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# Editorial

Playing games is an 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 video games – unfortunately often 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 Figure 1). Hence, SG have a great potential for many application areas – our bold hypothesis is that Serious Games are useful for all possible application domains and markets.

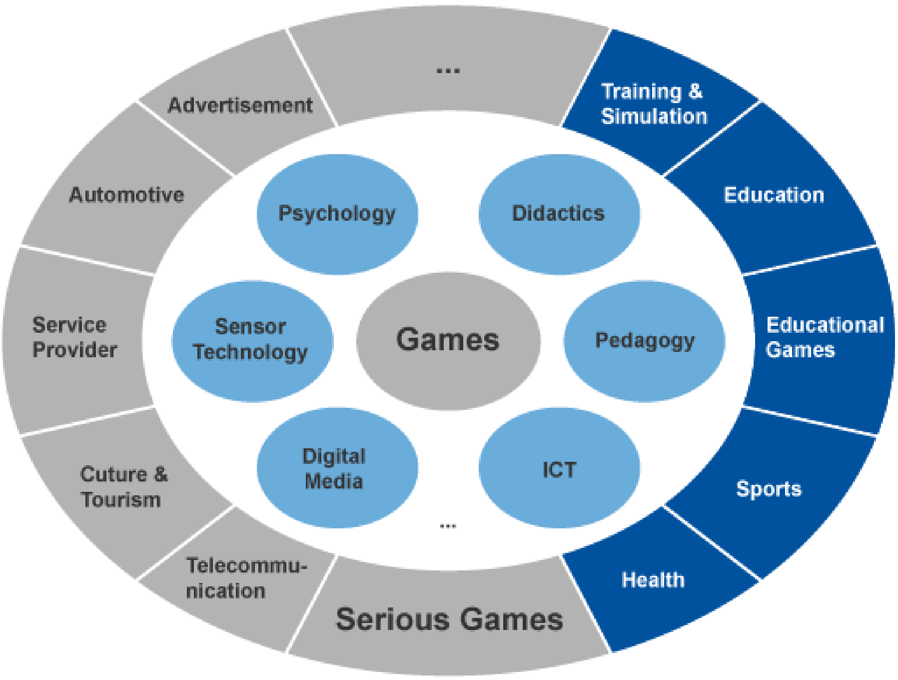



Figure 1. Understanding of Serious Games.

Applying SG to education, prevention, and therapy is on the one hand very promising because of the unique combination of motivation, simulation, and learning. On the other hand Figure 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 scientific papers presented at the GameDays 2011 are included. The papers underwent a two-stage review process to ensure quality of form and content.

The topics of the papers range from analysis and discussion of theory and trends (Felicia, Kickmeier-Rust, Nielsen, and Müller-Lietzkow) over the application fields of health (Mellecker, Knöll, Hardy, and Brach) and education (Kliem) to examples of good practice (Schönsee and Gouaïch) and work in progress (Martin and Weigelt).

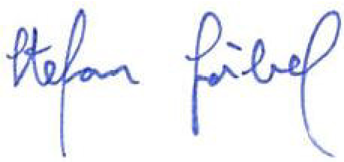
The papers address on the one hand fundamental issues of Serious Games like motivation, adaptation, personalization and on the other hand specific issues like space perception.

The editors would also like to thank all the institutions, associations and companies for supporting and sponsoring the GameDays 2011 conference: Hessen-IT, graduate school 'Topology of Technology', motivotion60+, Serious Games Conference, BIU, Darmstadt Marketing, Seniorenrat Darmstadt and Vitaphone. Without this ideal and financial support the GameDays 2010 would not have been possible.

Finally, the editors would like to express their gratitude to all people 'on and behind' the stage who helped to make the conference a success: the speakers, the many students and other helpers including secretaries etc.

Website of the conference: http://www.gamedays2011.de/

We hope that the papers instigate constructive discussions, new insights and ideas for further research and technology transfer.



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# Motivation in Games: A Literature Review

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### Abstract

This paper explains why and how video games can motivate students to learn. It explains key concepts linked to motivation, engagement and flow, and illustrates how some features in video games can promote intrinsic motivation, hence encourage and sustain learning. In the second part of the paper, empirical evidence of the motivational aspects of video games is presented, with reference to recent scientific studies conducted essentially between 2005 and 2011. Evidence collected demonstrates that games are employed to increase learners' motivation, in a wide range of settings, for different topics (e.g., science, literature, or engineering), and to address the different needs and specificities of learners (e.g., gender, age, or special needs). It also shows that games can teach both academic and non-academic skills, and motivate students to collaborate, share information, and increase their attainments, and that, in many cases, they are more effective than traditional approaches. These results emphasize that some additional mechanisms need to be implemented in games to ensure that they systematically manage to engage, teach and change students' behaviors. These include game design (e.g., personalized strategies, adapted challenge or a good balance between educational and entertaining features), and teaching strategies (e.g., briefing, debriefing, and teachers' support).

KEYWORDS: GAME-BASED LEARNING, TECHNOLOGY-ENHANCED LEARNING, E-LEARNING

## Introduction

### *Motivation and Learning*

Motivation is one of the key elements to learning (Keller & Kopp, 1987; Astleitner & Leutner, 2000) as it stimulates students' interests, supports individual and collaborative learning (Dillenbourg, Järvelä & Fischer, 2009), and may in some cases be a predictor of students' success (Pajares & Graham, 1999). Because video games support intrinsic motivation, a motivation that is believed to have an important lasting effect on learners (Habgood, Ainsworth & Benford, 2005), they have been considered and used for educational purpose. It is agreed that learning is both an emotional and cognitive process (Malone, 1982; Piaget, 1951) and that, when players are engaged in activities that are intrinsically motivating, they are more prone to demonstrate deep learning, and transfer this knowledge to other settings (e.g., outside school).

### *Playing and Motivation*

Well-designed video games can be ideal learning environments, as they inherently incorporate sound educational theories and concepts, and require players to learn and develop skills to succeed. Video games captivate the attention of players who experience emotions that may impact positively on the learning process (Baker, D'Mello, Rodrigo & Graesser, 2010). Players often experience a state of flow (Csikszentmihalyi, 1990) where they are immersed, engaged, and willing to achieve the goals and aims of the activity, regardless of the challenges ahead, and it was demonstrated that a state of flow can have a positive impact on learning (Webster, Trevino & Ryan, 1993; Kiili, 2005).

Games are engaging, fun, and they intrinsically motivate players to learn more about the game rules, its mechanics, and sometimes to learn and gather information when the game is over. Malone (1982) suggested that video games may promote engagement and intrinsic motivation, and possibly motivate to learn. Bowmann (1982), Provenzo (1991) and (Rieber 1996) also observed that game mechanisms, such as feedback cycle and intrinsic motivation, may benefit learning activities, and therefore ought to be integrated into instructional settings.

## Empirical Evidence

### *Video Games Motivate to Learn in Traditional Settings*

Video games (i.e., commercial, educational or bespoke) have been used in a great variety of contexts, including primary education, secondary education, third-level education, and the industry. Scientific evidence has demonstrated that they can successfully increase motivation to learn academic or non-academic topics such as mathematics (Lee, Luchini, Michael, Norris & Soloway, 2004; Kebritchi, Hirumi & Bai, 2010), science (Toprac, 2011; Squire, Barnett, Grant & Higginbotham, 2004; Barab, Warren & Ingram-Goble, 2009), languages (Hainey, Connolly & Boyle, 2011; Rankin, Gold & Gooch, 2006; Howell & Veale, 2009), history (Squire & Barab, 2004) software engineering (Navarro & Hoek, 2007; Shaw & Dermoudy, 2005; Papastergiou, 2009), to train medical students (Roubidoux, Chapman & Piontek, 2002), or to raise students' awareness on sensitive topics such as the environment (Klopfer & Squire, 2008), or healthy eating (Serrano, 2004). In these studies, researchers have gathered scientific evidence that video games can motivate students to learn academic skills while they are at at school or at home (Toprac, 2011), and sometimes encourage them to complete more exercises than in traditional settings (Lee et al., 2004). It also appears that learning benefits are increased when students have had a prior exposure to the topic, and when the game allowed them to put their knowledge into practice. Results from these studies also indicate that, in many cases, video games are perceived as an enjoyable and entertaining experience by students, and that teachers also acknowledge this positive effect. Games seem to improve students' perseverance and confidence, and some of them have welcomed the opportunity to use Game-Based Learning on a regular basis (Shaw & Dermoudy, 2005). Although the video games' genres employed in these experiments can vary from Real Time Strategy games (RTS) to First-Person Shooters (FPS), MMORPG (Massive Multiple Online Role Playing Games), which are based on collaboration between players to solve quests and puzzles, seem to particularly support intrinsic motivation (Dickey, 2007).

In addition to learning by playing, researchers have also reported on studies where students have been involved in the design and development of video games. In several cases, research shows a high degree of engagement and willingness to know more about the topic taught. It was found that learning by creating video games encourages students to become experts in the topic taught because they need to (1) collaborate, (2) investigate, (3) and synthesize information to be included in the game. Along with declarative and procedural knowledge, participants may learn meta-cognitive skills that should help them at school and for their future career. For example, Kelleher, Pausch and Kiesler (2007) found that students using Alice, a game development environments targeted at students with no or little knowledge of programming, were more motivated to program; they spent 42% more time programming, and expressed more interest in using Alice in the future than the students who used a version without story-telling features. Another interesting example was provided by Beavis & O'Mara (2010) who explain that game play is increasingly part of "what it means to be literate in the 21st century". They explain how students who created a video games using Game Maker, a free game engine, used (and consequently improved) their multi-literacy skills (e.g., graphics, audio, etc.). According to Beavis & O'Mara (2010), this experience emulated a working environment where students could collaborate, develop their knowledge-finding skills, and engage with communities in order to find solutions to some of the problems they may encounter.

### *Video Games to Teach Non-Academic Skills*

Although video games may not always be strictly based on the curriculum, it is agreed that they may change students' attitude and behaviour towards a topic, and motivate them to learn more. In some cases, games may also motivate participants to become experts in a specific topic through meta-gaming, a process through which players gain an in-depth knowledge of the game and its mechanics. Video games can be employed to raise awareness by providing an environment in which players can develop a better understanding of the mechanics (e.g., causes and effects) of real-life phenomena; some games and related experiments cover contemporary events such as the recent Haitian earthquakes, the Palestine conflict (Buch & Egenfeldt-Nielsen, 2006), the spread of infectious deceases (Neulight, Kafai, Kao, Foley & Galas, 2007), or the genocides in Darfur[1]. Studies conducted with such games have shown that players had an increased interest in the topic, and showed more empathy for the characters. For example, Buch & Egenfeldt-Nielsen (2006) have illustrated how Global Conflicts Palestine[2], a commercial educational video game on the Palestine conflict, has motivated students, helped them to appreciate the conflict from different perspectives, and supported a deeper understanding of the conflict. It is interesting to note that some game genres, such as MMORPGs, leverage learning resources and support knowledge and skills that are not always acknowledged in formal education, such as peer-to-peer support and online discussions forums (Williamson & Facer, 2004).

### *Accounting for Individual Differences*

Empirical evidence has shown that video games were particularly effective to engage students with low self-efficacy (e.g., those who don't believe they can perform some tasks successfully), special needs, attention deficit such as AD/HD (Attention Deficit/Hyper-Activity Disorder), autism, or Asperger syndrome (Amon & Campbell, 2008; Carr & Blanchfield, 2009; Saridaki & Mourlas 2011). Games can be employed to motivate patients to perform rehabilitation exercises (Betker, Desai, Nett, Kapadia & Szturm, 2007), or inform (and consequently reassure) them about their condition (Kato, Cole, Bradlyn & Pollock, 2008). Some researchers also found that motivations may vary across players based on their individual differences such as gender, age, personality, and sociocultural background; as a result, personalized or

[1] http://www.darfurisdying.com
[2] http://www.globalconflicts.eu

customized mechanisms ought to be included in video games for successful motivational outcomes. This was the case for Marty & Carron (2011) and Virvou, Katsionis & Manos (2005), who combined a tutoring system that adapted to users' knowledge and behaviour with a Game-Based Learning environment. These experiments showed that adaptive mechanisms in GBL can significantly increase students' motivation to learn. In a similar study, Deen & Shouten (2011) have developed a game-based system that adapts to users' preferences or "internal regulations", and they found that students felt less forced to learn English after they played an educational video game that satisfied their need for autonomy and relatedness.

### *Factors that Improve Motivation to Learn in Video Games*

As noted by Wilson, Bedwell, Lazzara, Salas, Burke, Estock, Orvis and Conkey (2009), very few studies have managed to identify which factors affect learning outcomes in video games, and to which extent. However, several scholars such as Wishart (1990), Oxland (2004), or Staalduinen (2011) have managed to identify some of the factors that may influence involvement and learning in video games. These aspects include control, challenge, complexity, achievable and clear goals, hidden secrets, adaptation, debriefing, conflict, fantasy, mystery, and safety. The narrative aspect of video games also plays an important role in increasing students' involvement, as demonstrated by Waraich (2004). Evidence has also shown that the use of multimodal interaction and multi-sensory cues may successfully engage learners, enable them to adapt the interaction to their own style, and help them to understand phenomena by providing new perspectives and quantitative representations (Salzman, Loftin, Dede & McGlynn, 1996).

### *Improving Attainment through Motivation*

As mentioned in the previous sections, although scientific evidence proves that video games do motivate to learn, it should be emphasized that motivation to learn is not always sufficient to increase both knowledge and academic results. The literature shows that several features should be considered for this purpose. Effective GBL approaches should include briefing, debriefing, game objectives linked to the curriculum, progression in the game linked to the students' proficiency in the topic taught, and an effective feedback process that identifies areas of misconceptions and provides remedial actions accordingly.

Because self-efficacy and confidence play an important role in attainments (and may be increased by playing video games), it is essential that students, after playing the video game, feel more knowledgeable or more able to grasp concepts that they perceived as complicated or too abstract beforehand.

## Difference in Motivation between Traditional and Game-Based Settings

### *Introduction*

Although it is understood that video games can motivate to learn, researchers have conducted controlled studies to explore the motivational and learning advantages of using video games in comparison to traditional settings. Literature presenting evidence of the advantage of GBL over traditional settings is based on both qualitative and quantitative data, and has been collected using a wide range of methods and techniques including pre- and post tests, interviews with students and teachers, recordings of students during game play, or focus groups. In the light of the literature, it appears that settings incorporating video games are often more engaging and educationally effective than settings that don't. GBL can be better than traditional teaching methods to improve learning and motivation for a wide range of topics including mathematics (Sorensen & Meyer, 2007; Miller & Robertson, 2010), physics (Squire et al., 2004), software engineering (Navarro & Hoek, 2007), languages (Yip & Kwan, 2006; Miller & Hegelheimer, 2006; Neville, Shelton & McInnis, 2009), history (Abrams, 2009; Watson et al., 2011), literature (Stevens, 2000), rehabilitation (Adamovich, Merians, Boian, Lewis, Tremaine, Burdea, Recce & Poizner, 2005), fire fighting (Tsung-Yen & -Fan Chen, 2009), digital skills (Beavis & O'Mara, 2010; Owston, Wideman & Brown, 2009), mechanical engineering (Coller & Scott, 2009), healthy eating (Serrano, 2004), algebra (Kebritchi et al., 2010), geography (Virvou et al., 2005), or reading comprehension (Bransford & Schwartz, 1999).

### *General Benefits Compared to Traditional Teaching*

The studies mentioned above have demonstrated that video game, compared to traditional teaching methods, strengthen students' knowledge, skills and attitudes towards the topic taught (Serrano, 2004), that a game-based learning approach is more motivating and educationally effective (Barab et al., 2009), especially for students with poor pre-test scores. GBL is often more effective than conventional educational software such as web-based or CAI (Virvou et al., 2005; Papastergiou, 2009; Tsung-Yen & Chen 2009). In some cases, the educational effectiveness of the game, can be improved by customized mechanisms such as pedagogical agents and Intelligent Tutoring Systems (Conati & Zhao, 2004).

Students are significantly more engaged by GBL compared to traditional teaching. They usually find the medium much more enjoyable (Toprac, 2011; Vogel et al., 2006) and can be in some cases, more focused and disciplined than in web-based instruction settings (Papastergiou, 2009). GBL improves students' self efficacy (Toprac, 2009) and can be more efficient than traditional methods for rehabilitation. This was illustrated by (Adamovich et al., 2005) who explain that attention, reward, progression, complexity, and skill acquisition are critical to produce improvements in neural structures and functions. They found that virtual reality and video games, because they include all these features, are a suitable tool, especially for the new “MTV generation”, who would be well suited to video game-based therapy.

Students following a game-based approach are able to test their knowledge and refine their understanding of the concepts they have learnt previously. Teachers often notice a change in the behaviours of these students. Amongst other noted benefits, games may be better than paper-based because students can complete exercises repeatedly, with increasing difficulty and challenges. They develop a sense of collaboration or competition between players (Lee et al., 2004; Miller & Robertson, 2010). Games often help students to become more perseverant, and it was suggested that they could be used as an additional resource to palliate teachers' lack of contact hours (Yip & Kwan, 2006).

Abrams (2009) conducted a particularly interesting study with three students who underperformed academically and found it difficult to be engaged in traditional settings. The study showed that when students are exposed to video games related to the history lesson, they manage to understand concepts by playing the video game. Their gaming experience enriched their understanding of the Second World War by providing them with more vivid details of the battles. The results of the study showed how video games can provide a meaningful context and an interactive visual representation that make the learning material 'accessible, useful and relevant', especially for students who usually find it difficult to be engaged in traditional settings. The video game helped them to memorize concepts more vividly because they were contextualized within the game.

### *Learning by Creating a Game*

Students who create an educational game need to collect and consolidate information from different sources, and review thoroughly the learning material before they integrated it into the game. They are also often committed to provide correct and typo-free information to their class mates This process tends to improve their memory retention, engagement, editing skills, and knowledge of the concepts. The process of creating educational games engages students in authentic activities, where knowledge is contextualized ands employed for a purpose other than just 'regurgitating information'. For example, Beavis & O'Mara (2010) showed that requiring students to create an educational game, improved their literacy kills, digital skills, writing skills and knowledge of the topic.

### *How is Engagement Characterized in GBL Environments*

Increased engagement in GBL environments is often characterized by students' interaction and discussions outside the classroom. This can be explained by the fact that while teachers are trying to engage students in typical classes (e.g., humor, questions, analogies, etc.), this approach does not always work, probably because teachers are at the centre of the activity and that the traditional setup of the classroom (e.g., the desks are lined-up in rows and the teacher is at the head of the class) is not student-centered. In contrast to common traditional classes, settings using GBL, where students play or create video games, can be more conducive to user-centered and collaborative learning. For example, while some team members may play the game, the other members can discuss strategy and provide suggestions. As suggested by Watson, Mong and Harris (2011), this type of settings promotes interaction within and between teams, and because the teacher is not the centre of instruction, this can result in a more engaging experience. Theses settings, usually referred as 'wall-less classrooms ' are effective because they emulate authentic computer supported collaborative working environments, where students collaborate, develop their knowledge-finding skills, and engage with communities in order to find solution to some of the problems they may encounter (Beavis & O'Mara, 2010).

### *Conditions for Successful Integration*

Researchers often indicate that while playing games is increasingly a part of what it means to be literate in the 21st century', it is not always acknowledged in traditional settings. As a result, teaching practices need to be modified in order to account for the digital literacies developed outside of school.

Most studies referred to in this review suggest that educational benefits are increased when the students have had a prior exposure to the topic and that the game allowed to put learned knowledge into practice (Navarro & Hoek, 2007). It also appears crucial that, in the case of bespoke educational video games, students be included in the development process, and introduced to new or unfamiliar game mechanics through a training module. Neville et al. (2009) advise that in-game training (e.g., demo levels or feedback) be complemented with class training sessions, and that attention be paid to contemporary games for affordance with which students would be familiar and would expect in a game (e.g., same quality than commercial games). Providing well-known control schemes may facilitate the learning curve and consequently improve the overall experience. Finally, Owston et al. (2009) advise that students should not be involved in collaborative activities (e.g., playing or designing a game) for more than 45 consecutive minutes, otherwise their' productivity may decrease significantly.

Video games have been successfully employed in physical education and physical health. This has been made possible due to recent progress and availability of pervasive and motion-based game consoles. Such environments provide a valuable alternative to traditional settings, because they make it possible to (1) motivate teenagers and adults to exercise frequently, (2) understand the value of exercise and good nutrition, (3) motivate to perform rehabilitation exercises with better results and less financial constraints than methods traditionally employed.

## Summary

Video games seem to unanimously motivate participants to collaborate and exchange information, thus promoting a social-learning perspective. This approach seems to be particularly effective in the context of inquiry-based learning, where participants are encouraged to elaborate, test and revise hypotheses, based on their finding in the game. The game in this case acts as a platform where exploration, observation, and deductions are key to successful learning.

Games constitute a truly motivating and engaging medium that can effectively be used to motivate students for a wide range of topics. Contributing factors to motivational outcomes are both linked to (1) the design of the game, (2) the medium employed to deploy the game, and (3) the environmental scaffoldings (e.g., teachers' help). In most cases, successful games include clear goals, rules, multi-sensory cues, narratives, and a good balance between the educational and entertaining features. Increased motivation is often experienced when teachers are actively involved in the introduction and use of the game, and evidence shows that video games are particularly effective for scientific inquiry.

Beyond design and technical considerations, it should be emphasized that teachers are key to successful GBL experiences; while GBL approaches can yield great motivational and educational benefits, teachers should be empowered to use and master GBL techniques and tools, and become more comfortable with games. Above all, teachers need to be provided with sufficient resource and appropriate tools, so that GBL can easily be integrated in classrooms.

## Acknowledgements

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# Educationally Adaptive: Balancing Serious Games

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## Abstract

A key factor for the success and efficacy of an educational medium is the extent to which it is capable of addressing the preferences, abilities, strengths, weaknesses, and goals of individual learners. Research in the field of learning and instruction has demonstrated in the past that one on one tutoring is the most effective and powerful way of teaching. Ever since, the research community attempted to equip artificial systems with the strength and abilities of human tutors. Specifically in a medium such as educational computer games an appropriate personalization is a key factor for fun, immersion, and ultimately learning. The same holds true for serious, in particular educational, games. Because the key strength of serious games is seen in their intrinsic motivational potential, it's all about focusing on the learners. More importantly, in contrast to conventional educational systems, in games this means accounting for both, a game related and a learning related hemisphere. This report attempts to emphasize the importance of advancing a construct such "educational game AI" and it illustrates recent technologies and approaches.

KEYWORDS: EDUCATIONAL GAMES, ADAPTATION, GAME BALANCING, PERSONALIZATION

## Introduction

Over the last decade, serious games have become accepted educational tools and the idea of using the great strength of modern computer games for educational purposes experienced a significant boost.

From an educational perspective, computer games offer a promising approach to make learning more engaging, satisfying, and probably more effective. Current approaches to learning/teaching with computer games are ranging from utilizing commercial entertainment games (the so-called '*commercial off the shelf games'*, COTS) to games designed and developed for primarily educational purposes. The major strength of digital games in education is a high level of intrinsic motivation to play and to proceed in the game and, thus, to learn within the context of a meaningful and continuous storyline and within the related para-social dimension provided by game characters. These strengths are acknowledged as supportive in the context of education for a long time. According to Malone (1981) the factors forming that strength and making games fun are challenge, fantasy, and curiosity. Educational games provide clear goals and rules, a relevant learning context, an engaging storyline, immediate feedback, a high level of interactivity, challenge and competition, random elements of surprise, and rich and appealing learning environments (cf. Prensky, 2001). These factors determine motivation to play but are also considered being important for successful and effective learning (for reviews see Merrill, 2002 or Schulmeister, 2004). On the other hand, educational games have also major disadvantages such as difficulties in (i) providing appropriate balance between gaming and learning activities, (ii) providing a continuous balance between challenge and ability, (iii) aligning the game with national curricula, or (iv) the extensive costs of developing high quality games (for a review see van Eck, 2006). Due to these problems, most of today's educational games cannot compete with their commercial counterparts in terms of gaming experience, immersive and interactive environments and storytelling, or intrinsic motivation to play. Moreover, most educational games do not rely on sound instructional models thus leading to a separation of learning from gaming and often they provide gaming actions only as reward for learning. Therefore, such games do not differ significantly from other traditional multimedia learning applications.

To move toward the 'next generation' of educational games, a significant community of researchers addresses the field of a sensible adaptation to the learner/player; undoubtedly, "balancing" computer games according to certain (presumed) preferences and needs of the players in an autonomous and adaptive manner is an important feature. To be enjoyable, a computer game must be balanced well (Tins, Brokken, & Ijsselsteijn, 2008, 2009), meaning the game must match an individual player's playing preferences, playing styles, and playing capabilities in a suitable way in order to avoid too one-sided gameplay. So far there is almost exclusively a tradition of adaptively balancing recreational games. Main goal is to avoid undesired player emotions such as frustration (because the game is too hard) or boredom (because the game is too easy; cf. Koster, 2004). Adams and Rollins (2007) list a number of requirements for well-balanced games are for example:

- meaningful choices;
- chance should not make player capabilities irrelevant;
- players must perceive the game to be fair;

Specifically in serious games, an appropriate adaptation is of crucial importance in order to reach and maintain fun and enjoyment on the one hand and effective, successful learning on the other hand (a review can be found in Kickmeier-Rust, Mattheiss, Steiner & Albert, 2011). Of course, the idea of (and the need for) a smart educational personalization is not only valid for educational games. Originally, the concept was developed in the field of conventional adaptive/intelligent educational and tutorial systems; an overview about adaptation techniques in e-learning can be found, for example, in Brusilovsky and Peylo (2003) or De Bra (2008).

