not lose his balance and fall down. While crossing the tightrope the player has to avoid a steel monster by jumping over the monster.

Treatment of the traditional group

The traditional training group (Trad group) received a treatment with four varying levels of balance exercises using specific training devices. The exercises are listed and described in Table 2.

Table 4. Treatment protocol of the traditional group

Name	Implementation	Frequency	Comment
Squat	Squats on the Aero-Step	3 series of 10 repetitions Breaks between the series: 30 s	Knee angle between 100° to 170° Slow execution Performed barefoot
Ball-handling	Single-leg stand on the Posturomed, while the hands moves a small ball around the body Clockwise and counter-clockwise	10 s per attempt 4 times on the right and 4 times on the left leg	The Posturomed can be adjusted in its difficulty by fixing the springs.
Rotary board	Both feet on the markers, trying to maintain the balance	Performing for two minutes with the aim not to fall down from the base	To ascend and under disturbance, the hands may be used for support.
Ball-cycling	Single-leg stand on the Sisselkissen, using the toes of the opposite foot to move a tennis ball around the Sisselkissen	Two trials on the right leg (two turns clockwise and two turns counter-clockwise) Two trials on the left leg (two turns clockwise and counter-clockwise)	Performed barefoot

Results

Data was analyzed using the Statistical Package for Social Sciences (SPSS), Version 17.0.

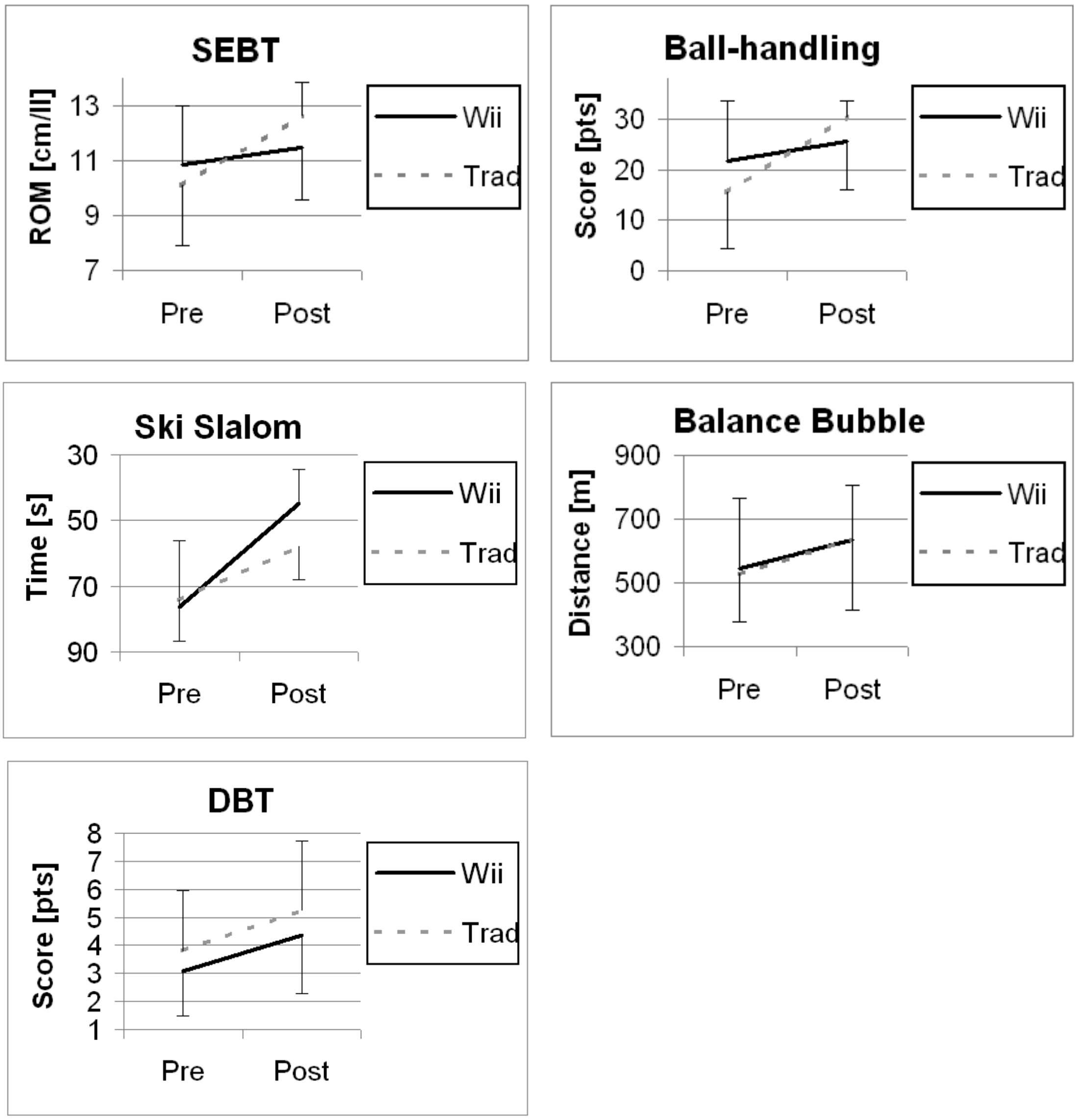
Performance tests

In Table 3 means and standard deviations of pretest and posttest measurements are illustrated (see also Figure 1).

Table 5. Descriptive Statistics of the five tests (t1 – pretest; t2 – posttest)

Test	Group	*M* (t1)	*SD* (t1)	*M* (t2)	*SD* (t2)
SEBT	Wii	10.88	2.11	11.47	1.91
[cm/leg length]	Trad	10.09	2.18	12.66	1.19
Ball-handling	Wii	21.82	11.85	25.64	9.68
[Points]	Trad	15.63	11.29	30.55	2.94
Ski Slalom	Wii	76.42	20.38	44.96	10.42
[Seconds]	Trad	74.34	12.26	57.91	10.02
Balance Bubble	Wii	543.70	220.70	635.88	170.70
[Metres]	Trad	527.94	148.88	640.42	224.89
Dynamic Balance	Wii	3.09	2.12	4.36	2.46
[Points]	Trad	3.82	1.60	5.27	2.08

Figure 1. Results of the five tests



The 2 × 2 ANOVAs with the factors group (Wii, traditional) and measure (pre, post) showed general improvements of the two groups for pre and post test measures in four of the five tests (Table 4; see also Figure 1): SEBT , ball-handling, Ski Slalom, and DBT. The improvement in the Balance Bubble test closely missed the 5% level. Interactions of group and measure indicating differential improvement were found in three tests) (Table 4: SEBT, ball-handling, and Ski Slalom.

Table 6. Results of 2 × 2 ANOVA for the five tests

Test		*df*	*F*	*p*	η^2
SEBT	**pre-post**	**1, 20**	**22.320**	**<.001**	**.527**
	pre-post × group	**1, 20**	**8.907**	**.007**	**.308**
	group effect	1, 20	.077	.785	.979
Ball-handling	**pre-post**	**1, 20**	**38.712**	**<.001**	**.659**
	pre-post × group	**1, 20**	**13.578**	**.001**	**.404**
	group effect	1, 20	.028	.869	.001
Ski Slalom	**pre-post**	**1, 20**	**51.848**	**<.001**	**.722**
	pre-post × group	**1, 20**	**5.101**	**.035**	**.203**
	group effect	1, 20	1.223	.282	.058
Balance Bubble	*pre-post*	*1, 20*	*4.020*	*.059*	*.167*
	pre-post × group	1, 20	.040	.844	.002
	group effect	1, 20	.007	.932	<.001
Dynamic Balance	**pre-post**	**1, 20**	**26.471**	**<.001**	**.570**
	pre-post × group	1, 20	.118	.735	.006
	group effect	1, 20	1.038	.320	.049

To confirm the results of the ANOVAs the Mann-Whitney U-test was calculated for pre-post differences (Delta). Significant results were found for Delta SEBT and Delta ball-handling (Table 5). In both tests, the traditional group showed a greater improvement. The groups also showed different performance gains in the Ski Slalom, where the Wii group could improve more than the traditional group. In Delta Balance Bubble and Delta dynamic Balance group differences were not significant. In the Balance Bubble test the Wii could improve a little bit more, while the traditional improved a little bit more in the dynamic Balance tests (Table 5).

Table 7. Results of the Mann-Whitney U-Test for the five tests

Test	Group	Mean Rank	*Z*	*p*
Delta SEBT	Wii Trad.	7.64 15.36	-2.791	.005
Delta Ball-handling	Wii Trad.	7.59 15.41	-2.833	.005
Delta Ski Slalom	Wii Trad.	14.55 8.45	-2.200	.028
Delta Bubble Balance	Wii Trad.	11.55 11.45	-.033	.974
Delta Dynamic Balance	Wii Trad.	11.05 11.95	-.341	.733

Questionnaires
Results for mood state and self-efficacy are illustrated in Tables 6 and 7, respectively.
2 × 2 ANOVAs showed neither significant general nor differential changes of the two groups for pre- and posttest measures.

Table 8. Descriptive statistics of the questionnaire mood state (t1 – pretest; t2 – posttest)

Mood state	Group	*M* (t1)	*SD* (t1)	*M* (t2)	*SD* (t2)
Arousal	Wii Trad.	4.73 5.00	0.82 1.64	4.77 5.00	0.68 1.43
Energy	Wii Trad.	4.36 5.27	0.87 0.65	4.68 5.00	0.81 1.18
Depression	Wii Trad.	5.36 5.64	0.45 0.64	5.55 5.50	0.57 0.89
Anger	Wii Trad.	5.27 5.73	0.79 0.65	5.55 5.73	0.69 0.90
Alertness	Wii Trad.	3.36 2.91	0.92 1.38	3.18 2.64	0.92 1.38

Table 9. Descriptive statistics of the questionnaire self-efficacy

	Group	*M* (t1)	*SD* (t1)	*M* (t2)	*SD* (t2)
Self-efficacy	Wii Trad.	4.05 5.36	1.28 .56	4.04 5.38	.77 .64

To measure a potential statistical difference between the two groups in terms of physical activity enjoyment, the Mann-Whitney U-test was used. The differences between the groups were not significant in any of the eleven items.
Furthermore, no significant differences between the traditional and the Wii group were found for flow experience. The item *feedback* closely missed the 5% level ($z(22)=-1.827$, $p = .068$).

Concerning the last part of the psychological questionnaire, the *subjective experiences* also did not show any significant differences between the two training groups (Table 8).