## The Origins of Educationally Intelligent Systems

Along with the industrial revolution and the invention of assembly-lines, a new view of learning and teaching emerged. Standardized tests emerged during World War I, teaching machines were invented in the 1920s, instructional films came up in the 1940s, or programmed instruction came up in the 1950s, in the 1960s and 1970s the educational television was invented and educational computer technology became popular in the 1980s and 1990s. (cf. Wulfeck, 2009).

The modern approaches to adaptive educational technology can be traced back to Lee Cronbach and Richard Snow (1977) and their *Aptitude-Treatment Interaction* model, which mirrors the idea that different aptitudes (abilities or prior knowledge) require different treatments (i.e., instructional methods, designs, or conditions). Further work in the area was also leveraged by Benjamin Bloom (1984) who posed the *two-sigma problem* that, essentially, states that tailored tutoring results in performance superior by 2 standard deviations in comparison to regular teaching. Ultimately, the idea is that learners are not overburdened by the educational demands and therefore quickly frustrated but, at the same time, not under-challenged and therefore bored. Insofar, the concept is closely related to the portrayed ideas of game adaptation. Commenced by Bloom, psychologists, educationists, and technicians attempted to develop technology that is able to take the role of a private teacher and to intelligently provide individual learners with suitable tutoring (cf. De Bra, 2008).

## Assessment

Naturally, balancing a conceptually complex environment such as a computer game (including visual, environmental, gameplay, game mechanics, narrative, and educational features), requires a robust, psychologically meaningful yet simple assessment that can be realized in real time in the background of the gaming and in addition to the computational demands of the game itself. Assessment, therefore, must be based on simple identifiable indicators and it must be based on valid heuristics; the indicators, thereby, may be divided into performance related aspects, emotional-motivational as well as personality related aspects. The performance related aspects include measuring, gathering, analyzing, and interpreting:

- scores;
- task completion rates;
- task completion times;
- task success rates (e.g., number of individual strikes in a shooting game);
- task success depth (the quality or degree to which a task has been accomplished);
- distances covered / progress in the game world;
- exhibited knowledge, competence states, or skills;
- incongruent behaviors as indicator for succeeding by chance (e.g., alternately exhibiting success and failure);

According to Wulfeck (2009), who delivered a comprehensive summary the present state-of-the-art, important dimensions of assessment are:

- individual preferences;
- progress/results/scores;
- traits/aptitudes;
- prior knowledge/ability;
- prior achievements;

In general, classifying the learners was subject of a large body of research (see Sampson, Karagiannidis, & Kinshuk, 2002 for an overview) and has a very long tradition. In fact, classifying goes back to the first attempts of assigning grades to students. An early example perhaps is *Joachim Heinrich Campe*, a German writer, linguist, and pedagogue who rewarded students with diligence cards and golden nails assigned to the name lists on the wall, as reported back in 1776 (cf. Kersting, 1992). In recent times, Sloane, Wilson, and Samson (1996) of the *Berkeley Evaluation and Research Center* established four principles of assessment: (i) the developmental perspective (viewing learning as a longer process that cannot be assessed by one shot), (ii) instructional fidelity (match between objectives for assessment and important learning objectives), (iii) teacher management and responsibility (valid for classroom assessment), and (iv) quality of evidence (e.g., standards of fairness, etc.).

In the context of autonomous intelligent, adaptive tutorial systems (ITS / ATS), classifying and modeling the learner plays a crucial role and bears one of the most substantial challenges to research. The cognitive aspects are in the center of most attempts and frameworks, for example in the CTM, the *Cognitive Trait Model*, which enables student modelling on the basis of cognitive abilities and resources (cf. Kinshuk, Lin, & Patel, 2006).

A well-elaborated and validated framework for assessing in particular cognitive aspects comes also from Kickmeier-Rust and colleagues (e.g., Augustin, Hockemeyer, Kickmeier-Rust, & Albert, 2010; Kickmeier-Rust et al., 2011), utilizing the ideas of *Competence-based Knowledge Space Theory* (CbKST).

Most concisely, CbKST is an extension of the originally behavioural *Knowledge Space Theory* by Doignon and Falmagne (1999) where a knowledge domain is characterized by a set of problems or test items / tasks. The *knowledge state* of a learner is identified on the subset of problems s/he is capable of solving. Due to mutual dependencies between the items captured by *prerequisite relations*, not all potential knowledge states are supposed to occur. The set of all possible states is called a *knowledge structure*. To account for the fact that a problem might have several prerequisites (i.e., and/or-type relations) the notion of a *prerequisite function* was introduced. Recent updates of this rigorous mathematical approach are described by Falmagne and Doignon (2010).

The principle idea of CbKST is to separate the observable behavioural aspects, i.e., whether a learner masters a problem or test item, from the not directly observable construct of aptitude/ability/knowledge behind the performance. The entities of aptitude matching the concept of problems or items are called skills or competencies. Equal to knowledge structures, prerequisites between competencies establish competence structures that include only meaningful sets of competencies a person can have. To give an example, having the competency to multiply integers but, at the same time, not having the competency to add integers are not meaningful or plausible. The relationships between the competencies and problems/items are established by a *skill function*. Such function assigns a collection of subsets of competencies (i.e., *competence states*) to each problem that are relevant for solving it. By associating competencies with the problems/items of a domain, a knowledge structure on the set of problems is induced. The latent competencies can be uncovered on the basis of a person's observable performance.

To account for the specific needs of educational games and to achieve a non-invasive, unobtrusive assessment, Kickmeier-Rust and Albert (2010) developed a formal model of the problem solving behaviour in game-based learning situations (LeS). Basically, LeS are characterized by a large degree of freedom and complex problem solving demands. The problem solution process is considered to be a meaningful sequence of *problem solution states* establishing a *problem space.* Stochastic process models are applied in order to estimate the likelihood of certain state transitions and to estimate the probability of reaching a solution state (within a specific time interval). In other terms, a LeS is segmented into a set of possible problem solution states, each mapped to one of a set of possible competence states. By this means, the educational AI of a game can interpret the behaviour of the learner in terms of available knowledge, un-activated knowledge, or missing knowledge, simply by mapping the actions of the learner to competence states.

Practically speaking, the global framework, termed micro adaptivity, attempts to analyse a learner's progress in the game environment (e.g., if s/he passes through a door or is making use of a specific tool) and to associate a probability of available or lacking competencies on a probabilistic level. Depending on an increase (what actually is desired) or a decrease of the probability of specific competencies, pedagogical/didactic meta-rules are utilized to select a specific intervention and feedback (e.g., *'if the probability of a competency v involved in a LeS decreases below a threshold w, and the probability of a competency x is above a value y, then trigger an educational hint z'*).

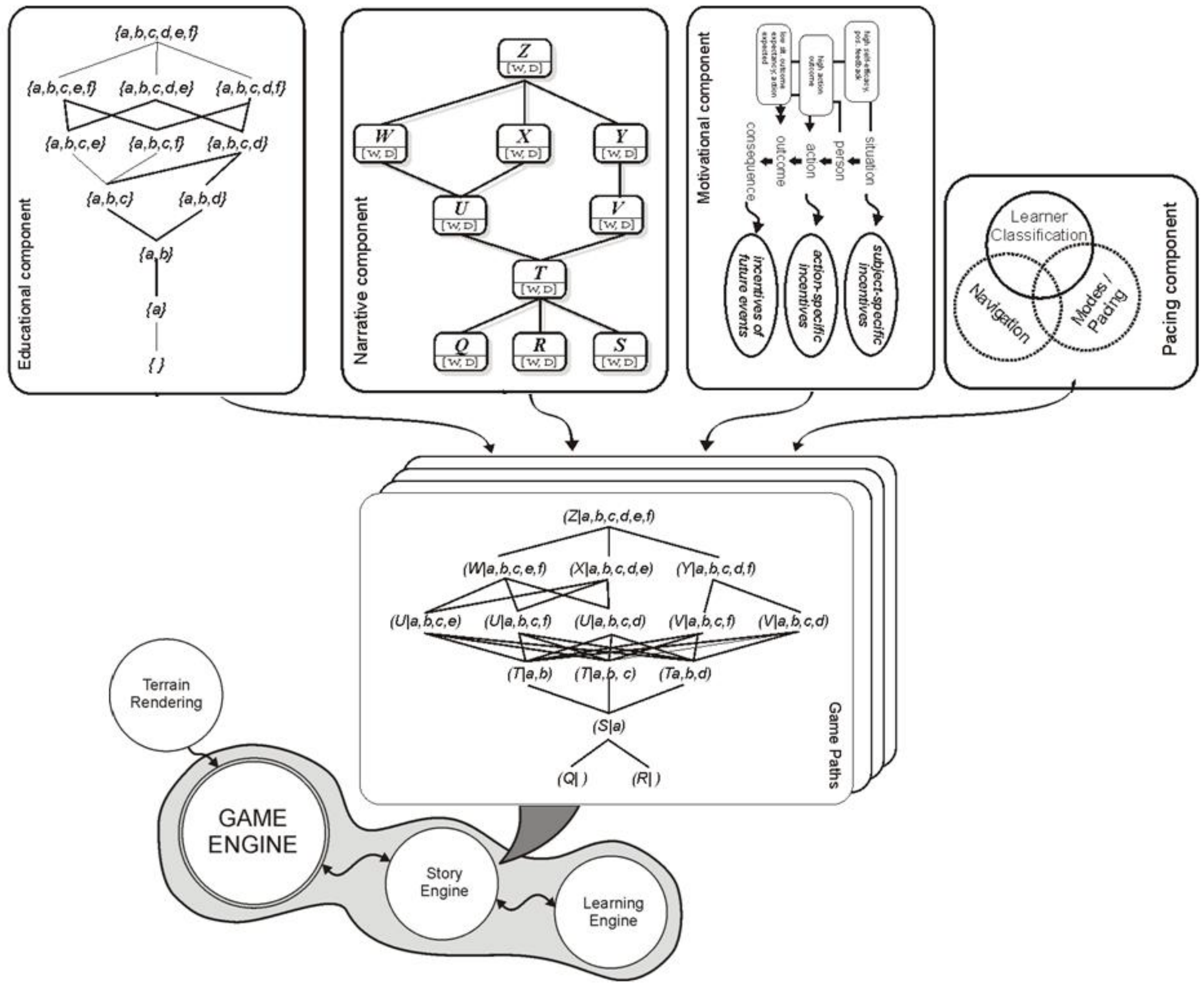


Figure 1. Conceptual architecture for micro adaptivity, a framework for an unobtrusive assessment.

From a technical perspective, the architecture consists of three modules (cf. Figure 1). In the centre is a regular game engine which is responsible for rendering the game, providing game mechanics, and the input and output mechanisms. The game engine is connected to a so-called story engine which monitors and controls the spread of the game's narrative in dependence of specific educational interventions and adaptations. The main task of this module is to assure that no breaks and inconsistencies occur in the virtual game world. Finally, moderated through the story engine, a so-called learning engine is responsible for interpreting the input coming from the game and for informing the story engine in the first instance and subsequently the game engine with educational suggestions or recommendations. Interventions and adaptations are only triggered in accordance with the game's story and global state. As indicated conceptually in Figure 1, as a foundation for the interpretation and reasoning process as well as the subsequent interventions and adaptations the system utilizes the competence space for a given domain, a problem space, psycho-pedagogical rules and heuristics as well as a story model, which drives the spread of the game's storyline.

Entirely different yet highly promising directions for assessment and reasoning are covered by attempts to incorporate machine learning techniques to improve the assessment heuristics gradually during the game play (cf. van Lankveld, Spronck, van den Herik, & Rauterberg, 2010). In addition to mere performance, these approaches account for oscillating psychological states (i.e., emotional states or, maybe more importantly, motivational states) and rather static psychological characteristics (i.e., personality traits). Assessment regarding emotional-motivational aspects includes for example:

- virtual character analyses (e.g., posture, alignment, locations, motions, etc.);
- force exerted on interactive game controllers (if available);
- facial expressions recorded by camera devices (e.g., webcams; if available);
- gestures recorded by camera devices (e.g., Microsoft's Kinect system; if available);
- speech analyses – natural language processing;
- text chat analyses;

Increasingly important, especially in consideration of the rapidly advancing technological measurement solutions, is also a strong focus on the rich possibilities of various psycho-physiological factors – even if such features and approaches are still in their infancy. Aspects considered by ongoing research are: Heart rate, heart rate variability, respiration rate, coherence between respiration rate and heart rate, blood pressure, blood volume pulse, activity of the corrugator supercilii muscle, activity of the zygomaticus major muscle, activity of the orbicularis oculi muscle, skin conductance level, skin conductance responses, eye movements, pupil size, eye blink rate, brain activity at various frequencies, or evoked response potential (cf. Tijs, Brokken, & Ijsselsteijn, 2008). Meanwhile a growing body of research provides the serious games community with knowledge about the interactions and dependencies between gaming behaviors, experiences, preferences, and psycho-physiological measures. An example is the work of Nacke and Lindley (2010), who investigated the relationships between gaming experience, level design, and psycho-physiological measures (electromyogram and electro dermal activity). Their results yielded that different game level designs effect emotional patterns during game play, which in turn has a high potential as an axis for real-time assessment and adaptation in educational games.

A further example is given by Kickmeier-Rust, Hillemann, and Albert (2011) who demonstrated the use of eye tracking for a real-time identification of motivational states in an educational game. The results of this study revealed that children can effectively learn while gaming; more importantly, a distinct finding presented in this study is that extreme groups such as high and low performers exhibit different visual patterns especially in their fixation duration and saccade lengths. Very concisely, good learners scan the visual field evenly with longer saccades and attend relevant areas on screen more frequently and in a more stable fashion than poor learners do. Furthermore distinct gender differences could be found in the interaction style with different game elements, depending on the demands on spatial abilities concerning navigating in the three-dimensional spaces.

But not only the continuously oscillating (psycho-physiological) states serve as assessment indicators, also the rather stable personality traits offer assessment indicators such as the adaptation and application of well-acknowledged personality inventories, for example, a widely accepted instrument for assessing the 5-factor model of personality is the NEO-PI-R personality questionnaire (van Lankveld, Schreurs, Spronck, & van den Herik, 2011). Just as an example, the factor "extraversion" involves:

- Activity: Active, energetic people have high pace and powerful movement. They need to be busy and radiate a feeling of energy. They have a busy and hasty life.
- Assertiveness: Assertive people are dominant, self-content, and controlling. They talk without hesitation and often lead groups.
- Excitement-seeking: Excitement seekers desire adventure, stimulation, and action. They like bright colors, noisy environments, and aculeate sensations.
- Gregariousness: Gregarious people prefer the company of others. They seek out others and like crowds and group activities.
- Positive emotion: People with positive emotion have fun and feel happy and joyful. They laugh easily and are often cheerful and optimistic.
- Warmth: Warm people desire to form emotional bonds with others by showing warmth and action. They are friendly and show that they genuinely like others.

The work of van Lankveld, Schreurs, Spronck, and van den Herik (2011) indicates, for example, that gaming behavior in specific situations (e.g., being forced to wait) can reveal personality traits, in their particular case extraversion, to a certain extent.

Highly interesting and most forward-looking approaches to assessment are the so-called brain-computer interfaces. In essence, these approaches are utilizing EEG and functional brain imaging techniques to directly interface the human brain with the game. This means that the player can control the game more or less directly through thoughts. For example Krepki, Blankertz, Curio, and Müller (2007) used motor imagery to play Pacman, Pong, or Tetris games. Finke, Lenhardt, and Ritter (2009), as another example, moved a character through a virtual scene by measuring the so-called P300 potential in the EEG.

Physiological computing systems that employ real-time measures of psycho-physiology to inform an adaptive system are at an early stage, of course. Fairclough (2009) argues that physiological computing has enormous potential to innovate human–computer interaction by extending the communication bandwidth, fundamental issues for research are the complexity of the psycho-physiological inference, representing the psychological state of the user, ways of designing explicit and implicit system interventions, or defining the "biocybernetic loop" that controls system adaptation.

In conclusion, in contrast to traditional forms of teaching (either in real or virtual environments), where the assessment occurs by test items, questions, or tasks, DEGs require an assessment that does not destroy or impair motivation, immersion, flow experience, or the game's storyline (Kickmeier-Rust & Albert, 2010). This "protection" is important from two perspectives. On the one hand, there is a large body of evidence concerning the negative impact of interruptions and attention splits on (problem solving) task performance and learning (e.g., Chandler & Sweller, 1992 in the context of cognitive load theory; Foerde, Poldrack, & Knowlton, 2007 in the context of cognitive neuroscience; or Gillie & Broadbent, 1989 in the context of computer tasks). On the other hand, from the perspective of fun and immersion, it is important not to compromise a fluent progress of game play and/or narrative (e.g., Jennett, Cox, Cairns, Dhoparee, Epps, Tijs & Walton, 2008).

## Adaptation – Personalization – Balancing

Assessment is the one thing in successful adaptation. The next thing is enabling the system to respond educationally meaningful and effective to the conclusions drawn from the assessment procedures, still protecting immersion and flow. Feedback and interventions can be interpreted as one mechanism that takes over the actions of a teacher, i.e., providing advice, explanations, and evaluations (Vasilyeva, Pechenizkiy, & De Bra, 2007). In game-based learning situations, adaptations on the micro level may occur through embedded feedback (e.g., through a non-player character), by guiding or hinting, or by adjusting the complexity/difficulty of a learning situation. Such kind of adaptation may indicate gaps between current and desired performance level and may enhance motivation and task strategies, it is able to reduce learners' cognitive load, and it can provide information that is useful for correcting inappropriate task strategies, errors, and misconceptions (Shute, 2008). Existing strands of research (e.g., Steiner, Kickmeier-Rust & Albert, 2009) also focused on equipping the game with a set of psycho-pedagogically inspired adaptive intervention categories and types which are aligned with the non-invasive assessment procedures of a learner's competence and motivation. Broadly speaking, these interventions strive to enhance cognitive abilities and to support the learners adaptively according to their behaviour and underlying available or lacking skills (cognitive and meta-cognitive interventions) and are supposed to enhance and retain learners' motivation and engagement on a high level (motivational interventions).

Research on adaptation in game environments involves also the macro aspect of storytelling; the challenge is integrating interactive storytelling with the demands of educational and psycho-pedagogical adaptation (e.g., a well-planned sequence of learning events). A fundamental phenomenon, commonly encountered in the creation of (educational) games is the tension between the control over the game by the author and the control exerted by the player over the continuation of the game during play. This phenomenon, referred to as the "narrative paradox" due to the seemingly incompatible interests of author and player, shows the interconnection of two challenges: the composition of an exciting game by an author (authoring) and the continuation of a game at a certain moment during play, ideally adapted to the player's needs (macro adaptation). A possible solution for highly adaptive games is an open, adaptive storytelling, tailored to the needs and actions of a player, based on more or less abstract rules defined by the author. As briefly introduced in the preceding section, the idea is, in principle, to develop a formal story model (e.g., the *Hero's Journey*, cf. Campbell, 2008) and link it, as a formal representation, to problem spaces, competence structures, and ultimately to game elements and assets. Göbel, de Carvalho Rodrigues, Mehm & Steinmetz (2009) describe an approach where atomic and modular game elements, the so-called *Narrative Game-Based Learning Objects* (NGLOBs), are re-assembled adaptively in accordance with educational adaptations.

Under the conceptual cloak of micro and macro adaptation, there is a broad range of dimensions and techniques to respond or intervene in order to balance a game and tailor its manifestation to the individual learners (Kickmeier-Rust, 2007). A very common technique is the so-called dynamic difficulty adjustment (DDA; van Lankveld, Spronck, van den Herik, & Rauterberg, 2010; Wong, 2008). This technique is widely used in entertainment games but also increasingly enters the AI of serious, in particular educational games. In simple terms, the idea is to increase the difficulty of the game or of game elements along with the increasing capabilities of the players. A similar approach is the so-called speed adjustment which actually focuses on racing-like games, where the speed of artificial opponents is adjusted with the player's speed and racing abilities. In terms of learning, there exists ground-breaking work to adjust the difficult of learning materials (in mutual dependence with the global game difficulty and game characteristics; Kickmeier-Rust, Göbel, & Albert, 2008). Also related to this type of balancing is the so-called *rubber banding* (Pagulayan, Keeker, Wixon, Romero & Fuller, 2002), which means artificially boosting performance (of a race car, for example) when falling behind.

A more sophisticated method, particularly when it comes to a learning-related adaptation and balancing, is *problem solving support*. This method attempts to identify where in a problem solving process (which is characteristic for many in-game tasks and quests) a player or learner is, to interpret whether support or guidance is required, and which type of support or guidance is the most appropriate one in the given situation (cf. Kickmeier-Rust & Albert, 2010).

In summary, prototypical techniques and methods of adaptation are:

- procedural and adaptive level and content generation (Nitsche, Ashmore, Hankinson, Fitzpatrick, Kelly & Margenau, 2006)
- strategy formulation (e.g., adaptive behavior of agents; Avery & Michalewicz, 2008);
- adaptive and interactive storytelling (Göbel et al., 2009);
- guidance, problem solving support, hinting (Kickmeier-Rust & Albert, 2010);
- motivational interventions; cheer, praise, critiquing (Kickmeier-Rust & Albert, 2010);
- adaptive presentation (Brusilovsky & Peylo, 2003);
- adaptive curriculum sequencing(Brusilovsky & Peylo, 2003);
- navigation support(Brusilovsky & Peylo, 2003);
- intelligent solution analysis (Brusilovsky & Peylo, 2003);

In general, each computer game has some elements of adaptation. The attempt to realize game balancing in a game-related as well as education-oriented sense are crucial still not trivial. To combine both worlds is clearly more than the sum of it.

Noteworthy are the results of two European projects, as role models of complex game balancing. The first project was ELEKTRA (www.elektra-project.org), which focused on assessment and adaptation on an unobtrusive level and on subtle educational guidance. The ELEKTRA prototype game is realized as a classical 3D adventure game in first-person view, and aims to teach 8th grade (i.e., 12 to 13 years of age) optics. Briefly, the aim is to save a girl, Lisa, and her uncle Leo who have been kidnapped by the evil Black Galileans. Moreover, the learner must stop the evil forces from taking over the entire world. During this journey, the learner must acquire specific, curriculum-related knowledge. The learning occurs in different ways, ranging from hearing or reading to freely experimenting. After finding a magic hourglass, the learner is in company of the ghost of Galileo Galilei, who is the learner's (hidden) teacher. The non-playing characters play a significant role in intelligent, non-invasive educational and motivational interventions. For example, Galileo tells the learner specific facts that are needed for certain events in the game and intervenes by providing the learner with hints or feedback. Figure 2 displays two screen shots of the game.

Figure 2. Screenshots from the ELEKTRA prototype game.

Figure 3. Screenshots from the 80Days prototype game.

The second example, we want to highlight is 80Days (www.eightydays.eu). This project focused on advancing the non-invasive assessment and on appropriate psycho-pedagogical support of learning. The distinct novelty of the project was the integration of adaptive, interactive storytelling (Kickmeier-Rust, Göbel, & Albert, 2008) and adaptive game balancing. 80Days leaves the well-structured domain of physics and produced a demonstrator game that is teaching geography for the age group of 12 to 14 (see Figure 3 for screenshots).

## How Important is Game Balancing?

We have tried to outline the basic idea of game balancing and illustrate some examples of approaches to an intelligent automatic adaptation to the players and learners in terms of playing and in terms of learning. Of course, this summary is not meant to be complete. Its intention is primarily to raise awareness that mere mixing of learning materials with computer games and game-like features is likely not successful and may lead to, what famous Seymour Papert called a *Shavian reversal*, a chimera that unifies the worst from two worlds.

A smart, perhaps intelligent individual balance and an emphasis on an autonomous, system-driven acknowledgement of individual needs and preferences, both in a game related as well as learning related sense is a key factor of a game's success. This, again, concerns both the game hemisphere and the educational hemisphere.

To substantiate this claim, we conducted a meta-review in the field of game-based learning literature. We particularly looked into scientific articles presenting results on the educational efficacy, the learning performance, of computer games. In total we analyzed over 300 papers published between 2009 and 2011 in SCI listed journals. One result was that only a small percentage of those papers (i.e., about 10%) reported serious, non-trivial educational benefits from playing the games. Even more impressing was the fact that from those studies reporting reasonable and statistically significant benefits, 90% share that the investigated games bear some form of educational adaptation or personalization. These results (the details and further aspects will be published in the near future) are in line with experimental findings that explicitly demonstrated that adaptation, personalization and subtle balancing results in superior gaming experience and educational gains (e.g., Kickmeier-Rust et al., 2008).

The European *network of excellence* GALA (www.galanoe.eu), which stands for Games and Learning Alliance, is a network that is dedicated to bring European leading players in the field of serious/educational games together, to fight fragmentation, and to establish synergies. The involved organizations and companies cover a broad spectrum from research to development and from commercial to educational organizations. Acknowledging the importance of advancing the "educational intelligence" of serious games, GALA established a technical committee dedicated to "serious game AI" involving personalization, adaptation, and game balancing.