Table 10. Descriptive statistics and results of the Mann-Whitney U-test for subjective experiences

Item	Group	M	SD	Mean Rank	*Z*	*p*
Difficulty	Wii	3.45	1.13	12.09	-.443	.658
	Trad.	3.27	1.56	10.91		
Engagement	Wii	2.36	1.03	11.83	-.107	.865
	Trad.	2.36	1.36	11.27		
Enjoyment	Wii	2.09	1.14	11.55	-.350	.972
	Trad.	2.18	1.33	11.45		

Discussion

Regardless of the group, all subjects were able to improve their balance performance in four of five tests from pre- to posttest. Significant improvements for all subjects were confirmed for the tests SEBT, Ski Slalom, ball-handling and DBT, but not in the Balance Bubble test. This result cannot be clearly considered a general exercise effect, because no no-treatment control group was examined. Furthermore, in three tests the pre-post effect is specified by a significant group × measure interaction indicating differential effects of Wii and traditional training.

The significant group × measure interaction qualifies the results of Brumels et al. (2008). Whereas both groups improved significantly, the traditional group showed a greater improvement indicating a specific training effect.

In the ball-handling test the traditional group also achieved a significantly greater improvement from pretest to posttest. Again, this result can be considered a specific effect of exercise. It should be noted, however, that the maximum number of points to be achieved was 32 and the average of the traditional group in the posttest was 30.55 points. A ceiling effect occurred, with only three of the eleven subjects of this group not achieving a maximum score.

The Ski Slalom test showed a different result. Here, the Wii group achieved a significantly greater improvement from the pretest to the posttest measurement. This can also be considered a specific effect of game exercise.

The Balance Bubble and dynamic balance tests did not provide significant interactions failing to indicate statistical differences between the performance changes of the groups from pretest to posttest. In the dynamic balance test both groups improved. It is not clear whether this is a true transfer or a simple test repetition effect, because a no-treatment control group is missing.

Generally, the results of the study reveal that the Wii group improved performance more in the game-based tests, whereas the traditional group improved more in the traditional tests.

With regard to a transfer from virtual to real movement it is conceavable, that the Wii group achieved a sensorimotor transfer to the ball-handling, dynamic balance and SEBT test. This effect may be either just a repeated measures effect or a true transfer effect. Furthermore, data do not allow to decide whether this transfer is sensorimotor or cognitive. The cognitive strategies may not only be improved by the treatments but also by playing the game three times in the pretest condition due to the low complexity of the games. Apparently, cognitive strategies appear and evolve very quickly during the first attempts. In conclusion, it should be noted that the types and proportions of the transfer process could not be accurately determined. Adoption of a control group and experimental manipulation of cognitive and sensorimotor processes are to be performed to decide these questions. The same difficulty holds for the traditional group concerning transfer from traditional to game movements.

No part of the psychological questionnaire showed any significant difference, neither in the posttest nor in the pretest to posttest measures. Particularly notable is the non-existing increase in the self-efficacy, although all subjects were able to significantly improve their balance performance. Contrary to the results of Brumels et al. (2008), the two training groups experienced their treatments as similarly difficult, enjoyable and engaging. This difference may be due to the different ages of the subjects. Whereas Brumels et al. (2008) examined younger adults (range: 18 to 24 yrs; M = 19.56 yrs), this study examined older adults (range: 18 to 67 yrs; M = 47.37 yrs). Compared to the relative values of the Wii group of Brumels, the subjects of the present Wii group experienced lower enjoyment (35 vs. 88 per cent maximum), lower engagement (39 vs. 88 per cent maximum), and greater difficulty (58 vs. 32 per cent maximum). The differences in the traditional group are considerably smaller for enjoyment and engagement (enjoyment: 55 vs. 63 per cent; engagement: 36 vs. 43 per cent; difficulty: 39 vs. 67 per cent). Therefore, the lack of differences may be due to the fact that older adults may not be as motivated by playing digital games as younger adults do.

Conclusion

Provided a repeated gaming effect can be excluded by testing a no-treatment control group, game-based balance training with the Nintendo Wii Fit TM may be suitable in prevention and rehabilitation of adults, although the overall efficacy of game-based training was not as high as that of a traditional training. In order to achieve equivalent or better effects, a more motivating and more variable game-based training program should be developed. While transfer effects of training are not clear, it is certain that specific effects of training are more pronounced than transfer between virtual and real performance.

References

Baranowski, T., Buday, R., Thompson, D. I., & Baranowski, J. (2008). Playing for real. Video games and stories for health-related behavior change. *American Journal of Preventive Medicine*, *34* (1), 74-82.

Bausch, L. M., Beran, J. N., Cahanes, S. J., & Krug, L. D. (2008). Physiological reponse while playing Nintendo wii sports. *Journal of undergrate kinesiology research*, *3* (2), 19-25. Retrieved March 2, 2009 from http://people.uwec.edu/dalleclc/KINSjournal/Spring%202008%20Manuscripts/bausch.beran.cahanes.krug.spring.2008.pdf

Boehm, H., Hartmann, M., & Boehm, B. (2008). Predictors of metabolic energy expenditure from body acceleration and mechanical energies in new generation active computer games. In Dagstuhl Seminar Proceedings 08372 - *Computer Science in Sport - Mission and Methods*. Retrieved April 24, 2009 from http://drops.dagstuhl.de/opus/volltexte/2008/1685

Boes, K. (Eds.) (2001). *Handbuch motorische Tests* [Handbook of motor tests] (2. edition.). Göttingen: Hogrefe.

Brumels, K. A., Basius, T., Cortright, T., Oumedian, D., & Brent, S. (2008). Comparison of Efficacy Between Traditional and Video Game Based Balance Programs. *Clinical Kinesiology, 62* (4), 26-31.