## Conclusions

In all our experience and on the basis of the recommendations and findings of a broad range of studies and surveys, a key aspect of a successful educational medium, in particular an education game, a smart and appropriate balance of various factors is crucial. The term balance, in essence, refers to an equilibrium of human dimensions, game-related as well as education-oriented dimensions. This complex set of relationships make it difficult to appropriately and successfully find a state of balance which assures immersive gaming and effective learning for a specific student/player. When the key strength of educational games, however, is seen in their intrinsic motivational potential, all success is up to an embedded and targeted assessment of the various factors and dimensions and a suitable adaptation and personalization accordingly. This is, of course, not a trivial attempt. There is a large community of researchers and practitioners working in the field of intelligent and adaptive tutorial systems but, as outlined, the field of games raises additional challenges. In this paper we have tried to give a brief overview of approaches to assess various factors and dimensions and to adapt accordingly in order to establish a promising balance. In our meta-review we mentioned concisely, we attempted to make clear that smart adaptation and personalization – or balance in other terms – is likely the most important factor for future, successful, and widely accepted game-based learning. Many of the techniques and methods, however, are not mature yet. The approaches and ideas, nevertheless, are recommended to be as strong part of designing the next generation of serious games – making serious games serious business.

## Acknowledgements

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# Adapting Playware to Rehabilitation Practices

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## Abstract

We describe how playware and games may become adaptive to the interaction of the individual user and how therapists use this adaptation property to apply modular interactive tiles in rehabilitation practices that demand highly individualized training. Therapists may use the interactive modular tiles to provide treatment for a large number of patients who receive hospital, municipality or home care, although the tiles can as well be used for prevention with elderly or for fitness with normal people. In this paper, we describe the extensive use of the modular tiles with cardiac patients, smoker's lung (COLD) patients and stroke patients in hospitals and in the private homes of patients and elderly. Through a qualitative research methodology of the new practice with the tiles, we find that therapists are using the modular aspect of the tiles for personalized training of a vast variety of elderly patients modulating exercises and difficulty levels. We also find that in physical games there are individual differences in patient interaction capabilities and styles, and that modularity allows the therapist to adapt exercises to the individual patient's capabilities.

KEYWORDS: REHABILITATION, PLAYWARE, MODULARITY, ADAPTIVITY

## Introduction

Using artificial intelligence in digital games allow the development of games that adapt to the individual users and become personalized. A prominent example of such intelligent game technology is playware. Playware is defined as *intelligent hardware and software that creates play and playful experiences amongst users of all ages* (Lund, Klitbo & Jessen, 2005). It is our view that the intelligent hardware and software may allow the playware tool to become adaptive to fit the individual user's needs and competencies, and this adaptivity may distinguish the playware tool from other play and game tools. Indeed, the intelligent hardware may allow us to create systems that can change their roles based upon a physical construction with the intelligent hardware, and the intelligent software may allow us to create systems (e.g. games) that can change their behavior based upon the user interaction with the systems.

We developed the modular interactive tiles with inspiration from modern artificial intelligence and modular robotics in order to explore flexibility in activity creation for end-users. The aim is to allow the end-user (e.g. a therapist or a doctor) to utilize her professional knowledge to adjust the technology in a fast and easy manner, for instance to the physical capability, mental capability, treatment level, fatigue level, and so forth of a particular patient.

It is our hypothesis that the inspiration from modular robotics may lead to a *highly flexible* and *easily adjustable* system for the end-user, and we investigate this with the development and practical use of modular interactive tiles for rehabilitation.

## Material

The modular interactive tiles (Lund, 2009; Lund & Marti, 2009; Lund, Pedersen & Beck, 2008, Derakhshan, Hammer & Lund, 2006) have been used in numerous experiments over the last few years for cardiac and stroke patient rehabilitation in hospitals, for therapy in children's hospitals, for physical play in kindergartens, for prevention in private homes of elderly, for physiotherapy of physically impaired in Africa, for soccer training, and music performances. The hardware of the modular interactive tiles has evolved over several generations to become the user-reconfigurable platform used for the rehabilitation experiments in this paper.

Each tile contains: one 8bit RISC Atmel ATMega 1280 processor, eight RGB LEDs, four infrared transceivers, one piezoelectric pressure sensor, and a slot for XBEE communication chip (the XBEE allows for communication to an external computer. Tiles having an XBEE chip automatically become master tiles). On the back of each tile are four super magnets for easy attachment to metal plates on walls. Connectors are formed like large jigsaw puzzle pieces (Figure 1, left), which mean tiles once linked together will not disconnect, even under heavy use. The modular interactive tiles are individually battery (Li-Io polymer battery) powered and rechargeable. A fully charged modular interactive tile can run continuously for approximately 30 hours and takes 3 hours to recharge.

The modular interactive tiles can easily be set up on the floor or wall within one minute (Figure 1). As with a jigsaw puzzle, the modular interactive tiles can simply attach to each other, and there are no wires. The modular interactive tiles can register whether they are placed horizontally or vertically, and make the software games behave accordingly.

Also, the modular interactive tiles can be put together in groups (i.e. tiles islands), and the groups of tiles may communicate with each other wireless (radio). For instance, a game may be running distributed on a group of tiles on the floor and a group of tiles on the wall, demanding the user to interact physically with both the floor and the wall.

Figure 1. Modular tiles assembled and used for hand or feet interaction.

Currently there are 10 music games and 15 non-music games for both physical and cognitive training. For documentation of patients' exercises and progress, it is possible to make radio connection between the tiles and a PC with a small radio (XBee) communication USB-key. The documentation software will show time and points on the PC monitor, and collect the data in a database. Hence, the patients can follow their points directly on the PC monitor, and the therapists/doctors can collect and view the data for each patient.

The modular interactive tiles were used as a test bed for the presented work, since the modular approach allows us to make the games scalable (e.g. adapt the size of the tiles platform). One can simply add more tiles and the game will still be running, but possibly at a higher difficulty level due to the larger size of the tiles platform.

In earlier experiments with the modular interactive tiles (e.g. for play, rehabilitation and to motivate people to exercise (Lund et al., 2005; Lund et al., 2008; Lund, 2009), the same game level was used for all players. The experiments did not look much into the difference between different players, but rather used programs that focus on being usable to as general group of players as possible. Some research has been done on classifying the players using a neural network and the results were promising (Derakhshan et al., 2006). In the present study, we focus on hardware adaptation, and how therapists may potentially exploit such adaptation possibilities in the daily rehabilitation practice (e.g. how they adjust levels by changing the physical set-up of the modular tiles).

## Experiments

The modular interactive tiles have been tested as playful physiotherapy, which is supposed to motivate patients to engage in and perform physical rehabilitation exercises, with special focus on elderly training. The modular interactive tiles were tested for an extensive period of time (5 years) in daily use in hospital rehabilitation units e.g. for cardiac patients (Lund, 2009). Also, the tiles were tested for performing physical rehabilitation of stroke patients both in hospital, rehabilitation centres and in their private home. In the test cases qualitative feedback indicate that the patients find the playful use of modular interactive tiles engaging and motivating for them to perform the rehabilitation. Also, test data suggest that some playful exercises on the tiles demand an average heart rate of 75% and 86% of the maximum heart rate (Lund, 2009). The modular interactive tiles have been used in the places and periods mentioned in Table 1.

There are many challenges to prevention and rehabilitation of elderly. For instance, fall incidence rates currently pose a serious health problem for older adults. In the United States, about 40% of the population age≥65 living at home will fall at least once each year, and the rates are much higher for persons aged >75 years and persons living in long-term care institutions (Rubinstein, 2006). The modular interactive tiles games and exercises enforce activities that combine physical training with sensory tasks and cognitive tasks. Based upon scientific findings with relation to elderly training, some of the games are designed to promote unpredictable, sudden movements, and the games allow a gradual increase of difficulty. The gradual increase of difficulty is provided in a very easy manner to the therapists and the elderly users who can simply change the difficulty level by changing the physical structure of the tiles construction, e.g. a smaller platform of tiles often provides an easier level than a larger platform of tiles for the same exercise.

### *Games*

A number of games were implemented for the therapists to use. An example is the "Color race" game, where patients have to chase 'their' color (i.e. one patient is red, another patient is blue, and so forth) which appear at random tiles. As soon as the patient hit a tile with the color on, then the color will turn off and appear on another tile, where the patient will move to hit the color. The game can be on time or on number of tiles hit (e.g. the patient who first hit 10 tiles with his/her color wins the game). Another example is the "Simon says" game. In the Simon Says game, initially a random tile lights up for one second, and the system waits for a response by the user. If the user presses the tile that lit up, the user proceeds to the next level, when two random tiles light up each for one second, one after another. The user then has to press the correct sequence of tiles that lit up. If the user succeeds, the user will progress to level three when three tiles will light up in a sequence, and the user has to press this sequence.

The game continues like this level after level (i.e. longer sequences have to be remembered) until the user makes an error.

Table 1. Use of the modular interactive tiles for rehabilitation.

| Place | Period | Patient group | Estimated number of patients |
|---|---|---|---|
| Sygehus Fyn Hospital | 2006-11 | Cardiac | >200 |
| Svendborg Municipality | 2007 | Home rehab | >10 |
| Svendborg Municipality | 2009-10 | Stroke | >20 |
| OUH Svendborg Hospital | 2009-11 | Stroke | >30 |
| Ringe Neurorehabilitation center | 2009-11 | Stroke | >60 |
| UH Hospital Kiel, Germany | 2010-11 | Bone marrow transplant | >20 |
| Neema Rehab Unit, Tanzania | 2009-11 | Physiotherapy | >30 |
| Odense Municipality | 2007-08 | Rehab | >30 |
| OUH HCA Children's Hospital | 2007-11 | Children therapy | >100 |

The tiles exercises address the challenges of elderly with relation to balancing, fall risk, muscle strength, reactivity, memory, attention, and concentration. There are numerous different exercises that each targets different challenges for the elderly and for specific patient groups, i.e. some exercises for cardiac patients, some exercises for stroke patients, some exercises for smoker's lung (COLD) patients, some exercises for private home rehabilitation, some exercises for brain training, etc.

For a specific patient group, the tiles exercises should be used in practices that match the individual aims of the therapist and patient. The tiles and exercises should allow set up in a flexible manner to target the individual patient needs and aims. Experiments with the therapeutic use of the modular tiles for stroke patients, smoker's lung (COLD) patients, cardiac patients and home rehabilitation patients is set up to try to verify if this is the case in the daily therapeutic practice, and the experiments are summarized below.

In 2009 we started a project with three departments of rehabilitation placed at three different hospitals in Denmark. The tiles have been part of these departments of rehabilitation from May 2009 and until now (July 2011). The new intelligent exercise-equipment is systematically used and assessed by therapists and patients connected to the three departments of rehabilitation.

The purpose of this study was to determine if our hypothesis regarding the high flexibility and easy adjustability of the system for the end-user stands. Therefore, we investigated and systemized how the tiles work as a tool in specific practices by gathering information about the users' opinions and experiences. Since we are studing a subject - the new pratice with the tiles - of which we only know roughly in advance what consists in, the appropriate research methodology for data collection is qualitative (Flick, 2009). In this study, we have been focusing on capturing both the patients' and the therapists' opinions and experiences. We have observed how the patients and therapists interact with each other and with the tiles in different training sessions. After each training session we have interviewed both the patients and the therapists and asked them questions in relating to an unstructured interview-guide and the just ended training session. We have collected data by video recording, taking notes, writing log books and by using a Dictaphone.

The target groups in this particular study have been physiotherapists and their patients who are cardiac, stroke and COLD patients. The tiles have been used for training individuals and groups of 3-4 patients with apoplexy or different heart diseases at the departments of rehabilitation at the three hospitals. The therapists have also used the exercise-tool for training groups of 9 patients at a time with chronic obstructive pulmonary disease (COLD) two times a week. For the study presented here, the exercise-equipment has been used by 9 therapists, of whom we have interviewed five.

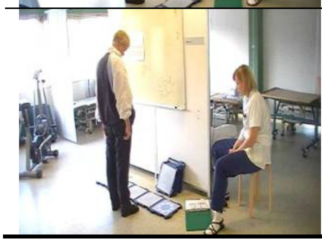
## Tests

We have investigated how the tiles have become part of the rehabilitation praxis by following the interaction between the physiotherapists and the patients during different training sessions. Through the analysis we have found some characteristic pattern of adjustments between the physiotherapists' knowledge, the patients' individual goals and the tiles. In this section we will start by introducing one empirical case where we describe a process of adjustments. This will lead us to an overview of the different exercises we have found.

### *An Empirical Case*

The physiotherapist Mette has organized a training session for her patient Marie who is a stroke patient. Marie has a high physical level but her balance and vision on the right side and her cognition has been reduced due to her illness. The purpose of this training session is to improve Marie's balance, her cognition and her field of vision. The tiles are according to Mette obvious to use in this case because this way Marie can train more than one of the three areas at the same time.

Table 2. Marie's training session with different physical arrangements of the modular tiles and exercises.

| | |
|---|---|
|  | **Exercise 1**<br><br>*Game:* Colorrace - 2 minute.<br>*Arrangement:* 8 tiles & formed as a "U".<br>*Times:* 3 times.<br>*Other items:* None. |
|  | **Exercise 2**<br><br>*Game:* Colorrace - 1 min.<br>*Arrangement:* 9 tiles & formed as a "U".<br>*Times:* 5 times.<br>*Other items:* The blackboard. |
|  | **Exercise 3**<br><br>*Game:* Simon Says.<br>*Arrangement:* 5 tiles & formed as a line.<br>*Times:* 5 times.<br>*Other items:* None. |

In the table above we have listed the different exercises in Marie's training program for this session (see Table 2).

In exercise 1, the 8 tiles have been organized as a "U" and the game "Colorrace - 1 minute" has been inserted. "Colorrace" is a game where the player has to step on the tiles that light up.

Mette has chosen this exercise because it gives Marie the opportunity to work with both her balance and her field of vision to the sides. First of all, by playing the game “Colorrace” Marie is forced to move her feet in a high tempo and when she is stepping on the tiles with her one foot she is balancing on the opposite leg. Secondly, because the tiles are arranged as a “U” Marie is forced to pay attention to the sides and not only in front of her.

The second exercise is based on Mette’s evaluation of Marie’s performance of exercise 1. During exercise 1, Mette observe how Marie’s balance and field of vision has improved. Marie is e.g. not overlooking the lightning tiles to the sides as she did at the last training session. The result of the evaluation is that Marie needs to be challenged more. In exercise 2 the tiles are being adjusted to the improvement of Marie’s physical development. Mette adjusts the tiles by adding one more tile to the arrangement. The expansion of the tiles forces Marie to work with her balance in a different way because she has to take more steps or have her legs more apart from each other than in exercise 1. To challenge Marie further, Mette introduces the element of counting. At first Mette is the one counting how many tiles Marie manage to step on for one minute and writing the result on the black board. But after a while, this task is put on Marie’s shoulder. Adding counting to the exercise is a way of making Marie speed up the tempo because she wants to do better. This is also a way of training Marie’s endurance and shared attention because she has to look at the tiles and step on them while she at the same time is counting. According to Mette, Marie is managing the tasks well.

The purpose of exercise 3, which is the last one in this session, is to slow the tempo down and let Marie train her memory. Mette adjusted the tiles to this goal by reducing the 9 tiles to 5 tiles and by exchanging the game “Colorrace” with the memory game “Simon Says”. With the game “Simon Says” Marie is forced to slow her tempo down because she has to pay attention to the lightning pattern on the tiles and memorize where the lightning tiles are placed.

Here we have presented a case where we have described how the tiles became part of a training session because the physiotherapist could adjust them to her patient’s individual needs. The way the tiles take part in different training session is through a specific adjustment to the patient’s individual needs. During our investigation we have found many different combinations of exercises on the tiles.

In three tables, we document the different exercises with the tiles used by the therapists for stroke patients, cardiac patients and COLD patients (Figure 2-5). For completeness, we include also the exercises from the home-rehabilitation project to make a more completely overview of the different exercises with the tiles (Figure 5). The results are found by the therapists, and expressed in the interviews.

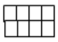
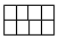
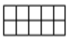
| Game | Arrangement | Treatment Area | Time | Participants | Result |
|---|---|---|---|---|---|
| Stepper (1 min.) |  | Fitness & endurance | 5 times (5 min.) | One patient | Improved the patient's mobility and condition. |
| Lunge (½ min.) |  | Balance, coordination & concentration | 6 times (3 min.) | One patient | Improved the patient's reaction. |
| Colorrace Floor (2 min.) |  | Fitness, endurance & concentration | 3 times (6 min.) | One patient | Improved the patient's physical level. |
| Colorrace Wall (1 min.) |  | Concentration, balance & coordination | 4 times (4 min.) | One patient | Improved the patient's competences to balance when the body weight is placed differently. |

Figure 2. Exercises for patients recovering from cardiac attack.

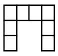
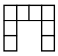
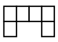
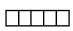
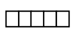
| Game | Arrangement | Treatment Area | Time | Participants | Result |
|---|---|---|---|---|---|
| Colorrace Floor (2 min.) |  | Balance & field of vision | Two times (4 min.) | One patient | Obtained more awareness to the left and the right side. |
| Colorrace Floor (1 min.) |  | Divided attention & field of vision | Five times (5 min.) | One patient | Improved the patient's capability to focus on more elements at one time. |
| Colorrace Floor (1 min.) |  | Balance | Five times (5 min.) | One patient | Improved the patient's balance on the right leg. |
| Colorrace Floor (1 min.) |  | Balance | Five times (5 min.) | One patient | Improved the patient's balance on the left leg. |
| Colorrace Floor (1 min.) |  | Balance & endurance | Five times (5 min.) | One patient | Improved the patient's balance and endurance. |
| Colorrace Floor (1 min.) |  | Balance & cognition | Five times (5 min.) | One patient | Improved the patient's ability to act on and understand instructions. |
| Colorrace Floor (1 min.) |  | Balance, cognition, endurance & divided attention | Three times (3 min.) | One patient & the therapist | Improved the patients speed and endurance. |
| Colorrace Floor (1 min.) |  | Balance & cognition | Six times (6 min.) | One patient | Improved the patient's mobility. |

Figure 3. Exercises for patients recovering from thrombosis.

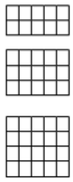
| Game | Arrangement | Treatment Area | Time | Participants | Result |
|---|---|---|---|---|---|
| Colorrace Floor<br><br>(2 min.) |  | Fitness, Condition, tempo & divided attention | From one to ten times.<br><br>(2-20 min.) | Two or more patients. Or a combination of patients, relatives and the therapist. | Improved the patient's physical and mental condition because the patients are being physical active while they are having fun. This combination can make the patient forget about their fear for exercising due to their illness. |

Figure 4. Exercises for patients with chronic obstructive pulmonary disease (COLD).

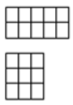
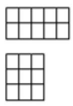
| Game | Arrangement | Treatment Area | Time | Participants | Result |
|---|---|---|---|---|---|
| Colorrace Floor<br><br>(2 min.) |  | Endurance & balance | 3 times<br><br>(6 min.) | One patient | Improve the patient's balance and physical level in their own environment. |
| Colorrace Floor<br><br>(1 min.) |  | Cognition & endurance | 5 times<br><br>(5 min.) | One patient | Improve the patient's mobility. |

Figure 5. Home-exercises for discharged patients.

Figure 6 shows an example of how the therapists used the tiles in training sessions where exercises on the tiles have been included in order for the patients and the therapist to reach their goal. As an exercise-equipment, the modular tiles are used by the therapists in training sessions in a combination with other exercises and equipment.

The list of exercises shows that the tiles are being adjusted to the patients' need when they are part of the rehabilitation praxis. The different parameters such as: the amount of tiles, the arrangement of the tiles, the games and the amount of time are parameters which the physiotherapist can fine-tune and thereby make them to some useful tools for their patients.

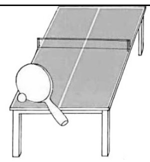
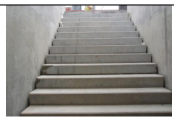
| Game | Arrangement | Treatment Area | Time | Participants | Result |
|---|---|---|---|---|---|
| Colorrace Floor<br>(1 min.) | | Balance, cognition, endurance & divided attention | Five times<br>(5 min.) | A patient who has a high physical level but damages on the cognition and balance due to a stroke. | Improved the patient's ability to act on and understand instructions.<br>Speed and endurance |
| Colorrace Floor<br>(2 min.) | | | Three times<br>(6 min.) | | |
| Step<br>(1½ min.) |  | Fitness & balance | One time<br>(1½ min.) | | |
| Table tennis |  | Cognition | One time<br>(5 min.) | | |
| Walk the stairs<br>(Down & Up) |  | Fitness | One time<br>(6 min.) | | |

Figure 6. A training session with focus on the patient's fitness, cognition and balance.

In interviews with the therapists, they also expressed the need for rearrangement and adjustment of exercise equipment to the individual stroke patients:

- "It is not more complicated to work with the tiles compared to other exercise-tools we use. We are used to re-arrange the set up all the time because we have to vary the exercises."
- "It is possible to adjust the tiles to the specific patient by re-arranging and shaping the tiles in different ways. This possibly is a necessity for the exercise-tool to be part of the equipment in the physiotherapy."
- "It is possible to work on more components, such as e.g. endurance, balance, view, memory and concentration, at the same time."
- "It is possible to evaluate the improvement on the patients' physical and mental level while they are interacting with the tiles."

Also, the interviews along with previous studies (Lund, 2009) suggest that most patients find exercising on the modular tiles motivational, since it is fun to compete against yourself and others.

## Related Work and Discussion

There are many challenges to prevention and rehabilitation of elderly. For instance, fall incidence rates currently pose a serious health problem for older adults. In the United States, about 40% of the population age≥65 living at home will fall at least once each year, and the rates are much higher for persons aged >75 years and persons living in long-term care institutions (Rubinstein, 2006).

Decreased balance is attributable to an age-related decline in multiple physiological systems that contributes to decreased muscle flexibility and strength, reduced central processing of sensory information, and slowed motor responses (American Geriatrics Society, British Geriatrics Society and American Academy of Orthopedic Surgeon Panel on Falls Prevention, 2001). In addition to an increased risk of falls, diminished balance and mobility may limit activities of daily living or participation in leisure-time activities. Accordingly, it is essential that balance exercises be incorporated into the physical activity programs of older adults. Indeed, the Panel on Prevention of Falls in Older Persons of American Geriatrics Society and British Geriatrics Society concludes: "Because a large body of evidence supports the recommendation that exercise, in the form of resistance (strength) training and balance, gait, and coordination training, is effective in reducing falls, the panel concluded that exercise, in the form of strength training and balance, gait, and coordination training, should be included as part of a multifactorial or multicomponent intervention to prevent falls in older persons and may be considered as a single intervention." (Panel on Prevention of Falls in Older Persons, American Geriatrics Society and British Geriatrics Society, 2011, pp. 151).

Research shows that only single-task activities fail to place the client in an environmental condition similar to that experienced prior to and during a fall (Silsupadol, Shumway-Cook, Lugade, van Donkelaar, Chou, Mayr & Woollacott, 2009). Hence, an exercise program should feature concurrent performance of balance exercises and additional tasks. For example, in addition to performing a physical balancing exercise, the person may simultaneously be asked to complete a cognitive task, or the dual-component training may involve combining a balance exercise with another form of physical activity, so that the multi-task balance training more closely replicates the activities of daily living in which a client's balance performance is most likely to be challenged by a disturbance. Indeed, the literature shows that an integrated exercise-training approach has been found to be effective (de Bruin & Murer, 2007). Also, researchers find that "regardless of which techniques are utilized, altering the sensory cues available to a client is an important consideration when preparing the overall balance-training program", and that "in addition to gradually increasing the difficulty of a balance exercise, it is paramount to continuously seek novel and fun balance exercises for clients." (Dalleck, 2010).

The modular interactive tiles games therefore enforce activities that combine physical training with sensory tasks and cognitive tasks. Some of the games are consequently designed to promote unpredictable, sudden movements, and the games allow a gradual increase of difficulty.

Related to the use of technology for elderly training, the following evidence of effect can be mentioned. Nitz., Kuys, Isles & Fu (2009) found that utilizing interactive video games may be an effective strategy to employ with designing balance activities for elderly, and progressively incorporating interactive video games into training can increase motivation and improve balance performance (Betker, Szturm, Moussavi & Nett, 2006).

Sveistrup, Thornton, Bryanton, McComas, Marshall, Finestone, McCormick, McLean, Brien, Lajoie & Bisson (2004) showed that the impact of virtual reality exercise participation of different groups ranged from improvements in clinical measures of functional balance and mobility, time on task, as well as participant and care provider perceptions of enjoyment, independence and confidence. It suggests that even simple applications of virtual reality have significant impacts on physical and psychosocial variables.

Sveistrup (2004) finds that technology can be of crucial importance when it integrates the means to modulate the level of difficulty, since improving the functional abilities of patients is commonly achieved by using tasks of increasing difficulty in combination with physical and/or verbal guidance of the patient's movements or actions, and concludes that the ability to change the virtual environment relatively easily, to grade task difficulty and to adapt it according to the patient's capabilities are important advantages of VR, since these features are essential to cognitive and motor remediation (Rizzo, Buckwalkter & Neumann, 1999). The modular interactive tiles were designed to easily allow such adaptation to the individual patient’s capabilities, and the training sessions show how the therapists are taking full advantage of this opportunity with the tiles.