Graves, L., Stratton, G., Ridgers, N. D., & Cableon, N. T. (2007). Energy expenditure in adolescents playing new generation computer games. *British Medical Journal, 335*, 1282-1284. Retrieved March 4, 2009 from http://www.bmj.com/cgi/content/full/335/7633/1282

Gribble, P. A. & Hertel, J. (2003). Considerations for normalizing measures of the Star Excursion Balance test. *Measurement in Physical Education and Exercise Science, 7* (2), 89-100.

Hagger, M. S., Chatzisarantis, M. L. D., & Biddle, S. J. H. (2002). A meta-analytic review of the theories of reasoned action and planned behavior in physical activity: Predictive validity and the contribution of additional variables. *Journal of Sport and Exercise Psychology, 24,* 3-32.

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), 305-317.

Lager, A. & Bremberg, S. (2005). *Health effects of video and computer game playing. A systematic review.* Stockholm: Swedish National Institute of Public Health. Retrieved April, 10, 2009 from http://www.fhi.se/PageFiles/4170/R200518_video_computer_game(1).pdf?epslanguage=en

Lanningham-Foster, L., Jensen, T. B., Foster, ,R. C., Redmond, A. B., Walker, B. A., Heinz, D., & Levine, J. A. (2006). Energy Expenditure for Sedentary Screen Time Compared With Active Screen Time for Children. *Pediatrics, 118* (6), 1831-1835.

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.

Kendzierski, D. & DeCarlo, K. J. (1991). Physical-activity enjoyment scale: 2 validation studies. *Journal of Sport & Exercise Psychology*, *13*, 50-65.

Marshall, S. J., Biddle, S. J. H., Gorely, T., Cameron, N., & Murdey, I. (2004). Relationships between media use, body fatness and physical activity in children and youth: a meta-analysis. *International Journal of Obesity, 28*, 1238-1246.

Parker, F. S. (2007). *Nursing Home Technology: Wii Video Game*. Retrieved January 13, 2010 from http://hospiceandnursinghomes.blogspot.com/2007/06/ nursing-home-technology-wii-video-games_06.html

Saelens, B. & Epstein, L. (1998). Behavioral engineering of activity choice in obese children. *International journal of obesity, 22*, 275-277.

Sweetser, P. & Wyeth, P. (2005). Game Flow: A Model for Evaluating Player Enjoyment in Games. *ACM Computers in Entertainment*, *3* (3). Retrieved January 13, 2010 at http://delivery.acm.org/10.1145/1080000/1077253/p3a-sweetser.pdf?key1=1077253&key2=2023119321&coll=GUIDE&dl=GUIDE&CFID=30058722&CFTOKEN=75596469

Teipel, D. (1995). *Studien zur Gleichgewichtsfähigkeit im Sport* [Balance ability studies in sport]. Köln: Strauß.

Wydra, G. (1993). Bedeutung, Diagnose und Therapie von Gleichgewichtsstörungen [Significance, diagnosis, and therapy of balance disorders]. *Motorik*, *16* (3), 100-107.

HEAD FIRST INTO SERIOUS HEALTH GAMING

a^2e^2 as a new approach of digital exercise coaching for seniors

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Abstract

With the development of an Adaptive Ambient Empowerment tool for the Elderly (a2e2) a group of technicians and media psychologists confront the challenge to change habituated unhealthy life styles. The main goal is to increase physical activity in seniors who are at risk of acquiring or are already suffering from chronic diseases. The a2e2 system incorporates exergames and applies a daily structure by using a digital coach. Several psychological processes must be taken into account if the system wants to stand a chance to achieve the behavioral change it wishes to mould into a healthier lifestyle. From the perspective of Self Determination Theory, competence, autonomy and relatedness need to be addressed in order to achieve well-being. Intentional modes of self-regulation to achieve well-being often fail. However, implicit self-regulation offers new opportunities that are especially suited to apply in a gaming environment. Research has already shown that a virtual coach and a virtual environment can be conducive to positive results concerning interaction with the system and physical activities. Since the available research is still sparse elaborate pilot studies are required. This paper presents a short overview of the core psychological concepts guiding the development of a2e2.

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ADAPTIVE AMBIENT EMPOWERMENT OF THE ELDERLY (A2E2), MEDIA PSYCHOLOGY, EXERGAMES, BEHAVIORAL CHANGE, SELF-REGULATION

Introduction

This paper provides a concise overview of the psychological theories and assumptions we believe should be guiding the development of a serious health game and its virtual environment. We exemplify our approach in introducing a2e2, an ICT solution for the adaptive ambient empowerment of the elderly (www.a2e2.eu). which is currently been developed with funding from the AAL Joint Program. The system is build around a virtual coach that guides through life style changes in order to prevent and manage chronic diseases in individuals that are at least 55 years old.