Shigematsu, Okura, Nakagaichi, Tanaka, Sakai, Kitazumi & Rantanen (2008) made important findings with the square stepping exercises. Square stepping exercise is performed on a thin mat (100*250 cm) that is partitioned into 40 squares (25 cm each, compared to the 30cm of the tiles). Patients perform different walking exercises of gradually higher difficulty level on the squares, including corrective steps in certain directions, as indicated by the instructor/therapist. Indeed, there is a whole scheme of step patterns going from elementary levels over intermediate levels to advanced levels. In all cases, the instructor/therapist needs to instruct the patient(s) on how to perform these step patterns on the thin mat.

Shigematsu et al. made numerous larger studies with control groups to investigate the effect of such square stepping exercises. In one study, they had a group of elderly to perform the square stepping exercises and a control group of elderly to perform normal walking. The statistical tests showed that the functional fitness of the lower extremities (one of the most common risk factors for falls) was improved to a greater extent in the square stepping exercise group than in the walking group. Furthermore, the perceived health status was improved in the square stepping exercise group. Hence, they conclude that the study “provides new evidence that square stepping exercise is a more useful exercise program than regular walking for older adults; thus, it may serve as a new form of exercise to prevent falls” (Shigematsu et al., 2008, p. 80-81).

This supports the therapeutic findings with the modular interactive tiles. As an important addition to the square stepping exercises, the tiles are by themselves lighting up in the pattern needed to be performed by the patient, and the tiles are providing immediate feedback to the patient on the correct/incorrect performance. Hence, the tiles are automatically instructing the patient and automatically giving feedback on the performance. This quality of the tiles is labour saving, it ensures correct movements, and it motivates patients. Further, the features of the modular interactive tiles allow for a combination of physical and cognitive training of elderly.

## Conclusion

The observations of therapeutic practices with the modular interactive tiles for a variety of patient groups (cardiac patients, stroke patients and COLD patients) suggest that therapists do indeed take advantage of the flexibility that the modular system provides, as was the hypothesized reason for utilizing inspiration from modern artificial intelligence and modular robotics in the design of the system. The therapists create the activities for the patients modulating exercises and levels by changing the physical set-ups with the modular tiles system. This is indeed important in the daily therapeutic practice, which is characterized by the treatment of patients with many different, individual needs. A system should therefore provide flexibility to adjust to treatment area, activity, patient level, and patient fatigue. The observations of therapeutic use in this paper suggest that the modularity gained from the inspiration from modular robotics is one solution to provide such flexibility. At the same time, the modularity provides an ease of use, possibility of use anywhere, and robustness through distributed processing.

Having used the qualitative research methodology (Flick, 2009) in the present work, we were able to obtain knowledge on the therapeutic practice with the novel tool. Future work should focus also on quantitative research providing knowledge on the potential effect, though we acknowledge that such studies are complicated when dealing with patients with highly individual differences, such as is the case with stroke patients.

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# Serious Games – Theory and Reality

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## Abstract

The following paper proposes a new two-step framework for the analysis of serious games, one that first looks at their use for personal and/or professional contexts. It then looks at the challenges serious game developers face in today's entertainment driven environment. It suggests that societal and market challenges must be resolved to allow for the creation of serious games that can successfully compete for an audience's attention and examine two prototype games with an appropriate mix of content and form but face several hurdles to succeed as full featured commercial products. In conclusion it suggests ways for serious games overcome these hurdles.

KEYOWORDS: EDUCATION, SERIOUS GAMES, FRAMEWORK, MONETIZATION, PRODUCTION OF GAMES

## Introduction

During the last decade nearly every game researcher has tried to write something about serious games or serious gaming. Some cast a wide net (Michael & Chen, 2006; Ganguin, 2010; Stapleton, 2004; etc.). Some focused specifically on pedagogy (Gee, 2005 and 2007a/b; Prensky, 2001; Becker, 2007; Wagner, 2009, p. 4f.). Others have tried to work out frameworks and taxonomies (Sawyer & Smith's, 2008; Smith, 2009). Other researchers have defined serious games from within their own domain of expertise such as health and rehabilitation (Wiemeyer, 2010; Göbel, Hardy, Steinmetz, Cha & El Saddik, 2011). Sometimes this leads to a very narrow understanding of what a serious game is. For historians, serious games are ones that provide authentic recreations of past events while economists define only accurate trade simulations as serious games. Even more research can be found in several edited volumes (Ritterfeld, Cody & Vorderer, 2009; Gibson, Aldrich & Prensky, 2007; Annetta, 2008; Siek & Herzog, 2009; etc.) and special issues on reviewed journals (mostly educational journals with a focus on eLearning, health or pedagogy; for an overview see Hoblitz, 2011).

There are almost as many definitions of what a serious game is as there are publications about them and a long list of such definitions can be found on the Serious Game Initiative Website (http://www.seriousgames.org/). That said, most of these definition have one thing in common: They exclude some part of what the other definitions include.

The following remarkable quote from Rusel De Maria (2007, p. 119) demonstrates the depth and breadth of the territory and illustrates the challenge, and perhaps the futility, of trying to capture a serious games definition:

> "A thorough review of the history of video games reveals that video games have contained a lot of very positive information and ideas. When I analyzed games from a historical perspective, I found more than fifty different experiential and inspirational aspects of video games, which included experience with very practical skills in areas like finances, basic economics, running a business, interior design, landscaping, city planning, and investment. I noted several skills like leadership, cooperative work/play, and relationship building, as well as responsibility to others. Concepts like fairness and justice, patience and restraint are common in many games, as is the idea that actions have consequences. To a lesser degree, history, geography, and other traditional educational subjects were thought, though more experientially than factually. Finally, conceptual skills like patterns recognition, 3D navigation, programming skills, mapping and visualization, creativity, and personal accomplishment can be enhanced by playing video games." (De Maria, 2007, p. 119)

In this paper we want, to describe our view on serious games and gaming (but not as *one* definition) and propose a new framework (beyond the existing approaches on a taxonomy of serious games/ gaming done by Sawyer & Smith (2008) or Ratan & Ritterfeld (2009)) that suggests that serious games (or even serious gaming) should be described more specifically in the context that they are used (e.g. Rego, Moreira & Reis, 2010). Some general terms/ genres identifying "types" of serious games have emerged, such as "games for change" but without a clear consensus or specific research base. The framework we propose is based on a market analysis performed at the University of Paderborn. The framework we suggest differs from former taxonomies because we used a two-step model instead of a squared matrix divided into fields and markets (Sawyer & Smith, 2008, p. 29) or simple market research heuristics.

After we describe the framework we will illustrate its use by discussing two short examples of serious game projects that were developed at the University of Paderborn ("Politworld" an educational game for schools and "Urban Life 2060" as Online MMOG designed to foster social and ecological sensibilities). These examples will demonstrate that most "serious games" projects do have serious challenges in the economics of game production and commercial markets. In our conclusions we will call for more research efforts within our emerging framework to better define and apply it and for more support from the German Federal System (which is calling for the creation of more serious games) to help developers surmount the market challenges they face in making serious games viable products in a viable market.

## Theory: A new Two-Step Framework

After reviewing the serious games literature we strongly believe that there is no "one size fits all" definition for serious games. This is not surprising because there is not one for digital games either (Egenfeldt-Nielsen, Heide Smith & Pajares Tosca, 2008). Points of debate that arise in attempting to define digital games include arguments on the need for a win condition or even a competition, the level of narrative content and the type the games are played (e.g. Salen & Zimmerman, 2004; Juul, 2005; Egenfeldt-Nielsen et al., 2008). Clearly World of Warcraft and Pong are radically different digital games even if they have some formal elements in common (which covers up all kinds of games as a term, Kerr, 2006). The variation and complexity increases when you consider that versions of the same game on a tablet and a next gen console may provide a different experience, have a different user interface and perspective and might have totally different content, playtime, solutions even if they have the same title or franchise (e.g. Tomb Raider on PC and Nintendo DS).

Therefore, for serious games we suggest a new analytical framework that can be split into two parts (or even two steps). First we create a set of partial definitions for starting to think about the technologies, content and uses of a given game

- *Serious game-applications*, which are the kind of games developed only for one special purpose. The aim of these serious game-applications is mostly education in a specific content area (such as games for health, military training, social change).
- *Serious game-technologies*, which can be either technologies developed for other games and reused in different action fields or existing gaming technologies that are altered to fit into new tasks (such as architecture, hardware or engines).
- *Serious game-content*, which means the usage of narrative structures in games as a medium to transport complex messages. This is also about the mixture of implicit and explicit content (such as political games, social change games etc.).
- *Serious game-simulations*, which are the best way to use existing game mechanics to explore new fields. These simulations are often what people out of the field associate with the term serious games (such as economic simulations, flight simulations, military simulation).

This first step does not cover a second important aspect: the specific player audience of the games themselves. After looking in-depth at 30 different serious games we have found there is a clear line to be drawn between personal and professional usage. We think that the existing examples clearly give proof that their individual orientation within the market gives you hints about the options to successfully produce these games so that they will be commercial successes.

In the consumer market (personal usage) most successful examples of serious games tend to fall into wellness or self-improvement categories on consoles (Wii Fit, EAs Active etc.) or handheld devices (e.g. Dr. Kawashima). Some complex trade simulations or games about scientific issues can be commercially successful in both consumer and practitioner markets. But most of serious games titles fail commercially because the publishers do not spend enough money on the development and/or marketing. For example, the management simulation CAPS, published in 2000, failed even though the technical content was of the highest level. The graphics were ugly, the business model relied heavily on the purchase of multiple modules and the marketing was below par. At this time in the history of digital games, most people have some experience with them, as either as players or as spectators. This has raised the audience expectations in terms of look, feel and depth of content and interactivity.

This can clearly be shown if you take a look at the market for trade simulations. To be successful in that field now on the one hand a game needs a narrative scenario (e.g. history or fantasy) and on the other hand too much “real world” detail in the mechanics of gameplay can be a detriment. In other words: The player does not want to learn how to fill a balance sheet nor to study economics to understand the game.

In the professional market (games not developed for “commercial off the shelf” sales) we observe different opportunities for serious games and serious gaming, and not only in applications but also in tools and the other segments of our framework’s top level. For example there is growth in the usage of commercial entertainment development tools (such as a game engine like “Cryengine 3”) to create the architecture in a serious game. Military and medical training delivered via a game fit our category of serious game-simulations. There are numerous examples for job training via serious games, such as the Cold Stone Creamery game created by Persuasive Games. In general serious games seem to be appropriate for training on the job.

Beyond the first level of the framework (with the four identified segments above), we found that we could make more precise differentiations based on purpose (not only personal or professional usage). We found that most explicit serious games are related to learning or training (in general education). Implicit serious games have a broader range from entertainment up to new approaches like gamification. We also could clearly see that these purposes are linked to a describable background (inner circuit of Figure 1). At that level of research (based on the analyzed games/ technologies) we think that for personal purposes wellness and self-improvement (summarized in the outer circuit with the keywords edutainment, fitness and recreation) counts most, education (meaning training and learning) less. For professional reasons there are questions in science and engineering, society (like problem solving via simulations) and the big field of professional training and learning. In combination of steps one (the field segmentation) and two (the positioning between well differentiated personal or professional purposes and motivations) we think it is distinctly clearer what kind of serious games or gaming is meant.

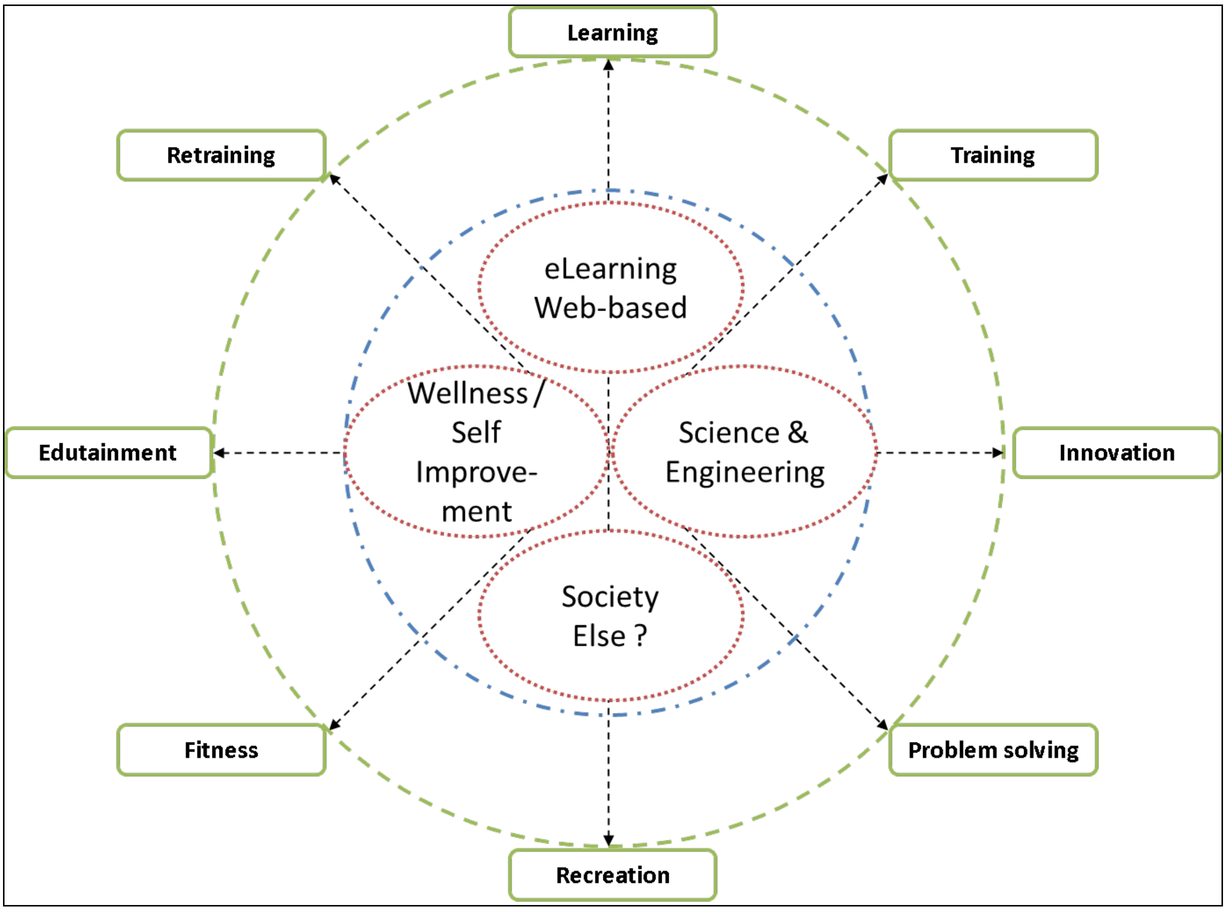


Figure 1. Separation of serious games into personal and professional usage.

Currently we do not have all the necessary market data to judge if all the approaches that map to our model are commercially successful (in general estimations are between 2-3% (5-7% depending on the meaning of technology – e.g. engines) of the world market share which is estimated up to 55 bn US-$ by DFC Intelligence). We do know from many exploratory interviews with serious game developers that the classic triangle problem of time, quality and budget is an especially acute one in serious games business. To succeed in their vision, they must have the quality and depth of commercial titles but serious game projects are rarely afforded anywhere near the development resources (in all senses of the word) or the customer/ client base of commercial titles. The one exception to this rule is serious game developers who specialize in work for the military. Serious game developers that work with the military generally have a much larger set of resources provided to them due to the life or death nature of the training and education they must deliver.

Our own work at University of Paderborn's Gameslab developing two different serious games projects is illustrative of the challenges professional serious games developers and products face (Politworld and Urban Life 2060).

## Serious Games Reality

The reality of the production side of serious games is somewhat bittersweet. While it is greatly rewarding for the developers to create a serious game-application or game-simulation there is likely that the title will struggle to break even financially especially if it is not produced specifically for a client. Are people – consumers or business customers – really willing to pay for niche products or solutions? It is often said that "games are made by gamers for gamers", indicating that the producers and consumers are the same. If the same can be said about serious games, how will they break out of that narrow niche to one that can more broadly support them? Can they find a place in the spectrum that includes with pure entertaining games, web-based learning or special technological solutions?

The only way to begin to get an understanding of these questions and possible answers to them was to develop serious games on our own. Doing this has brought us closer to an insider perspective and has begun to inform our initial taxonomy model. At that time of the writing of this paper we have created prototypes of two games that are pedagogically successful by evaluation and have the market production values the market expects, and we know what financial resources exist to bring them to market. Like Kelly, Howell, Glinert, Loring, Swain, Burrowbridge and Roper (2007, p. 45ff.) we will describe the prototypes and their challenges, but in lesser detail. For us it is more important to show that with these two examples we have done work in different fields (in a professional political education scenario and in a personal scenario) of our suggested new two-step framework.

### *Politworld as Educative Classroom Experience*

Politworld is a game created for schoolchildren aged 13 to 15 (German school classes 8 or 9) to teach them about political systems (or to be more precisely the way political systems impact societies). We created a turn-based game in which the players first have to choose a political system (dictatorship, democracy or communism). Then they get tasks to accomplish within a country using with their chosen political system. But they must do more than just manage their own nation. They game takes place in a virtual world with five continents and on each continent there are five nations. This allows an entire class of students to play together (up to 25). They are allowed to build alliances and they can spend their resources on different aspects (e.g. education, energy, pollution etc.) of their country's infrastructure as well. The players have a break after every round to debrief certain aspects with the teacher (who is the godfather/ dungeon master in the game). In our framework, Politworld is a serious game-application in the professional education area, developed for training and learning purposes.

Politworld's play style provides a more blended learning approach for the students than other political games. The players have to discuss aspects of nation building that are written down into a contract, which is then integrated into the game. These contracts are not procedurally scripted but instead they are balanced by keywords. Because these contracts are unique to a given play session, every Politworld game is different. As the game progresses the players get additional tasks like saving the environment or something else. Sometimes they get tasks they have to solve cooperatively with other players and their resources. Each player earns a certain amount of action points and virtual money based on his choices and his success (or lack thereof) in the development of the virtual world. Politworld's concept is based on German curricula for political education in schools. It is played on basic netbooks and with a slightly more powerful server. The teacher gets a guiding script and instructions on how to alter the game. During every round there is a feedback system showing the players not only the results of their individual actions but also the results of new alliances etc.

Politworld is now a fully working prototype created by nearly 60 students (part time) in nine months. The game prototype was created by a partnership between the University of Paderborn and the German federal institution "Bundeszentrale für politische Bildung". After finishing the prototype we moved to schools and play-tested the game. The students and teachers were enthusiastic about it and asked us for a finished game to keep. After a television report about the game, many schools asked for a free copy to use in their classes. None of them were willing to pay but all of them wanted to use our work. This clearly highlights the dilemma. To complete the game for the education market we would need at least another nine months with the same manpower. If we had developed a complete version of the game under typical market circumstances the game would have cost about around one million euros and could only be marketed in combination with the hardware resources of a package of netbooks or to a small number of schools with the appropriate lab set ups. We did ask schools if they would buy a whole system, including netbooks that could be used for other purposes as well, for 10.000 Euros for a class set. The answer was always no, even if the teachers were very interested. So even in the large K-12 education market this product wouldn't have a chance to earn enough money to even pay back our comparatively low development costs (let alone the actual market valuation of the resources we used to build the prototype plus the costs to finish it) much less make a profit.

### *Urban Life 2060*

Urban Life 2060 is still under development at the time of the writing of this paper (August 2011) but in contrast to the first example it is being created for the consumer market. The game is a browser-based, massively multiplayer, role-playing game (MMORPG). It is a "free-to-play" game, in which some revenue is generated by consumer purchases of a combination of additional time, content, virtual goods or bonus points in the game. A second revenue stream is provided by advertising sold as part of the web site of the game. The business model is the new state-of-the-art of the whole gaming industry. In 2010 nearly 20 bn US-$ were created by online games and free-to-play was one of the major online game business models.

For that reason the Gameslab of the University of Paderborn worked closely together with one of the new industry leaders, the browser game publisher Bigpoint, to produce Urban Life. Besides their financial support we also benefited from their knowledge about monetization in the free-to-play market (especially in virtual item sales). They get an opportunity to watch the development of, and experiment with, a "free-to-pay" game that is developed to allow only for non-crucial items to be purchased. Our goal in doing this, which is a modification of the successful commercial model, was to lower the barrier to success for the players.

In Urban Life 2060 the player gets to experience to life in a futuristic town. The player makes decisions and engages in actions to solve problems given by so called "task givers". He earns achievements and other rewards in virtual money, resources or activity points. In most browser games the player keeps these and can use them to his own personal advantage. But in Urban

Life 2060 players always have to decide on if, and by how much, they want to spend of their success on further development of the town to the benefit of their neighbors. In other words the player decides how much virtual tax he is willing to spend to influence the development of his town. This is one of several serious game aspects to the game.

The second is the overall scenario of the game. Urban Life 2060 invites the player into a world where brand new, high-tech town in the Antarctic is growing. In the creation of this town we integrated ideas based on real technological (engineering, architecture) and sociological (social networks, economic systems) research. We tried to prove that it is possible to give players information about the options for their future during the gameplay. Where Politworld was a networked, classroom-based game limited to 25 players, Urban Life 2060's online nature allows the town to grow in sizes of up to thousands of players, and to spawn as many towns as the players wanted to populate.

This potential for growth gives us the third serious aspect. At the point that Urban Life 2060 has thousands of users (or more) it becomes a population simulation as well. Because of different collective behavior the city development (and the game experience) no longer just belongs to the individual player but also to the collective.

Urban Life 2060 was developed by a student team of nearly 80 (the average size at any given time during the academic year was 65) over 9 months. Since as of this writing it is not yet complete, we cannot talk about market performance. But for us it is very clear that if it wasn´t a university project, it would be difficult to find a commercial company that would try to develop it, due to the experimental variation on the "free-to-Play" monetization model. Even though the purchasable items in the game are not directly required for success there have been some games that have been commercially viable on this model and hopefully that will give our game a chance to enter the market.

To put Urban Life 2060 into our new two-step framework we see it as a serious game-simulation developed for personal purposes motivated by an achievement system for recreation reasons. From our perspective the modified free-to-play model might have a better chance in the market than Politworld, which would rely on a school purchase (likely one that would have to be subsidized) model. The free-to-play business model seems to be appropriate for other kinds of serious games – even more than the typical commercial of the shelf product.

Both examples, one from the Professional side (Politworld) the other from the Personal side (Urban Life 2060), have shown clearly how complex the development of this content is and how much research is necessary to have rich content (not even mentioning the commercial quality presentation layer as well). So in comparison to the purely commercial gaming market our research, interviews and prototype development experiences tell us that somehow serious games-simulations (Urban Life 2060) or serious game-applications (Politworld) might need even more money to develop than the traditional serious games if they really want to fulfill their promise. This leads to a few interesting conclusions.

## Discussion and Conclusions

We believe that new two-step framework we have presented is a functional beginning for a model that combines aspects of a taxonomy (not unlike Sawyer & Smith, 2008) and a segmentation via markets and serious games components that might explain more accurately what we think serious games are. The framework allows researchers in the future to create more in depth research on segments of serious games and gaming. But there is still the question, what use is the research unless it will lead to commercial success and/ or even better games? For us the question is: Do serious games really matter in that sense?

From the practical side, our project development reality check showed us that even if you are willing to create a good serious game you need a lot of money or at least manpower. In comparison to e-learning or web-based learning tools, the development of full-featured serious game is much more complex and requires more time. So will the market for serious games be big enough to earn the money needed to compete with entertainment games? For serious games to really matter some major changes have to be made. Such games need a higher level of production so that the majority of them could be commercially successful. Currently they do need more resources as well as more research.

Additionally, if games like Urban Life 2060 want to succeed they need to have monetization options beyond an upfront purchase price for the game. If there will be none of these, there will be no rich content serious games in the market because the developer and/ or publisher will not create them. And even then it will always be a question in a hypercompetitive market if they will take risks with these games.

Personal purpose serious games developers could try to enter the free-to-play market. Most of these type of commercial games are launched by the publishers without a full feature set. They gauge the market adoption of a given game during its first few weeks and only fully develop the game if the initial launch meets its financial numbers in the first few weeks. Professional serious games only have a chance if they have been produced to order by a client funding the development or if they have strong support from the government especially in the case of educational games.

Lastly, serious games can have a bright and shiny future as long as the political and educational systems that express interest in them go beyond lip service to accept games as medium for teaching and invest in the future of modern educational systems. Especially in Germany, the educational institutions' interest in serious games grows but the stakeholders fear the costs to bring them to the schools or the public. Further research has to be done on other European and the North American markets on the question of who is really interested in serious games (besides the government)?

Despite all these critical issues we think the serious games will matter more and more, and their potential (referring to their positioning in the new framework) can be fully reached if they can be developed without the financial restrictions they currently labor under.

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# Do Children Choose to Play Active Video Games when Given the Choice Between Seated and Ambulatory Video Game Play? A Study of Children's Play Choice.

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## Abstract

**Background:** The development of active gaming offers a choice for children to be physically active whilst participating in an activity that is enjoyable and highly valued. Children expend energy when they play activity enhanced video games, yet little is known about their choice when given active alternatives over seated play.

**Methods:** This study examined (i) choice of play between a seated video game option or the same game played ambulatory; (ii) consistency in play choice with sustained play. Play behavior was recorded from postural monitoring and observation. Repeated measures analyses of variance were used to determine differences in total time, percentage of time and consistency of choice in each condition.

**Results:** Play choice was consistent over the four sessions with 76%, 23% of the available time spent seated and ambulatory, respectively. Follow up analysis indicated that the time spent playing in each condition was constant across all four video game sessions.