Through this system we aspire to introduce new and enriched activities into the lives of senior citizens. The need for a2e2 is induced by the dramatically growing population of senior citizens in Western cultures leading a rather sedentary life style. We will soon be facing the challenges surrounding the fact that the largest part of our society is of retirement age. Many medical and care taking professionals, government officials and companies are already warning that the current health care system will not be able to cope with the increasing need for services. However, it's long been known that life style diseases such as Diabetes type 2 or cardio-vascular insufficiency can be prevented or even reversed with increased physical activity. Sadly, dispensing medical advice does not necessarily result in a change of behavior. Especially sedentary behavior is largely habituated and therefore very difficult to break. Even an initial motivation to exercise will soon fade if it is not nurtured with ongoing support and motivating feed-back. Thus, exergames may well be useful for including fun into otherwise rather straining, uncomfortable or boring physical activity, but how can elderly individuals be motivated to use such games over longer periods of time? One answer to this question is a2e2. Its aim is the empowerment of the elderly with an intelligent digital coach that guides the elderly through every day from waking up to going to bed, while applying a push approach. With this push approach the user of a2e2 will be addressed several times a day and motivated for enhanced physical activity. The system offers five levels of physical activity ranging from breaking sedentary life style (e.g., getting up), enriched daily activities (e.g., performing little pirouettes while clearing the table), the introduction of new behavioral patterns (e.g., walking the stairs instead of taking the elevator), intentional exercises (e.g., core stability exercises within a gaming environment), up to a highly efficient strength, balance, and endurance training module that has proven very effective with heart and vascular patients among others (presentation by J. Hoff at the VU University, 30 November 2009). The user's needs and preferences are hereby taken into account as well as environmental circumstances, such as weather conditions. The system selects the most appropriate recommendation for each time slot and controls the user's behavior and well-being with an interactive self-report tool and multiple body (e.g., activity monitor) and ambient sensors (e.g., web cam). Taken together, a2e2 uses the full potential of each individual to establish and sustain a healthy and independent lifestyle for as long as possible.

As both the technical field and the field of media psychology have made great progress during the past few years, the time seems right for such an ambitious health application. The development of a functional virtual coach that responds to input from ambient and bio-sensors, acts upon individual preferences of the user and his/her past experiences with the system demands state-of-the-art technology. Implementing a virtual coach into the life of a user in a functional way provides another challenge completely. Psychological knowledge is required to introduce a coach that has impact and is being perceived as helpful. If the state-of-the-art technical development is not in synergy with an equally state-of-the-art psychological approach the durable implementation into the user's life will likely fail.

A2e2 is console based, has a touch screen interface as well as a key board and uses multiple sensors to gather information. On this platform a virtual environment is created with an intelligent agent as the digital coach and an avatar for the user's self representation. Both, the coach and the self representation are currently being developed together with selected members of the target group in order to assure a maximum fit in appearance, style, and behavior.

The digital coach acts upon a prototypical structure of the day with multiple possibilities for increased physical activity implemented as modules. While the system adapts itself to the lifestyle of the user, offering physical activities corresponding to his/her level it will not wear off, but sustain its value for the user. Based upon his/her progress over time the system will be able to provide accurate and motivating feed-back. All the information and activities in a2e2 can be accessed and reviewed by the user; this is the pull-component similar to those in commercial exergames such as the Wii-fit. However, most of the interactions will be instigated by the system.

In order to develop a functional push-approach we suggest to employ a comprehensive understanding of human behavior and the underlying psychology, as well as the human-computer interaction. This understanding results in several motivational strategies that can be implemented into the system. The following paragraphs provide an overview of the theoretical concepts we have identified as useful. Ongoing formative evaluation and a comprehensive final assessment will eventually provide us with the empirical evidence to decide whether this approach is as successful as intended.

This overview starts with a brief discussion of serious games and exergames before diving into what it is these applications aim to accomplish: behavioral change. First, Self-Determination Theory is introduced which claims that competence, autonomy and relatedness are essentials for sustained behavior change. We will then argue that with respect to self-regulation rational choice models are too limited to explain the selection and sustainable use of a life-style changing ICT-application. Instead, a psychologically valid virtual environment with a social entity such as the coach appears advantageous to guide the complex process of behavioral change: The user establishes a so called para-social relationship with the coach and is therefore no longer left alone to face these critical steps towards a more healthy life.

Changing the game

There has been extensive research in the field of behavioral change; especially health behavioral change. This body of research has led to several health behavior change models that offer a variety of strategies which can be applied to facilitate these changes . A few factors can be identified that play a role in several models as significant predictors for behavior changes: Self-efficacy, susceptibility, perceived benefits and barriers and threat severity. One important limitation of most health behavior change, models, however, must be acknowledged: They are primarily build as cognitive models assuming high levels of rationality and logic within the user. It seems therefore promising to extend the assumptions of such models with other, less rational, strategies such as heuristic, fun and affect-driven mechanisms. A gaming environment is well-suited to apply these alternative strategies and the development of this idea unfolds itself in the field of serious games (Ritterfeld, Cody & Vorderer, 2009).

Strictly speaking, serious games are all games that are considered serious by some agency without taking into account whether the implied promise of a well-intended effect holds true. In search of an overview Ratan and Ritterfeld (2009) created a database of all self-acclaimed serious games in 2007 and found that more than half of those games were devoted to academic education, whereas games for health account for roughly ten procent of all counts. As the nature of digital games is interactive, the game play is different in each single game play (Klimmt, Vorderer, & Ritterfeld, 2007). Consequently, the term serious games should be replaced by the concept of serious gaming, as Jenkins et al. (2009) recently proposed. The concept of serious gaming allows the focus to remain on the process and the outcome ambiguent; that a serious game will lead to serious gaming is not a given and should not be implied.

A new generation of (serious) games are exergames. These are games that are controlled by the users' bodily movements. Exergames were developed to increase physical activity as an answer to a sedentary lifestyle associated with new media usage especially in children and adolescents (e.g., Vandewater, Shim, & Caplovitz, 2004). According to the International Sports Science Association such digital games can push various age groups to physical activity and assist in the struggle against sedentary lifestyles (ISSA, 2007). One of the critical discussions about exergames concers first their contribution beyond a new media novelty effect: Can the usage be maintained over time? Second, exergames require an initial motivation to be used. Even if the game itself is highly motivating and fun to lay it remains still a challenge to prompt a person who is leading a sedentary life to participate in exergame motivated physical activity. If long term usage of exergames can be initiated and established, this genre has a huge potential for behavioral change.