**Conclusions:** These preliminary findings demonstrate that when given free-choice children will predominantly play video games seated. The advancement of active video gaming as an active alternative is dependent on future investigations into whether these innovative technologies offer enough entertainment value to sustain long-term adherence.

KEYWORDS: VIDEO GAMING, CHILDREN, PLAY CHOICE, TREADMILL, SEDENTARY BEHAVIOR

## Background

Until recently video game play was a sedentary activity, which has been implicated as a possible contributing factor for the increase in childhood obesity (Vandewater, Shim & Caplovits, 2004). However, technological advances in video gaming and a demand for active entertainment have resulted in the development of exergames, which couple an interactive video game with physical activity. Although not surprising, evidence has shown that energy is expended when children play activity enhanced video games or exergames (Graf, Pratt, Hester & Short, 2009; Lanningham-Foster, Jensen, Foster, Redmond, Walker, Heinz & Levine, 2006; Mellecker & McManus, 2008). However, most of these investigations have concentrated on exergame systems that provide a single gaming format, which do not offer sophisticated story lines, graphics, graduated levels of play and problem solving mechanisms available with the many seated video game alternatives. These are some of the underlying attributes that have been shown to be linked to the attraction to video gaming (Raney, Smith & Baker, 2006). However, it is unclear whether exergaming systems will sustain long term entertainment value or adherence without the additional applications and experiences common in seated alternatives.

To better understand the complexities of video game play that include an activity component an adapted treadmill fitted with a commercial gaming system was designed. Initial investigations suggest that it is well accepted and children perceive it to be an activity they like (Mellecker, McManus, Lanningham-Foster & Levine, 2009). This ambulatory media system was developed for use with children and to enable the user to use a variety of gaming consoles and to employ personal choice of video game play, which has been shown in children to be a motivator for engagement in physical activity (Dishman, Motl, Saunders, Felton, Ward, Dowda & Pate, 2005). Epstein and colleagues (2007) propose that the opportunity to play video games with a controller when exercising may be more valued and affect the choice to be active due to the similarities with conventional sedentary video game play. However, a review of interventions using video game technology as an active alternative suggests that active games may not be valued enough for play to be adhered to for a significant length of time (Foley & Maddison, 2010).

The main objective of this preliminary study was to examine children's choice when give the option to play video games seated or the same games played ambulatory, the consistency of this choice and the relationship between seated and ambulatory play choice. To achieve this we asked children to choose between playing X-BOX 360™ games seated or the same X-BOX 360™ games played walking on a treadmill. After an initial habituation session, the children were asked to attend four one hour free-choice play sessions during which we assessed sedentary and active choice. Specifically, we hypothesized that (i) when children are given free-choice to play seated video games or the same games played whilst ambulatory they will play the active option more than the seated option; (ii) play choice (time played and intensity) will be consistent across the four sessions.

## Methods

### *Subjects*

Previous data has shown that video game usage is higher among children 8-14 years of age (Roberts, Foehr & Rideout, 2005) and to ensure that the cognitive and motor skill requirements would be sufficient to walk and game safely we recruited 30 children with the following characteristics, 20 boys, 10 girls; age range 9-13y. The children were recruited from six Hong

Kong international primary schools located in high SES catchment areas. Invitations to participate in the study were distributed via electronic newsletters. The research protocols were reviewed and approved by the institutional review board for human ethics and informed written consent was obtained from the parents of the participants. No physical limitations or chronic diseases were reported for any of the 30 children. The ethnic distribution of the children in this study was 16 (43%) Asian, 13 (53%) Caucasian and one (3%) other. All of the children in this study reported previous experience playing console based video games and personal ownership of one or more video gaming systems.

### *Video Gaming*

Each child played in an individualized partitioned cubicle containing the sedentary and ambulatory video gaming options. The sedentary video game option, referred to as seated gaming, comprised of an arm-chair and a small table with a TV screen connected to an X-BOX 360™ interactive gaming system. The ambulatory gaming option comprised of the same X-BOX 360™ interactive gaming system wired via an adaptor to an LCD screen fixed to an adapted treadmill (see Figure 1). The interactive gaming system was developed using a foldable motorized treadmill (Kettler XF-0082N), which measures W126 × L55 × H120 cm. This small treadmill was specifically designed for children and for in-home use, primarily for walking. It is equipped with a small 0.75 HP DE motor, which has a modest maximum speed (range of speed from 1.0 to 8.0 $km.h^{-1}$). The treadmill was manufactured with safety handrails on both sides and an emergency safety switch that is clipped to the child when the machine is in use. Several adaptations were made to the treadmill to comply with recommended ergonomic standards during computer use (Straker, Pollock, Burgess-Limerick, Skoss & Coleman, 2008). The control panel was repositioned on a steel pole and bolted to the left and right stand frames. A frame was fitted onto the treadmill upon which a keyboard/console control desk and flat screen LCD television monitor (Philips model 150T4) were mounted. The height and angle of the LCD monitor and control desk were made fully adjustable to accommodate individual differences in height (detailed description of the design can be found in a previous publication Mellecker et al., 2009).

Twenty-two X-BOX 360™ games rated 'Everyone' by the Entertainment Software Rating Board, were available to play in both the seated gaming and ambulatory gaming conditions. The children were free to choose the games of their liking and change games at any time during the 1 hour session. Some of the more popular choices included Soccer Fifa 09, Kung Fu Panda, BEE Movie, Burnout Paradise and Beijing 2008. For privacy and to ensure that participants were not distracted or gaming choices were not influenced by other players, the children played all games with headphones. In addition, only one participant occupied and played in a cubicle at any given time.

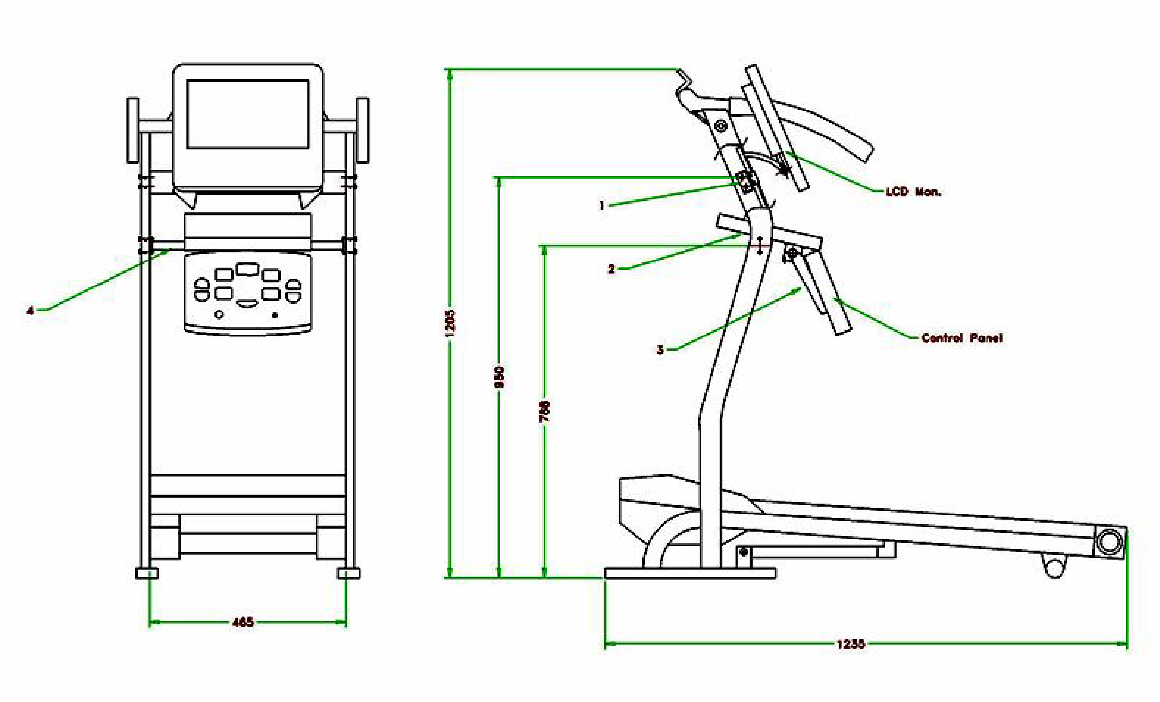


Figure 1. Schematic illustrations of the interactive gaming system.

### *Procedures*

The children were asked to visit the laboratory on five separate occasions. During the first visit, the children completed baseline assessment of anthropometric variables. The children were then introduced to their personal partitioned cubicle and the two video game options and given the opportunity to habituate to treadmill walking and X-BOX 360™ games. The subsequent four sessions (referred to as free-choice gaming sessions 1 to 4) involved the children playing video games freely for 60 minutes in their cubicle, switching between seated and active options at their leisure. Prior to beginning each of these sessions each child completed a 6-minute individualized calibration of the Physical Activity Monitoring System (PAMS) used to assess posture (seated or standing).

### *Anthropometric Measures*

Height was measured barefoot to the nearest 0.1 cm using a wall-mounted stadiometer (Invicta 2007246, Leicester, UK). Body mass was measured barefoot and in lightweight clothing to the nearest 0.1Kg using electronic scales (Tanita TBF-410, Japan). BMI was calculated from body mass and height.

### *Postural Monitoring*

We used the Physical Activity Monitoring System, previously validated in children (Lanningham-Foster, Jensen, McCrady, Nysse, Foster & Levine, 2005) to provide an objective measure of posture (sitting and standing). This system includes two inclinometers (Model CXTA02, Crossbow Technology, San Jose, California), to measure posture. The inclinometers are position on the right and left lateral lower thighs using velcro straps sewn into lycra shorts. A data logger (Ready DAQ AD2000, Valitec, Dayton, Ohio) was wired to the inclinometers and recorded posture every 0.5s.

Posture was defined as:

(i) Thigh inclinometers horizontal = sitting

(ii) Thigh inclinometers vertical = standing

We supplemented the PAMS postural data with direct observation given that the information retrieved from the PAMS unit is a measure of posture but does not indicate the mode of activity. For this reason, a post graduate researcher observed all of the children for the duration of play and was present during every video game session. The researcher recorded the number of times each of the children changed their activity choice (seated and ambulatory) video gaming. The researcher noted the postural changes during video game play but did not interact with the participants during the sessions.

## Statistical Analysis

All analyses were performed using SPSS (PASW Statistics 18, SPSS, Chicago, IL), with the level of significance set at $p< 0.05$. Means and standard deviations were computed for all key variables. To determine differences in time (total time and percentage of time) spent playing each game and consistency of choice, Game (seated and ambulatory) by Session (free-choice gaming sessions 1 to 4) repeated measures analyses of variance (RM ANOVA) were used. Post hoc comparisons were made with Tukey's Honestly Significantly Different test.

## Results

Full data sets were obtained for twenty-seven of the 30 children recruited. The descriptive characteristics of the 27 children are presented in Table 1. Of the three excluded participants, one child was missing more than two days of data because of equipment malfunction. Two of the participants dropped out of the study after two sessions due to other time commitments. The average time spent playing the video game options in all four 60 minute gaming sessions was 58 (± 2) minutes.

Table 1. Descriptive characteristics of the children.

| n=27 | Mean± SD (range) |
|---|---|
| Age (y) | 10.9 ± 1.1 (9.1-13.3) |
| Height (m) | 1.48 ± 10 (1.32-1.68) |
| Body mass (kg) | 40.0 ± 8.9 (27.0-66.7) |
| Body mass index(kg/m$^2$) | 18 ± 2.5 (14-24) |

Note. Mean± SD (range).

The time per free-choice gaming session spent playing video games seated or ambulatory is illustrated in Figure 2. There was no significant main effect for time ($F(2, 105) = 0.394$, $p = 0.711$, $\eta^2 = 0.009$), or a time by condition interaction ($F(2, 104) = 0.702$, $p = 0.522$, $\eta^2 = 0.016$), indicating that the time spent playing in each condition was constant across sessions. A significant between-condition effect for time was apparent ($F(1,44) = 137.335$; $p < 0.001$, $\eta^2 = 0.767$). Post-hoc analysis confirmed that more time per session was spent playing seated than playing ambulatory ($p< 0.001$).

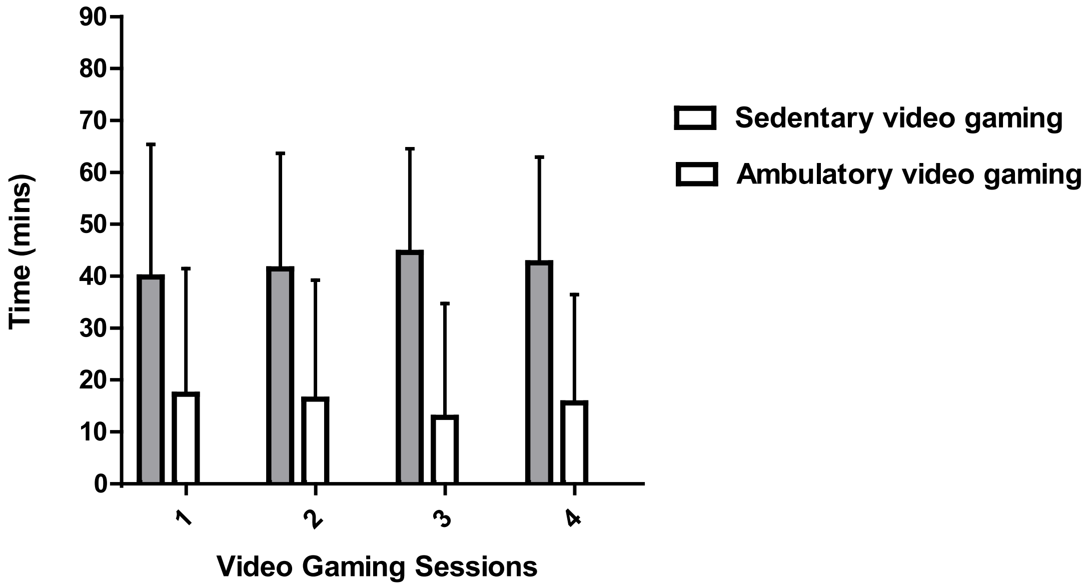


Figure 2. Mean time spent playing seated and ambulatory by sessions.

The mean percentage of time spent playing seated or ambulatory over the four free-choice gaming sessions was 76% ± 30 for seated play and 23% ± 30 for ambulatory play. The percentage of time per session for each of the games is provided in Table 2. No significant main effect was apparent for percentage of time across the four sessions ($F(2, 162) = 0.000$, $p = 1.000$, $\eta^2 = 0.000$); neither was there a percentage of time by game interaction ($F(5, 162) = 1.109$, $p = 0.357$, $\eta^2 = 0.032$). A significant between-game main effect for percentage of time was present ($F(1,67) = 56.239$; $p < 0.001$, $\eta^2 = 0.627$), with post-hoc analysis showing that the percentage of time spent playing seated was greater than ambulatory play.

Table 2. The percentage of time spent playing seated and playing ambulatory per session.

| n=27 | Session 1 | Session 2 | Session 3 | Session 4 |
|---|---|---|---|---|
| Seated video gaming | 63 ± 43<br>(0-100) | 72 ± 38<br>(0-100) | 79 ± 33<br>(0-100) | 73 ± 39<br>(0-100) |
| Ambulatory video gaming | 29 ± 41<br>(0-100) | 27 ± 37<br>(0-100) | 21 ± 34<br>(0-100) | 26 ± 39<br>(0-100) |

Note. Mean ± SD (range).

Postural monitoring from the PAMS showed that seventeen children spent 100% of the sessions seated video gaming in session 1, 2 and 3 and in session 4 eighteen of the children spent 100% of the session in seated video game play. However, the number of children choosing to ambulate 100% of the time whilst playing video games over the four sessions was 7, 4, 3 and 5, respectively. Review of the observational data, revealed that postural changes (ambulatory to seated video gaming) were apparent in all four sessions and that once seated children did not return to ambulatory video game play. Table 3 illustrates the percentage of time seated and ambulatory video gaming for the participants that made postural changes during the four sessions.

Table 3. Individual video game choice and percentage of time spent seated and ambulatory video gaming in the four sessions.

| *No.* | *Walk S1* | *Sit S1* | *No.* | *Walk S2* | *Sit S2* | *No.* | *Walk S3* | *Sit S3* | *No.* | *Walk S4* | *Sit S4* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3A | 24% | 67% | 1T | 41% | 59% | 7N | 37% | 63% | 1T | 71% | 29% |
| 8C | 42% | 58% | 2Z | 74% | 17% | 10B | 13% | 77% | 24D | 29% | 71% |
| | | | 7N | 58% | 42% | 21G | 82% | 18% | 27E | 40% | 60% |
| | | | 8C | 59% | 41% | 24D | 52% | 48% | | | |
| | | | 11L | 46% | 54% | 27E | 42% | 58% | | | |
| | | | 27E | 35% | 65% | | | | | | |

Note. No. = participant identification; S1-S4 = four video gaming sessions.

## Discussion

The primary purpose of this study was to investigate whether children would choose to play activity-enhanced video games rather than seated video games and whether this choice remained consistent with continued play. In contrast to our hypothesis, these preliminary findings show that when given the choice children would rather spend time playing video games seated than playing whilst walking. The children in this study spent approximately three quarters of the allotted time playing seated and this choice was consistent over the four sessions. When prescribing active video game play as an intervention it is possible that exercise equipment equipped with video game systems may need a feedback interface that makes video game play contingent on physical activity. Recent preliminary findings of a 5-week school-based intervention using a Gamercize stepper showed that when exercise equipment is combined with video games and video game play is contingent on activity children sustain exergame play (Duncan, Birch, Woodfield & Hankey, 2010). Previous studies testing the reinforcing value of contingent exergaming systems have reported similar findings when using multiple media platforms (video games, television) with exercise equipment (Faith, Berman, Heo, Pietrobelli, Gallagher, Epstein, Eiden & Allison, 2001). Faith and colleagues (2001) showed that children spend more time cycling on a contingent exercise bike and less time watching television over 12-weeks when compared to control participants.

The option to play the interactive multi-gaming format X-BOX 360™, provided the children with an opportunity to play a wide variety of games and multiple levels within the games. Multi-gaming format systems with these qualities are highly valued because players experience graded challenges and navigate through a number of increasingly difficult tasks to achieve a preconceived goal or to win the game (Garris, Ahlers & Driskell, 2003; Habgood, Ainsworth & Benford, 2005). Challenge is a highly valued attribute of video gaming (Vorderer, Hartmann & Klimmt, 2003) and may be one reason for long periods of sustained play (Hoffman & Nadelson, 2009). The success of achieving a goal within the game or "beating the game" is also rewarding and may increase the duration of game play (Hoffman & Nadelson, 2009; Sherry, 2004). A possible explanation for the limited time spent in ambulatory video game play and the observed postural changes from ambulatory to seated video game play, is that the children perceived the motor task to be contrary to their intended goal, "beating the game". The addition of the motor task may have limited their ability to meet challenges within the game and subsequently the attraction to the video game (Vorderer, Hartmann & Klimmt, 2003). It has been suggested that the desire to meet the in-game challenge or the longer term goal of mastering the game results in an experience of “flow” (Sherry, 2004). This theoretical perspective suggests that when an individual skill is balanced with a challenge, a series of neurological events occur which induce a pleasurable feeling (Sherry, 2004).

The mental state of “flow” has been associated with enjoyment and introduced as an argument for sustained video game play (Inal & Cagiltay, 2007; Weber, Tamborini, Westcott-Baker, & Kantor, 2009) and physical activity (Hagger & Chatzisarantis, 2007). It appears that video gaming activates sensorimotor, cognitive and emotional networks within the brain (Klasen, Weber, Kircher et al, 2011). Klasen et al. (2011) showed that these areas of the brain are activated by content in the video games associated with external factors (interaction between player and video game) such as balance between player skill and challenge, concentration, focusing and control. These factors are characteristic of flow and activate the sensorimotor areas of the brain that are responsible for motor function. According to Sinclair, Hingston and Masek (2007), concentration on movement diverts attention away from the game and disrupts the state of flow. The observational data from this study indicated that some children initially made the choice to video game and walk and then transition to seated video game play. Based on the argument above, if similar attentional resources are needed for video game play and physical activity then the challenge from the motor function may interrupt flow and this could lead to cessation of the motor task. Further investigations determining whether the addition of a motor task during video game play reduces the feelings associated with flow and subsequently participation in active video game play is warranted.

This study offers preliminary findings on the choice between sedentary and active video gaming and has a number of limitations. Firstly, we introduced video game play to a motor task that was disconnected with the game. This sensorimotor disconnect between the game and the motor task may have inhibited active video game play. However, one of the attractions to seated video gaming is the “game”, specifically those titles which offer sophisticated story lines, graphics, graduated levels of play and problem solving mechanisms not common with the many of the current active gaming systems. Offering the attributes known to attract children to video game play in both video game conditions offered insight into the value of the “game” and sedentary behavior. Second, we prohibited social interaction by partitioning of individual gaming units and in doing so we may have altered the way children play when given free choice since social interaction has been cited as a physical activity (Allender, Cowburn & Foster, 2006) and video game (Marijke, Chin, Jacobs, Vaessen, Titze & van Mechelen, 2008) motivator for children. Madsen et al (2007) have argued that social isolation was a contributing factor for the lack of sustained video game play in children during feasibility testing of Dance Dance Revolution and further research would be needed to investigate whether the addition of group participation would enhance choice or longer term sustainability of active gaming. Third, we only examined short-term game play and exploration of longer-term sustainability of active video gaming would be useful. Fourth, the large variation in the time spent seated and active whilst video gaming suggests large inter-individual variation, the underlying reasons for which our small scale sample was unable to explore. Finally, we failed to record the video game titles that the children were playing and were unable to determine if their choice of video game may have influenced their choice to be seated or ambulatory. In spite of these limitations, this preliminary study underscores the enormous gap in activity-enhanced video game research, particularly related to sustaining play over time. This must be resolved if activity-enhanced video play is going to be used effectively to increase physical activity levels in children.

## Conclusion

The preliminary findings reported here demonstrate that children choose to be seated when given the choice between sedentary and active-enhanced video game play, even in the short-term. These findings provide proof of concept and inform future research, which can be a catalyst for successful active video gaming interventions. Future research may benefit from building on these preliminary findings and investigating preferences for games that incorporate bodily movements, levels of exercise intensity and the demands on cognition and whether active video gaming offers adequate value to promote long-term engagement. The advancement of exertainment products as an activity option for enhancing physical activity depends on continued research efforts.

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# The Space of Digital Health Games

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**Abstract**

Digital health games run increasingly on mobile devices in order to stimulate and maintain health related behavior change. Yet, they interact with their topographic, social and cultural context in various ways and to specific degrees. In this article we discuss theories on locative media, urban as well as pervasive game design and set them in relation to current health game practice. Two approaches in "mobile persuasion" are contrasted: While some research emphasizes the transfer of newly learned behavior by providing a *seamless* experience, others focus on the *collision* between game rhetoric and "real world" context. Between the two, we argue, a "Situationist" approach may highlight interaction with everyday objects and environments as key to behavior change. We construct a new typology of game locations and give an overview into what we call "locative health games". Gaining a deeper insight to the role of space in digital health games, we claim, helps to address wider cultural implications and may well unfold new possibilities to leverage health messages. In conclusion, we present our concept for a mapping game, in which we interrogate how interacting with everyday environments may motivate young diabetic users to document their daily disease management.

KEYWORDS: LOCATIVE MEDIA, URBAN DESIGN, MOBILE PERSUASION, PERVASIVE GAMING, DIABETES GAME

## Introduction: Possibility Space

Persuasion has been defined as "an attempt to change attitudes or behaviors" with special emphasis given to users' voluntary participation (Fogg, 2003, p. 15). Computers, it has been argued, can be particularly persuasive when they make use of ubiquitous and mobile technologies. Potentially, they can intervene at any time and any place and may therefore find the opportune moment for present health related messages (Fogg, 2003, p. 10). We have shown elsewhere that health games seem to explore mobile technologies in various ways and so far to specific degrees. Mobile exergames – designed to produce physical activity in its players - seem to address a wide range of gameplay activities, pervasive gaming strategies and involve various real world locations. Meanwhile, disease management games seem to be concerned with more specific building blocks such as simulating self-care and gaining health related knowledge. They are being mostly developed for domestic use and so far these games only minimally interact with their built and social environment (Knöll & Moar, 2011). Several research projects are currently investigating the role of persuasive and mobile technologies in health related behavior change. Dealing with nutrition and eating habits, for instance the game project *Time to Eat* (Pollak, Gay, Byrne, Wagner, Retelny & Humphreys, 2010) indicates that the spectrum of potential applications may go well beyond the already established field of exercise games.

In this article, we follow the argument that new "possibility spaces" of serious games - and health games in particular – can be explored by experimenting with a wide range of design inputs (Sawyer & Smith, 2008). Broadening the discussion to the disciplines of locative media and urban design theory may help to illuminate how digital health games can interact with their spatial, cultural and social context. We identify several patterns that seem to occur in current design practice, from which we construct a new typology of "real world" health game locations. We go on presenting a framework of what we call "locative health games", which invites consideration about how games may use such locales in order to improve their overall experiences and achieve their health related goals. We conclude with the concept of a mapping game, which illustrates how playful interaction with objects and environments aims to motivate young diabetic users to document their daily disease management.

Space, we argue, may take on a twofold role in digital health games: First, it contributes to gameplay activities, which, for instance are designed to produce health related data input. Second, it may leverage health related behavior change exactly by raising users' awareness for environmental influences on their wellbeing. In the following section, we like to contrast two opposing approaches to space within persuasive theory: One seeks to integrate interactive simulations into the real world while the other aims for a collision between game rhetoric and urban context.