Motivation

There are many determining factors in why people do what they do. One of the perspectives on what motivates human behavior is *Self-determination Theory* (SDT) (Deci & Ryan, 1985; Deci & Ryan, 2000; Ryan & Deci, 2000). This theory is based on the core assumption that people are active organisms, driven by natural tendencies toward psychological growth and development, who deal with everyday challenges in their attempts to establish and maintain a coherent sense of self. In light of SDT, personal health and well being depend on the satisfaction of basic psychological needs. Research guided by SDT (Ryan & Deci, 2000) has examined factors that benefit or hinder self-motivation and self-regulation. This research leads to the establishment of three basic psychological needs – *competence, autonomy and relatedness*. These, when satisfied, provide for enhanced self-motivation and psychological well-being; but when thwarted, lead to lower self-motivation and reduced health. Games are motivating to the extent that players experience autonomy, competence and relatedness while playing (Ryan, Rigby, & Przybylski, 2009). The need for autonomy is met by the free choice of starting a game; the player autonomously decides to play. The need for competence is fulfilled by a task that is not too challenging but not too simple so one can feel competent; this is also known as flow (Csikszentmihalyi, 1990). The need for relatedness can be fulfilled by the social aspects of gaming; most playing is done within a social interaction or is perceived as such. The satisfaction of these primary needs leads to the subsequent motivation to continue playing. Earlier research by the authors (Ryan, Rigby, & Przybylski, 2006) also validated the idea that having ‘fun’ during game play can be attributable to the satisfaction of the above mentioned needs.

Studies of health care and therapy stress the importance of support for SDT’s need for autonomy. Recently Ryan, Williams, Patrick, and Deci (2009) applied SDT to physical activity, sport, and health. SDT stresses the importance of intrinsic *and* extrinsic motivation for physical activities. Autonomy and competence have great impact on enhancing people's intrinsic motivation, which in turn has been found to play an important role in sport and physical activity. Extrinsic goals that have been better internalized are found to be maintained better over time. A distinction can be made between different forms of extrinsic motivation in terms of varying relative autonomy. These forms of extrinsic motivation affect both, persistence and performance in physical activity (Ryan et al., 2009).

There is some concern among researchers regarding the acceptance of any form of technology among the elderly and the effect this has on the motivation to use available technologies. Ryu, Kim and Lee (2009) used an elaborated version of the Technology Acceptance Model and found perceived enjoyment to be a significant independent predictor of intention of use. This effect was found over and above its effect on perceived ease of participation. Compatibility (to what extent the ICT solution is compatible with the current lifestyle) was a strong predictor of intention to participate,

but not directly, as it seems to be fully mediated by perceived benefit and perceived ease of participation together.
In conclusion, the satisfaction of our most basic needs can be done by playing a game and this fulfillment will lead to sustained gaming. This same need fulfillment will enhance intrinsic motivation, which in turn influences physical activity, and enhance extrinsic motivation, which in turn influences persistence and performance of physical activities. When elderly people perceive such a game as enjoyable, benificial and easy to use along with being compatible with their livestyle, confidence is high that they will use it and continue to do so.

Self-Regulation

While there are many demonstrations that people are able to set personal rules and follow them, there is considerable evidence indicating that people have difficulty keeping them. However, intentional self-regulation is one of the most frequently prescribed ways to prompt behavior change, and often fails. Becoming aware of the necessity to self-regulation makes many people find excuses and justifications to rationalize non-compliance. Human beings have a strong tendency to stick to habituated behavior and are very reluctant to change once established habits – although they may know better. The challenge for any life style change intervention is to provide strategies of empowerment that go beyond intentional self-regulation. Ainslie (1992) suggests that we solve the problem of binding ourselves by manipulation of attention. For example, one can use entertainment as a means to control attention, so that one is not reminded of the availability of temptations, potential costs, efforts and dangers. Self-control in this way is achieved in an incidental and more implicit way. A variety of attentional control strategies are provided by immersive media such as games. However, attention control can be revoked at any time so it may require continued effort.
Implicit and incidental self-regulation are closely associated with integrative processing, a cognitive style that is largely independent of linguistic encoding, is impressionistic, parallel, flexibly attuned to multiple meanings, and closely coupled with emotional and sensor-motor systems. Implicit self-regulation is optimally suited to maintain the global integrity of an individual's personality system. This global adaptive function operates in three distinct ways. First, implicit self-regulation has been shown to promote *volitional efficiency*, such that the individual is capable of forming appropriate intentions and effectively translating these into action. Second, implicit self-regulation has proven to promote flexible and efficient *affect regulation*, such that the individual can avoid becoming overwhelmed or stuck in emotional or motivational states (Koole, 2009). Third, implicit self-regulation has been shown to promote an implicit sense of *meaning* in life, such that the individual is capable of creating meaning out of new experiences and maintain meaningful cognitive representations (Heine, Proulx, & Vohs, 2006). This implicit mode of self-regulation is not mediated by explicit intentions, but rather by integrated feelings or intuitions about appropriate courses of action (Baumann & Kuhl, 2002). The conceptual independence of implicit and explicit self-regulation is further corroborated by findings that the two kinds of self-regulation can mutually interfere with another. For instance, an emphasis on explicit goals may disrupt a person's cognitive access to implicitly represented needs, thereby leading to overall reductions in psychological well-being (Baumann, Kaschel, & Kuhl, 2005). Conversely, focusing on one's broader values in life can lead people to disengage from a specific goal that was recently frustrated (Koole, Smeets, van Knippenberg, & Dijksterhuis, 1999).

In short, people do not always behave according to their own best interests and intentional self-regulation often gives out to habituated behavior, accompanied by a multitude of rationalizations for non-compliance. One solution might be implicit self-regulation through manipulation of attention (Ainslie, 1992) by immersion in a virtual environment. Implicit self-regulation is associated with integrative processing and the global integrity of one's personality system: It has positive influence on volitional efficiency, affect regulation, and is able to give meaning. This facilitates any behavior change initiated by implicit self-regulation, integrates into the personality system, and supports the ideal that any change made will be a robust one.

Virtual interaction

Several studies have already indicated the relevance of a virtual environment for the promotion of physical activity: Exercise is perceived as less tiring, performed more enduring, calorie consuming and enjoyable if performed within a virtual environment compared to training without such a virtual encounter (Chuang, Chen, Chang, Lee, Chou & Doong, 2003; Plante, Aldridgem, Bogden, & Hanelin, 2003). As any environment, virtual environments can be inhabited by their users and consequently, enjoyed or disliked. Specifically, cues negatively associated with aging or death contribute to existential fear (Greenberg, Koole, & Pyszcynski, 2004; Magee & Kalyanaraman, 2009). Such mortality salience contributes to unhealthy habits (Das & Bushman, 2009).

Even though virtual coaches have become increasingly popular, scientific research about the phenomenon is still sparse. Blanson Henkemans (2009) researched the effects of the presence versus absence of an animated virtual coach, and, if there is an animated coach, the effect of its feedback style (cooperative versus directive). The author found that using an animated persona can be stimulating and improve the human-machine interaction. He also found that non-professional users had significantly better results with a cooperative feedback style than a directive one. It should be noted that the preference for a directive coach was higher for those with a low score on computer experience, reading speed, or education level, a high fear of invalidity, and an internal locus of control. However, a cooperative feedback approach was still most effective and preferred before other feed-back styles.

The presence of a virtual coach as a mediated entity offers the possibility for para-social interactions between the coach and the user of the system. According to Perse and Rubin (1989), para-social interactions are similar to interpersonal interactions in three ways: They are voluntary, offer companionship, and they are evoked by social (not physical!) attractiveness. Over time, para-social interactions can lead to a para-social relationship, which entails that a viewer would think of and "interact with" the media character not only during media usage, but also beyond, much like a person would think of his or her "real" friends in their absence (Giles, 2002). Recently, para-social relationship theory was applied to virtual entities (Jin & Park, 2009), but there is still a lack of knowledge which elements facilitate para-social relationships.

As can be deduced from the above text; virtual environment will increase a positive perception of exercising by the user, but caution must be applied as to what is included in this virtual environment. Specifically, any clues to aging or death must be avoided. To have an animated persona present in the virtual environment has been found to improve human-machin interaction. Such a virtual coach should interact with non-proffesional users in a cooperative rather then a directive feedback style. These interactions between the virtual coach and the user can be seen as para-social interactions, which are similar to interpersonal interaction because they are voluntary, they offer companionship and are evoked by social attractiveness. Repeated para-social interactions are likely to lead to a para-social relationship, which will form the bond between the virtual coach and the user that our a2e2 system relies upon.

Translating theory

To integrate any application truly into the user´s lifestyle in order to change behavior three separate processes for sustained use are identified. There must be a first incentive for selection, secondly the user should persist in using a2e2 which drives the third process; habituation. Without habituation, the selection would always have to take place consciously and intentionally, which is something we deem unlikely to continue over a longer period of time. The first incentive will be mainly driven by a new media novelty effect. The system has a daily adaptive update and uses several real-time online applications (such as a weather-feed) to entice and variate the daily selection of use. To help guide a2e2 from selection to persistence of use it is important to create numerous para-social interactions in order to establish a para-social relationship. This para-social relationship with the a2e2 virtual coach motivates users to keep using a2e2 and thus form habits that are part of a healthier lifestyle. In order to ensure the likelihood of such a para-social relationship it is of the utmost importance to carefully pilot the coach's appearance and behavior and develop the agent within an iterative design model.

Following the current research we incorporate incidental and implicit motivation strategies for behavioral change and commitment to action into a2e2. This should be achieved by implementing a variety of 'manipulations of attention' techniques which avoid focus on efforts and costs of physical activity as much as possible. Presenting exercise as a gaming experience is an adequate frame to evoke such incidental and implicit motivation. Several gaming environments will be developed for physical activities of all levels as indicated above. This will most likely result in better regulation of affectional states and volitional efficiency needed to commit to the course of action. In addition, the performance of the subjects will be more integrated with daily activities which will ulimately result in less costs to change their lifestyle.

In the overall virtual environment and the interactions between the coach and the user it is very important to avoid death salience and prime life salience instead. The environment must avoid any cue associated with mortality, but facilitate a connotation of life, future, and health. Within a2e2, for example, we avoid any health related fear appeals in the interactions and incorporate symbols for health and growth into the environment such as flowers and animals, hereby priming life salience.

Finally, as a2e2 wants to empower it is crucial to provide the user with the sense of controlling a2e2 instead of being controlled. Therefore, the sensory input will be ambient and non-obtrusive as to not trigger any loss of control by the user. Moreover, the system can be easily shut off at all times and push approaches can be ignored. However, the system will come back to life after some time and investigate the reasons for being shut off (i.e., asking questions which have to be answered by the user and guide future push approaches).