## Mobile Persuasion: Seamless Experience vs. Simulation Gap

Some health game research emphasizes how to transfer newly learned behavior from simulated environments to real world situations. Late 1990s studies have pointed to the role of self-efficacy beliefs in the context of videogames for health. They show that users, having rehearsed health related activities and knowledge in a simulated environment feel more confident with the newly learned content. As a result, they are more likely to apply such behavior in their everyday lives later on (Lieberman, 1997, p. 112). In order to increase such a likelihood, BJ Fogg seems to suggest to level down the spatial boundaries between simulations on the one hand and real world environments on the other. He argues, simulations embedded into everyday objects become particularly persuasive, since they would be less dependent on users' imagination and suspension of disbelief (Fogg, 2003, p. 77). Fogg insists the process of persuasion must be done overtly - otherwise, it would not only become morally ambiguous, but ineffective, too. In order to stimulate behavior change, users must be aware of the process of persuasion (Fogg, 2003, p. 48). This, of course, may be read as an appeal to designers to find ways of indicating and symbolizing persuasive technology being at work within objects and environments. In order to contrast what we call a *pervasive* approach to persuasive technology, we need to emphasize Fogg's claim for simulations to migrate into familiar objects and environments (See Table 1). Elsewhere, he highlights the concept of "augmented reality" and its potential for behavior change by layering digital content over existing physical structures. What foremost seems to matter to him about "mobile persuasion", is the question of "what gets added to your world" (Fogg, 2007, p. 10). In this notion, pervasive approach to mobile persuasion relies deeply on location and context awareness. Yet, it seems not to consider interaction or alteration of the material environement as a further possibility to stimulate and maintain behavior change.

Bogost counters with an observation on what he calls "mobile persuasive games". Like Fogg, he points to the importance of delivering digital rhetoric as close as possible to its real world context. Nevertheless, he points out Fogg's "psychological" approach would seek to *integrate* simulation into the simulated real world. Fogg's persuasive technologies would follow the "ubicomb influenced dream" of seamless and immediate experiences (Bogost, 2007b, p. 32). Bogost, in contrast, wants to advance a different and as he suggests more artistic approach to persuasion. Elsewhere, he argues that players may be persuaded precisely through what he calls a "simulation gap". The latter, he explains, occurs between a worldview expressed by a game designer and the worldview already held by players. For Bogost, interacting with a persuasive game ideally would stimulate an inner "state of instability". The resulting "simulation fever", as he hopes, might well leverage players to rethink established opinions and attitudes (Bogost, 2007a, pp. 214). As he specifies for mobile persuasive games, there would be a further possibility to stimulate behavior change. Next to providing a most seamless experience, he states, designers may seek to *collide* game rhetoric and real world setting. In order to do so, he likes to recall "defamilarization" - an artistic technique, which would compel the viewer to see the ordinary in a new and unfamiliar way (Bogost, 2007b, p. 36). Bogost seems to draw on an artistic tradition here, which has been highly influential on urban designers from the 1950s and 1960s onwards. To briefly revisit these theories helps to clarify Bogost's *rhetoric* persuasion and serves as a starting point for what we like to highlight as Situationist approach.

## The Situationist Approach: Subjective Mapping

We may note in passing that the belief in environmental change for improving individuals' opportunities was central to many social and urban reformers of the early 19$^{th}$ century. Indeed, it contributed extensively to the birth of today's discipline of scientific town planning (Benevolo, 1967). Hillier's "configurational theory" for instance has set out to broaden our understanding of how spatial layouts of cities and buildings influence people's movement and social interaction (1996). James, Jackson-Leach & Rigby recently have observed a growing interest in the environmental causes for lifestyle diseases such as obesity. For them, town planning and urban design with their capabilities in motivating physical activity and influencing food intake may be one ray of hope for tackling the disease (2010). Robertson-Wilson and Giles-Corti review various studies, which link neighborhood design attributes such as population density, mixed land use, connectivity to the so-called "walkability" of living areas. They conclude there would be "promising evidence" that the way we build cities may influence its inhabitants' weight status (2010). Initially, 1960s artist groups such as the Situationist International (SI) likewise considered material change as key to stimulate wider cultural and political change (Sadler, 1998, p. 13). What Bogost describes as defamilarization, can be seen more radically - as techniques of rerouting, hijacking or misappropriation of the society's pre-existing aesthetics for artistic purposes (Sadler, 1998, p. 17). It has been observed that Situationists explored state of the art technologies and were particularly concerned with the practice of urban geography. Their maps of personal "drifts" through the city did aim to criticize existing structures, but also attempted to enhance the experience of everyday life. With regards to today's mobile technologies, it has been claimed precisely the context between "the city, city landscape, and mapping" can be revived and may lead to creative and artistic recoding of urban life (Cosgrove, 2006). Nold's Bio-Maps illustrate a possible application of such practices to a healthcare context. They combine a Global Positioning System (GPS) with a biometric sensor that measures Galvanic Skin Response (Nold, 2009). Bio-Maps, it has been claimed, provide individuals and groups with objective as well as artistic means to *reflect on* subjective experiences. Indeed, what Boyd Davis frames as "subjective mapping" promises to unfold unprecedented possibilities for stimulating behavior change. Mobile devices, he notes, allow for precise positioning and interactivity. Unlike traditional maps, subjective maps can deliver what matters to users at a precise location in time. Through *reflecting in action*, he states, users may modify their behavior in the light of the current state of their maps (Boyd Davis, 2009).

Such practice and theory, which we have associated here to Situationism, indicates: Health games may explore further possibilities for behavior change precisely by confronting users with subjective *and* health related maps. They contrast the focus on transferring newly learned behavior - either through pervasive design or game rhetoric - with particular emphasis given to interaction with objects and environments. In this notion, space may play the following roles:

- A Situationist approach emphasizes interaction with space as a motivation strategy for gameplay activities designed to promote health related behavior. In order to do so, it seeks to integrate well-established knowledge about learning and behavior change, which we have discussed above.
- Furthermore, it seeks to reformulate the belief in environmental change to leverage behavior change, originating in early social ad urban reformers. In this notion health games can help to make aware of social and spatial influences on wellbeing. Reflecting on particular places and their impact on health, Situationist designers hope, may well encourage interaction with everyday environments. Locative health games, which we like present in the following, may suggest a re-use *and* re-shape of environments according to subjective requirements. In turn, *hybrid* – digital and physical - environments may help to initiate and sustain health related behavior change.

Table 1. Approaches to Space in Mobile Persuasion.

| *Mobile Persuasion* | *Behavior change through…* | *Urban design contributes to…* |
|---|---|---|
| *Pervasive* | **Transfer** of new newly learned behavior from simulated to real world set-ups. | **Seamless** and embedded experience. |
| *Situationist* | **Interaction** with space raises awareness for environmental complexes. | **Artistic practices** stimulate re-shape and re-use of environments. |
| *Rhetoric* | **Rhetoric** stimulates “simulation fever” & reconsideration of established behavior. | **De-familiarization** & Collision. |

## Context Awareness

Context awareness, however, is key to all three approaches presented above. Fogg observes that information will be increasingly tailored to context rather than individual user profiles. Yet, in order to deliver contextualized information, merely locating users may not be sufficient. Technologies could deliver a variety of contextual cues such as whether users are on their own or with others, what task they are performing, whether they are in a rush or at leisure and possibly even what kind of mood they are in (Fogg, 2003, p. 40). The knowledge about urbanism and space may well help to inform such context detection. So we can only welcome that current research on how context awareness may contribute to persuasive health messaging is partly based at departments for urban planning (Lin, Jessurun, de Vries, & Timmermanns, 2011). Their health advisory system *Motivate* considers users’ location, environment, weather, agenda, and individual profiles in order to find which aspects of context awareness have crucial impact on health related decision-making. More research in this direction promises to deliver a broader toolkit for designers dealing with health related locative media. Yet, in order to design persuasive game play activities, we argue, health games in particular must emphasize interactivity related to awareness. In the following section, we pay more attention to locations and how they may contribute to health games.

## Typology of Game Locations

Walz provides a set of "questions that may be asked about space when designing and analyzing games" (2010, p. 130-131):

- Player: Where in the game is the player and where is the game for the player?
- Modality: When, and for how long does the game take place?
- Kinesis: How does the location affect kinesis and rhythms between players?
- Enjoyment: How does the game's locale affect the pleasure of playing? What emotions does the site inspire?
- Context and Culture: How do the context and culture of the location affect play related activities?

We have used this list of "locative dimensions" elsewhere to identify real world locations at stake in current health game design practice. For mobile exergames, we have indicated a wide spectrum of locales ranging from parks to public and private indoor spaces such as waiting halls and hotel rooms. We have observed the usage of staircases as well as street furniture such as benches, walls and rails on public spaces (Knöll & Moar, 2011). In the following we discuss patterns that seem to occur and organize them in a new typology of health game locations. We characterize each entry with the help of Walz' locative dimensions and pay particular attention to their potential health context and how they may contribute to mobile persuasion (See table 2).

### *The Park*

The Park stands for an outdoor game location with distinctive spatial boundaries and entrances. It invites play sessions taking place on special occasions. The GPS word spelling game *Seek 'n' Spell* for instance suggests meeting up with their friends in a park for play sessions of up to 20 minutes (Retronyms, Inc., 2009). Parks can affect gameplay in a variety of ways. They are fenced off from car traffic and provide a safe environment for pedestrians with almost unrestricted possibility to move around. Its topography such as small hills, towers or stairs provides different obstacles for players to overcome. As an outdoor location, The Park provides unobstructed GPS and cellular signals and therefore allows locative games to constantly track players' position and movements. Designers highlight emotions evoked such as feeling safe, being active and healthy (Retronyms, Inc., 2009). The cultural context of parks cannot be dealt with comprehensively in this paper. However, we like to point to their tradition for being both: Sites for public health care and more "hedonistic" connotations of play (Koolhaas, 1978, p. 70). Players may encounter friends as well as strangers in an informal atmosphere. The Park may contribute to both strategies within mobile persuasion. It provides a safe and healthy environment to rehearse health related behavior. Meanwhile, since it is frequented primarily on "special" or non day-to-day occasions, it hardly fosters direct transfer of learned behavior through seamless experience. In contrast, The Park emphasizes and encounters play and therefore contributes to collide health game rhetoric with its urban context.

### The Conduit

The Conduit includes a wide range of locations from streets and sidewalks to corridors and staircases. Unlike The Park, it has less noticeable spatial boundaries and is mostly conceived as a space connecting two locations. The Conduit seems a more prominent part of our everyday routines, providing a game modality of short-termed but highly frequented play periods. Staircases are an interesting example for The Conduit. The stair climbing game *Monumental* (MeYou Health, Inc., 2010) combines physical exercise with the virtual storytelling of visiting world famous monuments such as the Eiffel Tower. It is played throughout the day, for short play sessions of up to ten minutes. Indoor staircases as well as streets with surrounding high buildings generally will have little or no GPS reception. However, their topography can directly influence play rhythm, especially when designed to produce physical activity. With regards to average staircases or corridors, The Conduit would not normally evoke strong emotions. *Monumental* sets out to augment less interesting real world game locations by digital storytelling. Cultural contexts vary, though we may experience traversing a Conduit often on our own. Games such as *Monumental* therefore seek to augment Conduits with a virtual community. The Conduit contributes foremost to provide a seamless experience: Being pervasively available in everyday environments, it helps to integrate gameplay fostering new health related behavior into daily routines.

### Agora

Agora is the name for market places and public squares in ancient Greek cities, which had been commonly used as a place for popular and political assembly. Ching points to an Agora as a well-defined urban space, which enclosures may consist of arcades or gallery spaces. They would include surrounding buildings into their domain and activate the space they define (2007, pp. 157, 411). For our purposes, we emphasize public spaces providing service and shopping including inner city pedestrian zones, large supermarkets and indoor shopping malls. Unlike The Conduit, The Agora hosts many people and sparkles social interactions of various modalities. It is pedestrian friendly, mostly fenced off from car traffic and enables positioning through GPS signal and / or wireless LAN. Agoras may contribute to certain locative games particularly well, for, as Sieverts notes, they artificially reproduce and "dramatize" social interactivity for mostly economic interests (1997, p. 37). *Cruel 2 B Kind* (McGonigal & Bogost, 2006) plays precisely on social norms in public spaces encouraging players to make compliments to total strangers. Health games dealing with players' food decisions may target Agora's grocery shops and (fast food) restaurants as well as the public place between them.

### The Social Place

As The Conduit, social places such as the school, office and workplaces are a distinctive part of our everyday life. They are frequented for longer periods, several times throughout the day. We have mentioned the game project *Time to Eat* earlier, which deals with nutrition and is primarily played in school restaurants (Pollak, Gay, Byrne, Wagner, Retelny, & Humphreys, 2010). Their play rhythm is less influenced by topography but by social interaction. Positioning information, however, might be not available. Gay points to the potential of social influence in behavior change and emphasizes the close relationship between real and virtual support groups and the social dynamics stimulated by spatial configurations and layouts (2009, p. 51). The Social Place seems to be suitable for pervasive and rhetoric persuasion. Bogost himself has outlined a nutrition game, which makes use of location awareness by confronting players with a simulation depicting the consequences of (bad) eating habits (Bogost, 2007b). Additionally, we may point to studies that have shown the way that layouts of restaurants and supermarkets may "nudge" people to make certain food decisions (Thaler & Sunstein, 2009). Situationist health games may address school or work restaurants in order to make players aware of such health related architectural settings and may even stimulate a discourse on their alteration.

### *The Waiting Hall*

The Waiting Hall can have distinctive spatial boundaries, but would often be characterized by open areas and easy access. They have been seen as transient places of an urban and mobile lifestyle. Sieverts for instance has indicated the lack of attention that is paid to the needs of people in so-called "Non-Places" (1997, p. 87). In contrast to The Conduit, The Waiting Hall emphasizes that we paradoxically often sit or stand while being on transit. Its game locations include airports, hotel rooms as well as airplanes, trains or buses. The time we spend in such locations varies a lot, yet more importantly it has been characterized as "moments of downtime", in which people would feel "trapped in silence" (Fogg, 2003, p. 189). In this regard we may frame The Waiting Hall as evoking few emotions by it self. Likewise, its cultural context is challenging: It provides many fellow travellers and potential contributors to the gameplay, but most people would state that they experience Non-Places on their own. In terms of persuasion, The Waiting Hall highlights potentials for de-familiarizing in a health game context. Bogost has shown this for instance with his mobile game *Airport Security*, which expresses criticisms of policies relating to Security measures. It is played precisely while going through security checks (Bogost, 2007b). Mobile exergames explore the small space available to us in The Waiting Hall as playground for exercises (Jog Hop, LLC., 2010).

### *The Water Cooler*

Our last entry refers to landmark objects, which may often stimulate opportunistic social encounters. They are part of interiors or may consist of what urban designers call "street furniture": Outdoor benches, stairs, rails, walls, streetlights, public art, bus stops or ATMs. Interestingly, more traditional studies on how health and community design may impact physical activity refer to street furniture as "amenities" mere aesthetic value (Frank, Engelke, & Schmid, 2003, p. 165). It may be precisely through strategies of locative health games that such spots can stimulate physical activities, too. Water Cooler objects are often encountered for a short period of time and are more or less frequented throughout the day. They often generate an increased social interaction around them and provide a micro topography. These in turn can be addressed by the gameplay of exercise games as an obstacle to interact with (Mc Gonigal, 2009). The interplay between street furniture and players may be described as sportive engagement that playfully contests players in the way free runners explore the urban landscape (Feireiss, 2007). Water Cooler objects evoke emotions by the way they are designed and by the social interaction they stimulate. They are being referred to as "natural habitat" or "challenging spots" (McGonigal, 2009). The potential to stimulate health related behavior apart from exercises through interacting with Water Cooler objects has not yet been further explored. Being ubiquitous to everyday routines, they seem to advance a pervasive approach to mobile persuasion. In addition, their landmark as well as small-scale character makes them locations easy to indicate, to map and potentially to alter.

Table 2. Typology of Locations in Locative Health Games.

| *Typology* | *Where* | *Modality* | *Play Rhythm* | *Emotions* | *Context* |
|---|---|---|---|---|---|
| Park | Outdoor, Spt. boundaries. | Special occasions. | Good Signal, Topography, Free movement. | Safety, Leisure. | Friends, Strangers. |
| Conduit | Indoors, Part of building. | Short term, Frequently. | No GPS, Topography. | Routine. | Few people at all. |
| Agora | Pedestrian zones, indoor shopping malls | Various periods, Frequently | GPS, wireless LAN | "Safe", Choreographed Public place. | Many people. |
| Social Place | Indoors. | Short term, Frequently. | No GPS, Arch. Layout. | Various, Familiar. | Colleagues, Staff. |
| Waiting Hall | Mostly indoors, Transport facilities. | Short term, Frequently | No GPS, Small scale | Bored, "Feeling Trapped". | Strangers. |
| Water Cooler | Outdoors & Indoors, Street furniture. | Short term, Frequently. | Good Signal, Topography, Free running. | Challenging, Out & About. | Colleagues, Strangers. |

## Locative Health Games

The term locative media has been framed to indicate interaction of media content to locales (Galloway & Ward, 2005). Walther has presented a comprehensive list of pervasive gaming *formats* outlining various technical possibilities for digital games to interact with space (2007). In the following, we seek to apply Walther's pervasive gaming formats to the field of health games and relate them to more cultural and urban implications. In addition to the typology of game locations presented above, we like to discuss a new framework of what we call "locative health games". They interact with different types of locations in order to achieve specific health related purposes.

### *Mobile Interfaced*

Walther sets apart "mobile interfaced games" from practices of "true" pervasive gaming, since they do not implement users' position or movement to their game rules. Such games would often be merely miniaturized versions of traditional videogame formats - running on smaller screens of mobile devices (2007). An example for a mobile interfaced health game may be Bayer's glucometer system *Didget*. It can be attached to Nintendo's portable play console DS and is distributed with the adventure game *Knock'Em Downs* (Bayer HealthCare, Inc., 2009). Additional items and game worlds reward players' testing habits. Though the Didget consists of portable devices, we have noted elsewhere, it does not address specific game locations or attempt to explore pervasive gaming strategies (Knöll & Moar, 2011). However, mobile interfaced health games may point to an interesting aspect of context awareness. Whereas they seem to pay less attention to social and topographic context, they allow integrating medical data into their gameplay. Due to attached biosensors, they foremost motivate through positive feedback and operant conditioning as described by Fogg (2003, p. 49). Combining self-monitoring with positioning and / or social interaction may enhance such approaches to mobile persuasion

### *Mobile Embedded*

In contrast, mobile embedded games integrate player's position and position change to their game rules (Walther, 2007). We have shown elsewhere that mobile exergames seem to use this format extensively interacting with a variety of game locations and topographies (Knöll & Moar, 2011). With regards to the typology of game locations presented above, we may state that since they require GPS signal and free movement, mobile embedded exergames such as *Seek 'n' Spell* seem to take foremost place in park-like spaces. Locative attributes of what we have described as The Park above seems to largely contribute to leverage physical activity. Unlike mobile interfaced games, its designers indicate and address preferable game locations. Still, it is important to note that mobile embedded games are not location specific.

### *Location Specific*

Walther defines a location-*based* game as including relative or absolute but static position to its game rules (2007). With the notion of location *specific* we like to include games that respond to attributes of locations rather than to their global position. *CryptoZoo* (Mc Gonigal, 2009) may be seen in this category. It suggests specific spots in the urban landscape to interact with. We have called the typology of locations targeted by such games Water Cooler objects. Interestingly, location specific games seem not necessarily to rely on GPS based positioning. In CryptoZoo, players locate and share spots on a map at the game's website. All gameplay activities start off from one specific location, e.g. balancing over a series of park benches, but may be transferred to other spots with comparable locative attributes. Such transfer points towards a fourth category: translocational health games.

### *Translocational*

Smartphones and PDA's tend to use a combination of GPS and WiFi data to determine geographic location. Due to the limitations of these technologies, activities that seek to use this data are limited (mainly) to the outdoors. A further distinction needs to be made here between different two modes of utilizing data relating to geographic location. As stated above, location specific applications can locate and integrate known geographic features. Whereas this can make for a rich 'embedded' experience in gameplay for example, it does limit applications to specific locations. In order to enable a location sensitive game to be played anywhere, properties such as stored visits, speed, orientation and relative movements need to be incorporated. Such 'translocational' media has been used to deliver a locative sensitive, but not location specific, drama for example by (Parry, Bendon, Davis, & Moar, 2010). *Monumental* seems to be an example for a health game in this category. It targets a distinctive typology of game locations, which we have described above as The Conduit. In Monumental, it does not matter in which specific staircase users play. Translocational health games emphasize the idea of re-visiting various locations within one typology such as restaurants. Since play results can be stored, players can compare performances and may see the results of different behaviors. Such a feature may become of particular importance for locative health games dealing with disease management, as we like to outline below.

## Concept for a Mapping Game

"The Creature" is an ongoing research & design project aimed at providing a locative game experience that motivates children with type-1-diabetes to document their daily disease management. Recording sugar levels, insulin dosages, food intake and exercise regime are crucial to diabetes education, since it is on this basis that doctors can discuss potential therapy improvements. For diabetics, sugar levels are the result of multiple factors, yet their control is often credited as good or bad individual disease management. A mapping game may help to reveal probably unexpected correlations between sugar levels and the built and social environment. In the following, we will specify design implications of what we have framed earlier as Situationist approach:

- On the one hand, we aim to find out how game locations can help to motivate daily diabetes logging. The gameplay may start off from established "building blocks" for health games (Lieberman, 2010), of which the nurturing of a virtual pet seems to be widely used in diabetes games (Knöll & Moar, 2011). Our design interest lies in exploring how such virtual characters may respond to different game locations in order to sparkle interaction with the player. Conceptually, such a mapping game may start off as translocational, addressing various places and allowing the player to compare his "performances". For instance, whereas one day, sugar levels at the school restaurant were good, another day they were too high in the fast food restaurant. Potentially, the mapping game might turn location specific, allowing the player to compare different "performances" at places he or she re-visits. Location specific gameplay may encourage diabetics to improve or maintain good sugar levels at one specific location such as the school restaurant.
- On the other hand, to map diabetes management – that is to relate relevant data to their locations – may raise awareness of its environmental influences. Such social, spatial and environmental circumstances may add an interesting layer to diabetes education. On a basis of such maps, doctors and patients may discuss broader influences on patients' wellbeing and potential therapy improvements.

Further research & design must interrogate the claims being made for such Situationist approach to health games. Thus might show in how far the new typologies of locations and formats we have presented in this paper help to design and analyze locative health games. For the purpose of our mapping game, the presented framework directs us to what we have called Water Cooler objects as a significant type for further research. These spots are visited frequently in users' daily life. They seem to be of temporary character and seem more likely to be altered by individuals and (game) communities. Moreover, they can be chosen according to which sort of social interaction players prefer. Developing game play activities around such objects, we hope, may increase frequency of data in put and may enhance player's identification with and care for a virtual character. In upcoming interviews, we plan to ask users to map their diabetes management in the form of hand drawn maps. Such sessions will help us to advance the discussion on specific Water Cooler objects to be addressed by the gameplay.

## Conclusion

We have contrasted two approaches towards space in mobile persuasion here and related them to current health game design practice. Whereas advancing the transfer of newly learned behavior emphasizes context awareness - either integrating or colliding game rhetoric to its health related context, we have highlighted interacting with space as a further possibility to stimulate health related behavior change. What we have called a Situationist approach to health games builds upon various strategies of user motivation discussed in persuasive theory. Yet, it invites consideration that behavior change can be stimulated and sustained through becoming aware of and altering built and social environement, too. However, mobile platforms may unfold a whole spectrum of what we have described as locative health games, integrating real world locations to their gameplay. We have conceptualized a new typology of such real world locations and went on showing how different kinds of locative health games make use of them. Further research & design must specify the discussion on locative health games, which potentials and challenges we have aimed to outline here.

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# Adaptation Model for Indoor Exergames

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## Abstract

In this paper we propose an approach towards adaptive long-term motivating and physically demanding exergames for indoor training. Various previous approaches have been using ergometers (especially ergometer bikes) in interactive applications (mostly virtual cycling simulations) since decades. Nevertheless exertainment applications for indoor training are not applied in a broad range. In this paper we present a structured analysis of existing commercial and scientific approaches towards interactive indoor training. On this basis a concept and model for adaptive exergames was developed. Exergames based on this concept are usable with different devices and provide adaptation possibilities for the psychological as well as the physiological needs and properties of different end users. In this way the proposed concept integrates the diverse dimensions of Sport, Game and Technology.

KEYWORDS: SERIOUS GAMES, GAMES FOR HEALTH, EXERGAMES, ADAPTATION, INDOOR CYCLING

## Introduction

Lack of exercise is a global phenomenon (World Health Organization, 2010). Exergames, which promise to combine the motivational aspects (affects) of gaming and the effects of exercise on constitution and health became more and more popular in the recent years. With this development they became the focus of scientific studies. Various authors investigate the effects of playing exergames and analyze if exergames raise the human energy expenditure (EE) adequately (Baranowski, Buday, Thompson & Baranowski, 2008; Wiemeyer, 2010) and if their effects are comparable with the effects of regular sports and exercises (Brumels, 2008; Kliem & Wiemeyer, 2010). Most studies concentrate on commercially available and popular exergames, such as Wii Fit or Dance Dance Revolution (DDR). The studies verify, that exergames raise the human EE significantly (short-term effects) and that playing these games can improve balance, reaction and coordination (Brumels, 2008; Kliem & Wiemeyer, 2010). Compared to regular sports and exercises the effects of those commercial exergames are low and do not always meet the minimum recommendations for physical activity.

The reasons for the different effectiveness of exergames and regular exercises with regard to physical training have rarely been investigated. Since the studied games have been developed with the focus on a maximum amount of entertainment and acceptable price of sale, it can be assumed that the sport and training science aspects played a secondary role in the design and development process of these games.

It thus remains an open question if it is possible to develop exergames that reach a similar long-term effectiveness as conventional training methods. If this is the case, these exergames should ideally be attractive and motivating for a long period of time. In order to achieve this goal, Exergames have to fulfil seamlessly multiple requirements from the different expert domains of Gaming, Sports and Technology as shown in Figure 1.

Exergames must be of a high quality from the playful perspective to be attractive, they need to be adaptive to provide a low barrier to entry for newcomers. At the same time they need to provide enough challenge and difficulties for more experienced users, otherwise they will lose their attractiveness and challenge after a very short period of time.

From the perspective of sport science the Exergames must pose an adequate load for optimal adaptation. If the load (particularly intensity, duration and density) is too high or too low adaptations will be suboptimal. In addition, overload may lead to over-reaching, over-training, or injuries. Therefore adaptation technologies for the training stimuli are required. The technologies have to combine, unite and match the sportive and playful aspects in a seamless way. It is not sufficient to add some playful elements to a regular training exercise, or vice versa, to add some exercise to a regular game.

Since exertion games, in contrast to regular computer games interact more with the human body the requirements concerning the used hardware and software are different. The hardware requires sensors to capture and measure human movements with sufficient accuracy and without bothering the player as well as actuators (Visualization, Hap tic, Force Feedback) to provide different kinds of feedback to the player

To fulfil all these requirements from the different domains Gaming, Sport and Technology and to seamlessly integrate those into Exergames it needs concepts and models to describe and analyse the impacts and influence of possible solutions for those requirements. The solutions for the requirements, as they are used in the expert domains alone can not be simply plugged together.

In the following sections we describe existing commercial and scientific approaches for the application field of indoor cardio training and analyse which aspects of the different domains they fulfil. Based on this analysis we build up a theoretical model, consisting of components, modules and interdependencies which play a role for the development of exergames. To evaluate this model we realized a prototype for the application example indoor cardio training. The prototype was evaluated in a study with *n*=48 participants which showed tendencies for the mode of operation of singular modules.

## Related Work

For the playful realisation of indoor cardio training there already exist various approaches. The existing approaches realize a selection of aspects or modules of the proposed model in different ways. Commercial applications for the field of indoor cardio training are mostly available as add-on to regular training ergometers, or as a combination of video games with special ergometers as game controllers. The existing scientific approaches mostly focus on the user experience of exergames (Thin, 2010).

The approaches can be classified with regard to the hardware and the type of the interaction in the application (see Table 1). The hardware can be differentiated between stationary regular bikes equipped with a roller break to be used indoors (Tacx), regular cycling ergometers (Daum, Kettler), and special game controllers (XRBike, Cyberbike, Fisher-Price Game Bike). The regular bikes provide realistic haptics, look and feel, and realistic usage since they are equipped with brakes and gearings. The cycle ergometers are developed for indoor use only with adjustable resistance, but without brakes and gearing, they run more silent and have no possibilities for steering. The game controllers provide steering, sometimes also a brake but rarely digitally adjustable resistance, which is needed to adapt the training load to the fitness level of the player during gaming.

Table 1. Classification of different approaches to interactive cardio training.

| | *Bike* | *Cycling-Ergometer* | *Game-Controller* |
|---|---|---|---|
| *Game* | VR Race (Tacx) | *ErgoActive* | XRBike,<br>Fisher-Price Game-Bike,<br>Cyberbike (BigBen) |
| *Simulation (Video, 3D-Cycling)* | VR-Trainer (Tacx) | Ergoplanet (Daum),<br>Tour Concept (Kettler) | Puffer (ATARI) |

Theoretical models for the effects of exergames base on the "Flow" theory (Csíkszentmihályi, 1975). Flow is the state between boredom and anxiety. It can be reached if an exercise is challenging, but not too difficult. The Gameflow (Sweetser & Wyeth, 2005) adapts the Flow Concept for Computer games (see Table 2).

Since Exergames combine computer games and exercises, they need to provide not only the adequate level of psycho-physical load. The Dual Flow Model (Sinclair, Hingston, Masek, 2007) adapts the Flow theory and accordingly the concept of Gameflow to exergames. Following the Dual Flow model the Flow in Exergames must be divided in Attractivenes (psychological Flow) and Effectiveness (physiological Flow). To match the Effectiveness, the physiological level of Flow or adequate level of exertion a system for heart rate adaptation (Sinclair, Hingston, & Masek, 2009) can be used.

Table 2. Comparison of Flow (Csikszentmihalyi, 1975) and Gameflow (Sweetser & Wyeth, 2005).

| Flow (Csikszentmihalyi, 1975) | Gameflow (Sweetser & Wyeth, 2005) |
|---|---|
| Balance between perceived skills and perceived challenge (the activity is neither too easy nor too difficult). | Challenge - games should be sufficiently challenging and match the player's level of skill. |
| The merging of action and awareness. | Concentration - games should require concentration, and the player should be able to concentrate on the game. |
| Clear goals (expectations and rules are discernible and goals are attainable and align appropriately with one's skill set and abilities). | Player skills - games must support player skill development and mastery. |
| Unambiguous feedback (successes and failures in the course of the activity are apparent, so that behaviour can be adjusted as needed). | Feedback - players must receive appropriate feedback at appropriate times. |

| Flow (Csikszentmihalyi, 1975) | Gameflow (Sweetser & Wyeth, 2005) |
|---|---|
| Concentrating and focusing, a high degree of concentration on a limited field of attention (a person engaged in the activity will have the opportunity to focus and to delve deeply into it). | Clear goals - games should provide the player with clear goals at appropriate times. |
| A sense of personal control over the situation or activity. | Control - players should feel a sense of control over their actions in the game. |
| A loss of the feeling of self-consciousness (no feelings of self- doubt or self-concern). | Immersion - players should experience deep but effortless involvement in the game. |
| Transformation of time (one's subjective experience of time is altered). | Social interaction - games should support and create opportunities for social interaction. |
| Auto telic experience (the activity is intrinsically rewarding - it is undertaken for its own sake). | |

To verify, to extend and to understand the interaction between the components of the Flow, Gameflow and Dual Flow theory in exergames, and further on to try out different ways auf realizing these components it is necessary to develop exergames which provide different levels of adaptation. By adjusting single aspects their influence on the complete system can be measured. Since the three concepts only deal with the "human" aspects and leave out technological influence the model needs to be extended.

## Concept and Model

To investigate the effects and the interaction of individual parameters for the successful use of Exergames, it is necessary to identify them and to modify and adapt them independent of other influencing parameters. Besides the theoretical concepts described in the related work, the model presented here also contains aspects gained by explorative studies with different prototypes for exergaming (Göbel, Hardy, Wendel, Mehm & Steinmetz, 2010).

As described in the introduction, aspects from the domains of Gaming, Sport and Technology are relevant for the development of exergames (Göbel, Hardy, Cha, El Saddik, & Steinmetz, 2011). Various aspects of the different domains influence each other and influence the Attractivenes, Effectiveness, Flow, User Experience and Gameflow Experience (Nacke, Drachen, & Göbel, 2010) of the games. To investigate the mode of operation of all these parameters need to be considered separately. Figure 1 shows the previously identified three domains (Göbel et. al., 2011) with a selection of examples for their constituent parts.


Figure 1. Relevant Domains for the Development of Exergames and their constituent parts.

This model is now elaborated and improved. The aspects relevant to the development of exergames can therefore be identified as the application-specific "Hardware", "Software", and the human "Psychology" and "Physiology" as shown in Figure 2. Both cannot be considered separately, since they influence each other. The Software component and its modules "Gaming" and "Training" as well as the psychological component with its modules "Effectiveness" and "Attractiveness" can be modified during gaming, so they are classified as adaptive. The "Hardware" as well as the physiological characteristics of the player cannot be influenced during gaming, so they are classified as static.

The Software can be a single game, a fixed or variable sequence of different minigames as well as training or gaming analyses, high score lists, training information or entertainment units. The content expression, such as training configuration or style can be determined at runtime. This way, by changing its content, the software can modify its effects on the player at runtime. This leads to different characteristics of the application with respect to the Flow, Gameflow, Dual Flow and User Experience. It can be assumed that this also leads to different psychological impacts on the player. For instance, different levels of fun, challenge, tension, immersion, presence, arousal and so on (Nacke, 2009). By changing only one parameter, while measuring the effects on the player or in studies with several players and different setups while keeping all other parameters at a fixed level, the effects of single parameters can be quantified.

The whole Software of an Exergame is commonly called "Exergame" or "Game". Considering adaptive exergaming, it is necessary to separate between at least two components in the application. In Figure 2 all for the parameters relevant to gameplay (everything which influences the Attractiveness), such as Game Concept, Game Logic, visualisation, design, and visual feedbacks are considered separately from the sportive and training control elements (everything which influences the Effectiveness).

This does not mean that one side is more or less important than the other one – they cannot compensate for each other – but to identify their impacts on the game they need to be adjusted and researched separately.

In which way the different aspects influence the psychological effects of the application needs to be considered separately. The Flow aspect of challenge for example can be influenced by the cognitive (gameplay) challenge as well as the (physiological) training load. In cardio games, the training challenge is more or less physical exertion. In other scenarios, with coordinative elements, the physiological and cognitive challenge cannot be completely distinguished. To reach the "Flow" corridor both, gaming challenge and training challenge, need to be balanced.

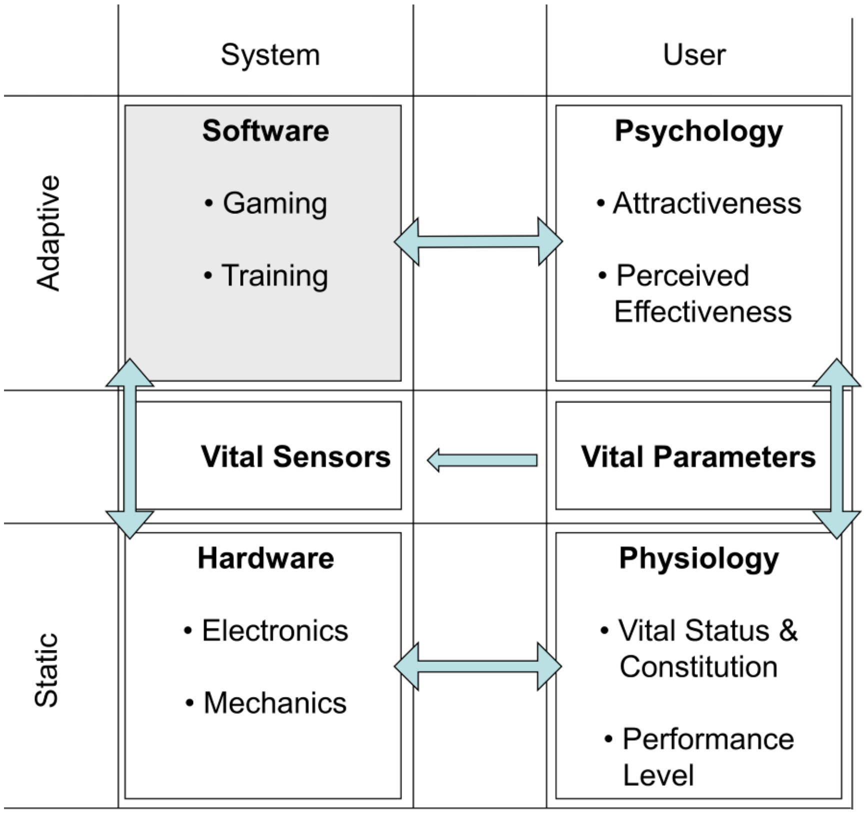


Figure 2. Refined Model of the relevant aspects for the development of Exergames.

The "Training" module of the software component includes the relevant elements and functions for the adaptation of all parameters relevant to successful training. We assume that the control of these parameters directly influences the perceived Effectiveness of the player. The control itself follows guidelines of training in sport. To provide precise adaptation parameters the perceived exertion and vital parameters of the player play an important role. The perceived exertion is an indicator for the player's feeling, it includes daily variability in fitness, fatigue and pre-exhaustion. It must be collected by asking the user, which interrupts the game (Borg, 1998). A second basis for the training adaptation is the vital state given by the vital parameters of the user. By the use of sensors this data can be accessed in real-time and therefore be used for real-time adaptation. For example, the resistance of an ergometer bike can be adjusted, so that the game is played at a predefined heart rate. One difficulty for the calculation of adequate training parameters is that the calculation base on the performance of the individual user. This needs to find ways to measure the fitness of the player in a safe way. The needed sensors as well as the actuators belong to the "Hardware" component. For the adaptation it is not relevant if the heart rate is measured by an ear clip, a finger tip or a chest belt. It is also not relevant for the adaptation if the resistance is controlled by a mechanic, magnetic or electronic brake as long as there is no undesired change or variability.

In contrast to classical video games, which are mostly controlled by mouse and keyboard or game-pad, rarely by (force feedback) steering wheels, the used hardware plays an important role. While playing exergames the player interacts physically with the hardware. The mechanical elements (shape, haptics) of the hardware as well the electronic elements (sensors and actuators) define the possible usage of the device. All these elements are static during the play of a game, they cannot be adapted. This is similar to the constitution of the player, his size and abilities (very important in rehabilitation) do not change significantly during one playing session. So the hardware as well as the constitution of the player can be considered as consistent. The hardware can have changeable components, a controller in an exergame for rehabilitation for example may need different grab handles or the saddle and handle bar of an ergometer can be adjusted. Those mechanical changes are done before the play so they can be considered as static during the game. To ensure a valid comparison of games, those settings must not influence the game (a grab handle, saddle or handle bar must be adjusted in an adequate way before starting the game).

A further aspect of the hardware, which could be considered as dynamic part is for example the adjustable brake of an ergometer bike to change the resistance. This brake system is controlled by the “Training” module of the software, so the control and dynamics are part of the software. The fixed parameters such as maximum braking power and reaction time belong to the static specification of the hardware. These specifications can play an important role. If they do not fit the needs of the game – for example if the brake is too weak – the “Training Control” cannot work properly and the “Effectiveness” cannot be matched. The static parameters (mechanical, functional or haptic properties) of the hardware can also influence the User Experience of the whole system. A real bike provides a more realistic feeling than a cycle ergometer and in this way can impact the perceived immersion.

In sum all these factors play an important role for the User Experience. To reach a high degree of user experience, all factors have to be considered. For the quantification of the impact of adaptation methodologies and algorithms those factors need to be identical. For example to compare different games they need to be evaluated with the same hardware to eliminate misleading influences.

## Implementation

In order to evaluate the proposed model a prototype called *ErgoActive* was developed which implements three different concepts of gameplay (three types of Attractiveness) and provides the possibilities to adjust several parameters relevant for training (adaptive Effectiveness). The prototype has an interface (RS232, Bluetooth SPP) for different training devices. It can be used with a treadmill, an elliptical trainer or a cycle ergometer. All three minigames can be played with these three devices. For the evaluation the cycle ergometer was chosen.

In the minigame ”ErgoActive Video Cycling“ (ErgoVideo) a previously recorded video is played according to the speed of the player cycling on the ergometer. The faster the player cycles the faster the video plays, if the player stops cycling, the video will also stop. The recorded track includes GPS data such as position and height of the track. The height information is used so modify the resistance according to the inclination of the track, which should convey a realistic feeling. The application has no reactive elements. Since it is a video recording the quality of the visual appearance is very realistic. The user can choose between different tracks, recorded at different seasons and places (winter, summer, hills, and flat land). The initial resistance can be adjusted and if the inclination of the track is too high the player can reduce the resistance of the cycle ergometer manually. The Minigame ErgoVideo can be controlled via the speed mode, using cadence or heart rate as a control parameter is technically possible but not reasonable for the current gameplay.

Figure 3. The used ergometer-cycle (left) and a player playing Pigeon-Hunt (right).

The minigame ”Pigeon Hunt“ is a classical comic-style side-scroller game. It uses a definable input parameter such as speed or cadence (rpm) to control a flying bird. By changing the parameter, this means increasing or decreasing the cycling speed, the player controls the height of the bird. This way he can earn points by collecting letters which enter the screen from the right side. The faster the letters are, the more points the player will get. The players learn fast to get a feeling for the speed. Since there is a time delay between the changing speed and the reaction of the bird, collecting the letters is a challenging task. The resistance can either be adjusted manually or it can be automatically adjusted according to special training goals as described later.

The MiniGame ”Ergo Balance" is a combination of ”Shoot-Em-Up“ and ”Skill Game“. The screen shows a clown balancing on top of a ball. The player needs to keep the input parameter (heart rate, speed, and cadence) at a fixed level in order to keep the clown balancing. If the player cycles too slowly, the clown will fall to the left side, if he cycles too fast, the clown will fall to the right side. At the same time the player has to click with a mouse at balloons falling down in order to gain points.

The Configuration-Interface provides access to the Training Control API (TCA) of all three minigames. Each Configuration can be saved as a profile with a unique name. The parameter “mode” defines which sensor value is used to control the game. ErgoBalance allows for speed, cadence and heart rate as attributes for the control parameter mode. The game “Pigeon Hunt” allows speed and cadence as mode. Using the heart rate as control parameter is technically possible, but does not make sense according to the game concept and gameplay in the current version. The heart rate cannot be changed so quickly that it would be possible to collect the letters.

For each of the individual modes (heart rate, cadence, and speed) the targeted average value as well as maximum and minimum value can be defined. The average value is the value which keeps the controlled game element at the “regular” position. For the Pigeon game the bird is flying in the middle, for the Balance game the Clown is standing upright if the average value is reached. The minimum and maximum values define the allowed interval, if the target value is out of the range, the bird dies and the clown falls down. The size of the interval defines the coordinative difficulty of the game. A smaller interval requires the player to be more precise. For the speed values from 20 to 35 km/h with a stepping of 5 km/h are allowed. The cadence can be set from 60 to 140 rpm in steps of 10 rpm. The target heart rate is allowed to set from 80 to 220 bpm.


Figure 4. Screenshots of the Minigames ErgoBalance (left) and Pidgeon Hunt (right).

The exertion of the games depends partially on the above mentioned control parameters. Furthermore the duration of the game and the resistance of the ergometer can be used to control the overall exertion. The duration can be set in steps of 1 minute from 1 to 60 minutes. The cycling power of the bike can be adjusted from 60 to 200 Watts. The resistance is adjusted dynamically and keeps the power constant depending on the current cadence, this allows following training guidelines nearly independently from the gameplay. Alternatively to these fixed settings a dynamic adaptation algorithm allows playing at a specific heart rate for the defined amount of time, this mode is called heart rate adaptation. The desired heart rate range can be calculated automatically, corresponding to defined training goals.

$$h = p/100 * (220 - a)$$

With heart rate $h$, age $a$ and the percent $p$ of maximum heart rate (Robergs & Landwehr, 2002). The value $p$ depends on the selected training goal. The concrete settings the parameters which control the training stimuli, depend on training guidelines set up by experts. The Training Control API provides only the control possibilities.

## Evaluation

The evaluation was performed in a gym accompanied by a squash court. All participants took part voluntarily and were not paid. The participants were informed about the general concept of interactive indoor cycling and that the study will be about their personal opinion of the games.

The sample contains $n$=48 participants (age 14-64 years, M=31.69 years, SD=14.82, gender distribution: 70.8% male, 29.2% female).

As a first step the participants filled out a questionnaire about gender, age, sportiness, TV watching and computer use per day and their estimated personal fitness level. As an indicator for sportiness and TV watching the participants were asked how many minutes per week they are engaged in sports and how many minutes they watch TV or use the PC.


| Fitness level | Power (Watt) |
|---|---|
| Excellent | 140 |
| Good | 120 |
| Average | 100 |
| Sufficient | 80 |
| Poor | 60 |

Figure 5. Setting of the Power/Resistance of the Cycling Ergometer depending on the Personal Fitness Rating.

Furthermore the participants were asked to rate their own fitness level in 5 grades (1=excellent, 2=good, 3=average, 4=sufficient, 5=poor). Depending on this rating the power of the ergometer was set to a basis value of 100 Watts (equates to 3=average) +/- 20 Watts per level as shown in Figure 5, right table.

After these initial questions the participants played each game (Pigeon Hunt, Ergo Balance, Virtual Video) and filled out the corresponding questions immediately after playing a game.

Figure 6 shows that motivation is higher when playing Pigeon Hunt and Ergo Balance compared to Virtual Video (Friedman test: $\chi^2 = 44.98$, $p<.001$).

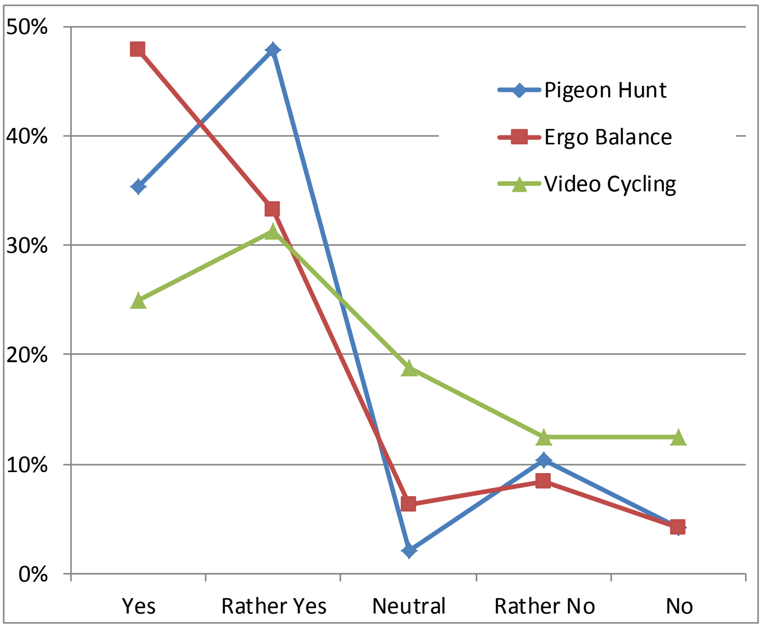


Figure 6. Answer to the Question "Does this game motivate you?" – Both Games, Pigeon Hunt and Ergo Balance, are more motivating than the Virtual Video Cycling.

Figure 7 shows that Virtual Video is rated differently by male and female participants. However, 3 (games) x 2 (gender) ANOVAs reveal significant gender effects only for exertion. The female participants rated the games more exhausting than the male participants, this implies that the gender should be included in the calculation for the setting of their power/resistance.

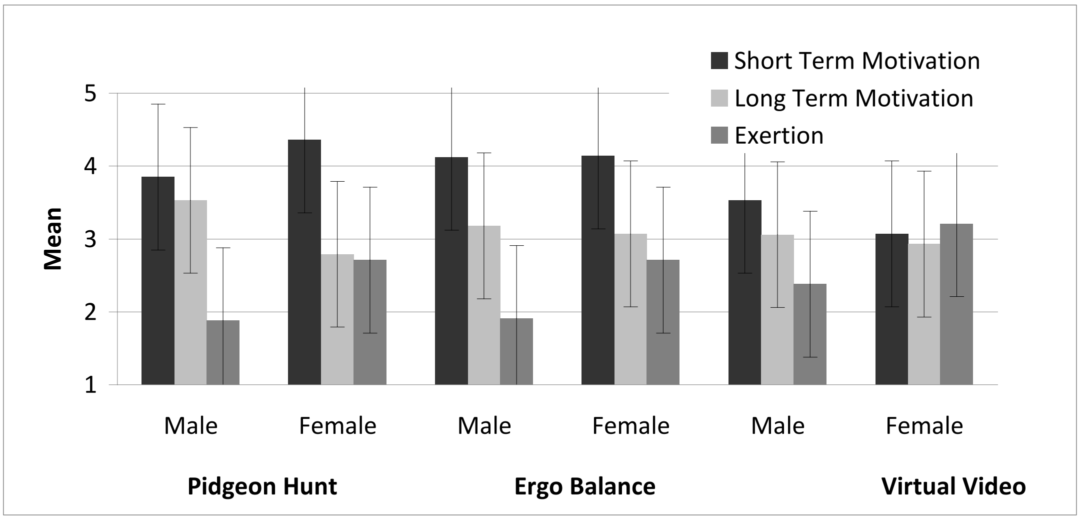


Figure 7. The Motivation, Long-term Motivation and perceived Exertion are rated differently, depending on the gender of the participants.

It was also calculated if the assessment of the games depends on the times the participants watch TV or use PC per day. This is not the case. The judgement is significantly related to the fitness level of the participants ($r$ = -.30; $2p$ = .036).


Figure 8. Correlation between the Personal Fitness rating and the perceived motivation.

As shown in Figure 8, people with a higher personal fitness rating find the applications more motivating than people with lower fitness rating. However, these differences are not significant.

Most people (83.3 %) answered that they would like to play the games again. More than three fourths (77.1 %) would prefer the games to the regular cardio training in the gym, but only a few (31.2 %) would buy such a system for the use at their homes.