Taken together, we acknowledge the necessity to link the system to the essentials identified within SDT: *competence, autonomy and relatedness*. By making exergames available at different levels and adapting the system to the user's level a sense of competence can be achieved by the user. Autonomy is promoted and maintained by overtly giving the ultimate control of the system to the user and minimizing the impact of input-requirement. Relatedness can be achieved with enabling a para-social relationship from the user to the coach.

References

Ainslie, G. (1992). *Picoeconomics: The strategic interaction of successive motivational states within the individual.* New York: Cambridge University Press.

Baumann, N., Kaschel, R., & Kuhl, J. (2005). Striving for unwanted goals: Stress-dependent discrepancies between explicit and implicit achievement motives reduce subjective well-being and increase symptoms. *Journal of Personality and Social Psychology*, *89,* 781-799.

Baumann, N. & Kuhl, J. (2002). Intuition, affect and personality: Unconscious coherence judgments and self-regulation of negative affect. *Journal of Personality and Social Psychology, 83*, 1213–1223.

Blanson Henkemans, O. A. (2009). *ePartner for Self-Care: How to enhance ehealth with personal computer assistants.* Retrieved from http://repository.tudelft.nl/assets/uuid:b2dc963a-aa71-4de5-846d-ef916084469/BlansonHenkemans_Proefschrift090525.pdf

Chuang, T.-Y., Chen, C.-H., Chang, H.-A., Lee, H.-C., Chou, C.-L., & Doong, J.-L. (2003). Virtual reality serves as a support technology in cardiopulmonary exercise testing. *Presence: Teleoperators & Virtual Environments, 12*, 326-331.

Csikszentmihalyi, M. (1990). *Flow*. New York: Harper and Row.

Das, E., & Bushman, B. (2009). *Feeling without spending a dime: Life and death salience exert opposite effects on worldview defense and consumption patterns.* Unpublished manuscript.

Deci, E. L., & Ryan, R. M. (1985). *Intrinsic motivation and self-determination in human behavior*. New York: Plenum.

Deci, E. L., & Ryan, R. M. (2000). The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. *Psychological Inquiry, 11*, 227-268.

Giles, D. C. (2002). Parasocial interaction: a review of the literature and a model for future research. *Media Psychology, 4,* 279–305.

Greenberg, J., Koole, S. L. & Pyszczynski, T. (2004). *Handbook of experimental existential psychology*. New York: Guilford.

Heine, S. J., Proulx, T. & Vohs, K. D. (2006). The meaning maintenance model: On the coherence of social motivations. *Personality and Social Psychological Review, 10*, 88-111.

ISSA (2007). *Press Release: Video Games May Offer Health Benefits, Experts Suggest.* Retrieved from http://www.issaonline.com/pressroom/01-18-07.cfm

Jenkins, H., Camper, B., Chisholm, A., Grigsby, N., Klopfer, E., Osterweil, S., Perry, J. Tan, P, Weise, M., & Chor guan, T. (2009). From Serious Games to Serious Gaming. In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.), *Serious games: Mechanisms and effects* (pp. 10-24). New York, N.Y.: Routledge/LEA.

Jin, S. A. & Park, N. (2009). Parasocial interaction with my avatar: Effects of interdependent self-construal and the mediating role of self-presence in an avatar-based console game, Wii. *CyberPsychology & Behavior, 12* (6), *723.*

Klimmt, C., Vorderer, P. & Ritterfeld, U. (2007). Interactivity and generalizability: New media, new challenges? *Communication Methods and Measures, 1* (3), 169-179.

Koole, S. L. (2009). The psychology of emotion regulation: An integrative review. *Cognition and Emotion, 23*, 4-41.

Koole, S. L., Smeets, K., van Knippenberg, A. & Dijksterhuis, A. (1999) The cessation of rumination through self-affirmation. *Journal of Personality and Social Psychology*, *77*, 111-125.

Magee, R. G. & Kalyanaraman, S. (2009). Effects of worldview and mortality salience in persuasion processes. *Media Psychology, 12*, 171-194.

Plante, T. G., Aldridgem A., Bogden, R., & Hanelin, C. (2003). Might virtual reality promote the mood benefits of exercise? *Computers in Human Behavior, 19*, 495-509.

Perse, E. M. & Rubin, R. B. (1989). Attribution in social and parasocial relationships. *Communication Research, 16,* 59-77.

Ratan, R. & Ritterfeld, U. (2009). Classifying serious games. In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.), *Serious games: Mechanisms and effects* (pp. 10-24). New York, N.Y.: Routledge/LEA.

Ryan, R. M., & Deci, E. L. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*, 68-78.

Ryan, R. M., Rigby, C. S. & Przybylski, A. (2006). The motivational pull of video games: A self-determination theory approach. *Motivation and Emotion, 30*, 347–364.

Ryan, R. M., Rigby, C. S. & Przybylski, A. (2009). Virtual worlds and the learner hero: How today's video games can inform tomorrow's digital learning environments. *Theory and Research in Education, 7* (2), 214-223.

Ryan, R. M., Williams, G. C., Patrick, H., & Deci, E. L. (2009). Self-determination theory and physical activity: The dynamics of motivation in development and wellness. *Hellenic Journal of Psychology*, *6* (2), 107-124.

Ryu, M., Kim, S., & Lee, E. (2009). Understanding the factors affecting online elderly user's participation in video UCC services. *Computers in Human Behavior, 25,* 619-632.

Vandewater, E. A., Shim, M. S., & Caplovitz, A. G. (2004). Linking obesity and activity level with children's television and video game use. *Journal of Adolescence, 27* (1), 71-85.