## Summary and Outlook

In this paper a model was presented which identifies the relevant components which are needed for the development of exergames. The model describes the interaction between these components and can be used as the theoretical basis for the design, implementation and quality assurance of exergames. Grounded on this model a prototype was implemented which contains all the components and elements of the presented model. The prototype has been evaluated with $n$=48 participants. The results are discussed in this paper. It was possible to identify differences in the impact of different configurations of the software component of the model as intended by the model. The different gameplays of the 3 implemented minigames yield different results concerning the player's motivation. The overall results depend on the gender of the participations and their estimated fitness. The implementation of the games was rated as motivating by the participants for both, the short and long-term motivation.

The Training Control API allows adjusting the training load of the games (time, power, heart rate, speed, cadence), this way the prototype provides the ability to play at an arbitrary, user-defined level of exertion. It is reasonable but still an open question if this solution allows gaming at the same level of exertion as in a regular indoor training and if the EE is higher than during playing Wii Fit or Dance Dance Revolution.

The adaptation of exergames in the dimensions of gaming and sport allows the creation of attractive and effective exergames for a broad range of end users. The adaptation provides a low level of entrance for newcomer as well as a high challenge for experienced users.

For the future various studies based on the model are planned. The results will show if the model can be validated and if the model needs further refinements. The planned improvements in additional prototypes will allow changing single elements in the software (designs, feedback) and will allow further investigation of the effects of different realizations of the identified elements. For example, some people asked if the speed is shown as a number during the game Ergo Balance - the study did not address the question how this would affect the overall motivation and if this is a subjective wish or a general improvement.

An already planned extension is to compare the effects of the visual representation (2D-comic-style vs. 3D compared to autostereoscopic 3D displays) and its influence on the motivation and playability. The long-term motivation was included in the study only as a value estimated by the users, long-term studies together with gym will show if those estimations correspond to the real usage over a longer period of time.

A last but crucial issue is to show that the concept provides the opportunity for evidence-based successful training at all, this is planned to be tested in cooperation with experts from sport science and medicine.

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# Modern Principles of Training in Exergames for Sedentary Seniors: Requirements and Approaches for Sport and Exercise Sciences

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## Abstract

Reviews of the literature show that computer-animated games are ascribed a potential in motivating home-based exercise. In order to develop such "exergames" for sedentary seniors, three main tasks are identified and performed in this paper from a sport science point of view: First, a training target and physical exercises must be conceptualized, suitable for preventive training, for home-based execution and for integration into computer-animated games. Second, volume and intensity of the training have to be determined, including adaptations for different fitness levels and progression rules for continuous training. Third, criteria of movement quality should be defined for monitoring by technical sensors, recognizing beginning and end of series and decision-making on changes of training configuration on different time scales.

For each task, the literature is reviewed and the solution for the project at hand is described. The first and third tasks seem to be solved due to a comprehensive literature base and to technical development, respectively. On one hand, approaches to the second task can be based on well-accepted general principles of training. On the other hand, the status of underlying theories does not allow derivation of concrete values for volume and intensity. Therefore, specific trials are necessary.

KEYWORDS: ELDERLY, EXERGAME, PREVENTION, SERIOUS GAME, TRAINING PRINCIPLES

## Introduction

Due to demographic development, every third person will be over 60 years old in 2035. This development will have enormous consequences for the health care system. While the benefits of health-oriented physical activity are well-recognized, problems arise with application of this knowledge: Seniors often lack choices for preventive exercise (Hinrichs & Brach, 2011), which is

- appropriate, individualized and scalable
- attractive to beginners and supports motivating for sustainers
- based on modern training principles
- within reach even with impaired mobility

Recent technical development in video tracking, sensors, and computer-animated games allow for home-based technical solutions which meet such requests for preventive exercise. In this context, the term "exergame" has been established to demonstrate the combination of "exercise" and "game" in this specific form of computer-based games. Harley and colleagues (2010) demonstrated, how Nintendo's Wii in connection with a certain conception could be used to foster social processes in sheltered housing settings. Evaluations of the psycho-physical side of exergames, however, show an inconsistent picture. This might be due to the fact that using technology in addition to or instead of instructors or personal trainers implies special tasks for exercise physiology and sport science, which sometimes may not be solved in an optimal way. The aim of the present paper is

- to substantiate these problems from the perspective of sport science, and
- to introduce exemplarily an approach that was used to design an exergame system for seniors

This exergame system is part of a research project called "Motivotion60+", which is included in the research and development framework of *Ambient Assisted Living* (AAL) of the *German Federal Ministry of Education and Research* (BMBF). "Motivotion60+" aims at integrating prevention into the everyday lives of Senior Citizens. The goal is to maintain and to improve the physical and mental fitness of the elderly so that they can live healthy and independently in their own homes as long as possible. As the name of the project indicates by the combination of the terms motivation and motion, this goal shall be achieved through the motivation of the elderly to healthy physical activity. In this context, the project partners rely on a combination of familiar items like TV, as well as innovative devices. Sensors, web-based platforms and modern means of communication are used to motivate the target audience to sporting activities in a fun way. Outdoor, endurance-oriented activities belong to this project as well as indoor game-based exercises. While we believe that the general aspects discussed in this paper apply to both parts, the concrete solutions described below focus on the indoor games.

In the following section, we summarize reviews of comparable exergames. Then we derive three main problems to be approached by sport science, in order to design the exergame system as mentioned above: (1) conception of exercises, (2) conception of training stimulus, and (3) quality control and rules of change. Sections three and four contain literature-based approaches to the first and second problem. Section five gives a sketch on a multi-level control circuit we use to manage the quality and rule of change problem.

## Exergames and Sport Science

Before results gained by scientific research are summarized, the concept of serious games in general and more specifically the concept of exergaming are presented.

A *serious game* is a game not considered as an end in itself as games usually are. Serious games still should be entertaining, but in addition they serve an explicit and carefully thought-out purpose and are not intended to be played primarily for entertainment (Wiemeyer, 2009). Exergames are a particular form of serious games. The term exergame indicates that physical exercise and gaming is combined. The objective of these kinds of games is to motivate people to participate in physical exercise. This objective is reached by hiding the tiresome side of working out with the fun side of playing. Therefore, the whole exercise process seems to be more attractive (Görgü, Campbell, Dragone & O'Hare, 2010).

The beginning of this new active world has primarily started with the release of the Nintendo Wii in 2006. The Nintendo Wii is usually described as the most well-known commercial example of an exergaming platform. A major reason for the recent rise in interest in exergaming is linked to the concern over the current high levels of obesity in Western society (especially in children). It is hoped that the fascination that video games have for children can be harnessed to engage children in greater physical activity (Sinclair, Hingston & Masek, 2007; Hingston & Masek, 2007).

### *Summary from Evaluation Reviews*

Due to the fact that the Nintendo Wii is commercially the most successful product, most scientific studies have been conducted to test the potential of this specific game concerning motivation for physical activity. The results gained by these scientific studies can be summarized as follows:

- Böhm, Hartmann and Böhm (2008) as well as Graves, Stratton, Ridgers and Cable (2007) show that playing different exergames uses significantly more energy than playing sedentary traditional computer games but not as much energy as playing the sport itself. The achieved intensity values can be classified as effective with reference to the minimum training volume (Wiemeyer, 2010).
- Positive effects of playing exergames on elementary perceptual-motor performance (Green & Bavelier, 2007), reaction time and balance performance (Wiemeyer, 2010) have also been detected.

The results gained by Kliem and Wiemeyer (2010) confirm that the Nintendo Wii may be a suitable medium of training balance in prevention and rehabilitation of adults. However, as the overall efficacy of game-based training is not as high as that of "real" training, they claim for a development of more variable game-based training programs. The findings gained by Brumels and colleagues (2008) also show differential results referring to the effects of game-based training. Nevertheless, their results underline the potential of exergames with reference to motivation. The majority of participants perceived the game-based training as less demanding as real exercises. Moreover, the participants playing exergames reported about more joy in comparison to the participants carrying out the real exercises.

Although this paper focuses on the possibility to increase the motivation to more physical activity it should be mentioned that next to the potential of exergames to improve motor skills and abilities, studies also show that the therapy of cancer, diabetes, asthma, burns, and brain injury can profit from the application of serious games (Wiemeyer, 2010). Moreover, Baranowski and colleagues (2008) prove that players of exergames can be positively influenced either in their eating behavior or in their physical activity or even in both. Lager and Bremberg's (2007) literature review provides strong evidence that video and computer game playing in general has positive effects on spatial abilities, which are very important for problem solving. However, once more the authors criticize methodological deficits of many studies.

### *Conclusions From a Sport Science Point of View*

In general, authors of reviews seem to agree in ascribing exergames a large potential for motivation and support of healthy activities for different target groups. Beneath these encouraging results, another aspect is important for the design of the "Motivotion60+" exergame. Taking into account an exergame approach of "hiding the tiresome side" of exercise, it is not surprising if exergames fail to reach effective activity levels. Instead of this "game-first" strategy, exercises could be prioritized as follows: defining goals, planning exercises and training parameters as in advanced training, but then integrating this into a computer-animated game and a "story". A problem of this approach, however, could be the lack of a human instructor or trainer, who normally gives support and supervision to the athlete or client, and who not only designs plans on different time-scales, but also decides on short-term changes of the plan if necessary.

For the project at issue the decision was made to prioritize exercise in the sense of meeting modern training principles. On the other hand, concessions to motivation through games and stories were warranted as far as possible. From this basic conception, the following three tasks for sport science could be derived. They have to be solved within this project:

1. A conception of physical exercises has to be developed. Exercises should target on preventive training, be suitable for home-based training and for combination with computer-animated games.
2. Training parameters have to be determined in a dynamic way on the basis of training scientific principles. Users with different capabilities and fitness levels should be able to start exercising and individually increase training load without a trainer being present.
3. Criteria of movement quality have to be defined so that the quality can be monitored by technical sensors, the beginning and the end of series can be recognized and decisions can be made concerning changes of training configuration (i.e., advancement or fall-back) and to prevent that some user might trick the system (i.e., playing the game without performing the exercises correctly).

Specifying tasks from a sport science perspective does not mean that only sport scientists would deal with them. The tasks were worked on by an interdisciplinary team including game-designers, engineers and scientists. In the following three sections, snapshots of this work in progress are presented along the three tasks.

## Conception of Exercises and Integration into Computer-Animated Games

### *Rationale for the Development of the Virtual, Indoor Training Program*

A main target for the program development was to define relevant exercises for an older population as addressed in "Motivotion60+". Among the multitude of optional exercise forms a limited subset had to be selected which was adequate and feasible for the addressees of "Motivotion60+" and could be translated into the virtual training setting of the project.

As a first step we defined a training target which seemed feasible and had a substantial impact on quality of life and clinical prognosis in the target population. Based on the fact that fall risk is associated with aging with more than 30% of people over 65 years and 50% of people over 80 years suffering from a fall each year (O'Laughlin, Robitaille & Boivin, 1993) we chose "fall prevention" as the training target for our exercise program.

Motor deficits such as lack of strength, balance and functional performances such as walking or stair climbing have been identified as dominant risk factors for falls (American Geriatrics Society, British Geriatrics Society and American Academy of Orthopaedic Surgeons Panel on Falls Prevention, 2001). More recently, deficits in complex, motor-cognitive skills have been shown to increase risk of falling in epidemiological studies. Cognitive deficits as well as motor deficits including falls represent the dominant predictor for loss of independence (Lord, 1994). Loss of independence represents the most feared issue in older people's life and is more frequently rated as accidents, robbery, or even death (Salked, Cameron, Cumming, Easter, Seymour, Kurrle & Quine, 2000). Even when autonomy is not at stake, the sequelae of falls severely affect older people as functional (ADL) and instrumental Activities of daily living (IADL) will be lost permanently in up 50% of fallers after severe falls. (Lin & Chang, 2004). Apart from somatic traumata a large number of persons who suffer a fall, develop psychological trauma with respect to fear of falling associated with restriction of physical activity, increasing isolation and decreasing quality of life (Bruce, Devine & Prince, 2002; Kannus, Parkkari, Koskinen, Niemi, Palvanen, Jarvinen & Vuori, 1999; Stel, Smit, Pluijm & Lips, 2004).

A large number of well-designed, randomized interventional studies (RCTs) with standardized training interventions have been performed within the last 15 years (Gillespie, Gillespie, Robertson, Lamb, Cumming & Rowe, 2003; Gillespie, Robertson, Gillespie, Lamb, Gates, Cumming & Rowe, 2009). As a stand alone intervention or within multiple intervention strategies, exercise training had turned out to be the most frequent study intervention to prevent falls in a non-selected population. Intervention effects depend on the preselection of the study population, intensity and standardization of training and other methodological issues with training effects reaching up to a reduction of falls/near falls by 45% (Wolf, Barnhart, Kutner, McNeely, Coogler, Xu & Atlanta FICSIT Group, 2003) with an average of 15% in non-specific training programs and 25% in more specific training programs (Gillespie et al., 2003).

Based on results of systematic reviews and systematic meta-analysis, the use of progressive resistance training, even more the use of progressive functional training with focus on static and dynamic balance and functional training of motor performances such as climbing seems to be most effective. In contrast mere endurance training or walking sessions such as Nordic Walking did not show a significant reduction in risk of falling (Sherrington, Whitney, Lord, Herbert, Cumming & Close, 2008; Chang, Morton, Rubenstein, Mojica, Maglione, Suttorp, Roth & Shekelle, 2004; Gardner, Robertson & Campbell, 2000). Recently, complex training tasks including motor as well as cognitive challenges such as dual tasking or dance exercises had been included in interventional fall prevention studies or studies on risk factors for falls (Trombetti, Hars, Herrmann, Kressig, Ferrari & Rizzoli, 2011; Schwenk, Zieschang, Oster & Hauer, 2010).

The selection of training exercises in the present project "Motivotion60+" was based on the results stated above. Progressive training adjusted for individual performance levels of strength, dynamic balance and complex exercises with both cognitive and motor challenges were suggested as the core of training exercises.

In a second step we adjusted the selected exercise to the requests of the technical partners. Adjustments relate to the introduction of the exercises into the "story" of the training program (the flight of the participant to major capitals and related "typical" training tasks), the adjustments to technical request and the organization and rating of the training sessions according to different performance levels. Adjustments had been a compromise between optimizing physiological training effects and translation into motivating, virtual training locations.

### *Overview of Exercise Mini-Games*

The story of the “Motivotion60+” game is a journey to world-famous cities. Most of the seniors travel for private purposes (Gallup Organization, 2011). For persons with diminished capabilities for trips, continuing interests in foreign countries or cities can be assumed. Each city is represented by a “typical”, well-known scene (e.g. Venice: pigeons on Saint Mark's Square) or activity (e.g. Rio de Janeiro: soccer). The scene serves as framework for an exercise mini-game according to the conception presented above.

In total, seven mini-games were developed. They can be divided into three different categories: strength exercises, balance and stabilization exercises and complex exercises. In addition, knowledge facts on cities and countries are presented during each mini-game. Later, the user can test his or her knowledge through a quiz. The airplane flights between locations are also embedded into an exercise mini-game: while the plane is steered by whole body movements (lateral bending of the trunk, lifting the arms) with additional balance requirements (foot positions), collisions with birds or mountains should be avoided. Table 1 gives an overview of the seven mini-games according to the three categories, Figure 1 presents screen-shots.

Table 1. Overview of the seven mini-games according to the three categories.

| *Venue* | Plane | Rome | Paris | Paris | Venice | Rio | Athens |
|---|---|---|---|---|---|---|---|
| *Game story* | Steering the plane | Riding a chariot in the Colosseum chariot race | Climbing the tower of Notre Dame | Ringing the bell of Notre Dame | Chasing pigeons on Saint Mark's Square | Keeping the goal in the soccer stadium | Dancing Sirtaki |
| *Exercise category* | Balance and stabilization | Balance and stabilization | Strength | Strength | Complex exercises | Complex exercises | Complex exercises |
| *Exercise description* | Lateral bends, different foot positions, arms straight lateral | Lateral bends, different foot positions | Marching | Squat | Abduction standing on one leg | Sidesteps and lateral bends, reaction and time-to-contact | Dancing with single stand phases |

Exemplary, the mini-game “Chariot Race” with its basic idea and its training components is presented. The “Chariot Race” in the Colosseum of ancient Rome belongs to the balance and stabilization exercises. The exercise consists of steering the chariot through the Colosseum by leaning the upper part of the body to one or the other side. In addition, the player is challenged to collect coins that are lying on the ground by running over them, and avoid collisions with rivals. The speed of the chariot can be influenced by lifting one arm. There are several parameters, which are used to adopt this exergame to fitness and capabilities of the user, and also to define progression in the sense of exercise physiology principles. The underlying exercise is assigned to the balance category, which belongs to coordination as motor capability. Unlike endurance or strength training, the training parameters cannot be measured in SI units of work (volume) and power (intensity). Thus, definitions should correspond to the idea of extent and difficulty of exercising:

1. Therefore, exercise *intensity* is defined by task difficulty, which itself is determined by three foot positions: hip-wide stance, semi-tandem stance and one-leg stance.
2. Exercise *volume* is determined by the range of the lateral bending motion used to steer the chariot. Thus, a decrease in steering sensitivity—e.g., more bending is required for

a lane change during an overtake maneuver—is utilized to increase exercise volume.

3. Additional cognitive and sensori-motor challenges are controlled through the number of coins, i.e. chances to receive extra game points.

Whereas this exercise generally trains motor skills like posture control, it also imposes requirements to cognitive skills. During the game, the player has to react appropriately according to different situations (changes in the race course, turns, coins, rivals). Considering the coordinative skills according to Roth (2003), this exercise requires vestibular, kinesthetic and visual information and creates time, situation and complexity pressure.

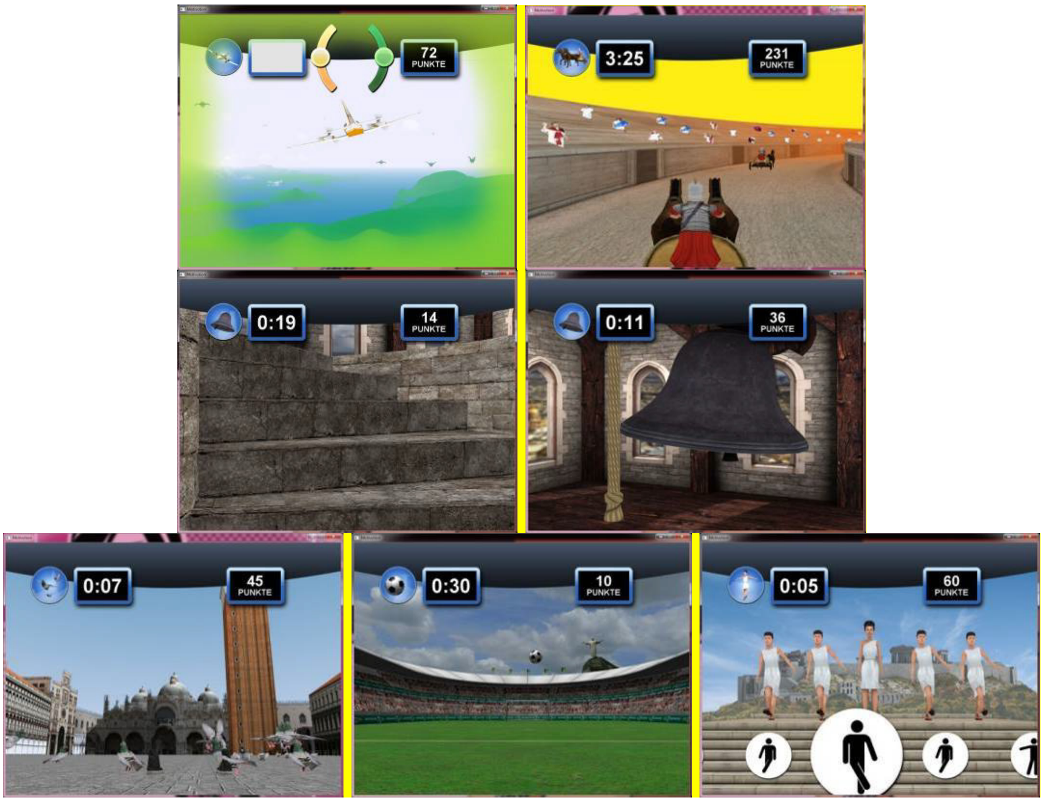


Figure 1. Screen-shots of the seven mini-games. Top row: balance exercises (flight, chariot race), mid row: strength exercise (stair-climbing, bell-ringing), bottom row: complex exercise (pigeon-chasing, goal-keeping, dancing).

## Parameters for Adaption and Progression of Exercise Requirements

The second task identified in the introduction is to determine start configurations of exercises and to assure training progression. In common training situations, a human instructor or trainer is responsible for planning and controlling the training process (Schnabel, Harre & Krug, 2008). The system of "Motivotion60+" replaces the role of a trainer. Thus, the training configuration of the different mini-games must be determined in advance. In the first subsection (4.1), helpful advice is searched in the literature. Afterwards (4.2), conclusions for the project are presented.

### *From General Principles of Training to Concrete Exercise Configuration*

Weight training can be used to exemplify the need for exercise configuration: How many repetitions in what velocity should be conducted? How much extra weight is to be moved over what distance? How many breaks are between the sets and how long should they be? In summary, the training configuration describes the training stimulus, which is ascribed to cause the favored biological adaptation, i.e. strength development. There is a large number of different training principles in exercise physiology, describing training methods and recommendations for dynamics of training configuration. They do not give any explicit instructions on how to organize the training process, but can be considered as general orientation according to three categories (Olivier, Marshall & Büsch, 2008, Table 9): (1) training principles derived from pedagogy, (2) general training principles related to performance development, and (3) specific training principles related to a certain (a) capability, (b) target group or (c) discipline. The following paragraphs contain principles that are considered important for the training configuration of the "Motivotion60+" mini-games.

The most important general principle is that the training stimulus must be above threshold so that biological adaptation can be achieved (Weineck, 2010). Furthermore, a training process should always be individualized, because a training stimulus can be adequate for one person and at the same time may be not challenging enough for another person. According to comparable principles developed by Harre, Richter and Ritter (1973), Letzelter (1978) and Schnabel et al. (2003), it is absolutely necessary that the loading increases systematically. Even if there exist numerous possibilities of how to increase the loading of someone's training, this article limits itself to explain the principles used for the training configuration of the "Motivotion60+" mini-games. One possibility to increase the loading is by increasing volume and intensity of an exercise. In training configurations for children or beginners the loading is normally increased by increasing the volume first followed by intensity. Another possibility is to increase the demands on movement coordination. With regard to the question on how much the load is increased, it can either be increased gradually or variably. In training configurations for children or beginners the loading usually increases gradually.

The training configuration of the mini-games had to be established in advance. Thus, it was necessary to define exactly when and how to increase the training load. Therefore, we conducted a literature research using "Sportdiscus", the largest literature database in sport science. The search terms *periodization, strength training, training volume* and *training intensity* were used. Most of the resulting papers and articles present an overview of this topic in the area of high-performance sport, whereas there was no result focusing on the training of the elderly which is of interest here.

### Conclusions for the Adoption of Training Principles

With reference to the training configuration rules found in the literature, it becomes clear that there are generally accepted and useful training principles. However, our literature search could not yield papers with concrete configurations suitable for the purpose of home-based training with the elderly. Concrete specifications of training parameters were exemplarily told by Stone (1981) and Fleck (1999a, 1999b) for high-performance sports. Loads between 1RM and 10RM (xRM being the repetition maximum load for a certain exercise which the athlete is able to perform x times but not x+1 times) clearly are neither suitable nor safe for health-oriented home-based training in the elderly (without instructor present). The idea of simply scaling down the load should not be expected to be helpful in adapting the configuration to the target group, because the other parameters would be influenced.

Considering the broad spectrum of capabilities in aged users starting the exergame, and considering adaptations by regular exercise, a very flexible system of training configurations with rules for upgrades but also for downgrades on different time scales is essential for successful training. Due to the research deficits mentioned above, we have determined a provisional training configuration in our system and will adjust it afterwards according to the results gained in the first user study. In addition, the system should generally be open to subsequent adaptations and future upgrades. This corresponds to the *open system approach.*

While training dynamics are thus left to further development, we were able to define an overall training volume by taking §20 SGV V (Fünftes Sozialgesetzbuch, Section 20 of Book V of the German Social Welfare Code) as a basis. This section allows health insurances to remunerate course fees, if the participant exercises ten weeks of 60 minutes each in a course of defined quality. Consequently, we set this value as an overall goal and used quality-assured exercise time as "currency" to measure exercise volume. Several regulations were defined:

- With regard to the conception of mini-games, the user has to play at least 20 minutes in each category.
- Only movements corresponding to established characteristics of training quality are considered as training time.
- Furthermore, we considered a minimum of 30 or 60 seconds, respectively, of uninterrupted playing as countable for categorial and overall exercise volume. This regulation is necessary to achieve a training stimulus which is above threshold.

Beneath these few regulations, individual freedom of choice to play the mini-games of individual preference, exercise variety and an ensured minimum degree of effective training are clearly the advantages of this program over group training.

### Control of Movement Quality and Decisions on Training Progression

The system should be able not only to set up and to adapt targets, but also to control what the user really does. Therefore, a multi-level control circuit was conceptualized. It is displayed in Figure 2. It consists of three parts: (1) a three level exercise configuration unit for defining a target, (2) a control unit to measure and to evaluate actual movements and game performance, and (3) a set of rules to decide on changes of configuration.

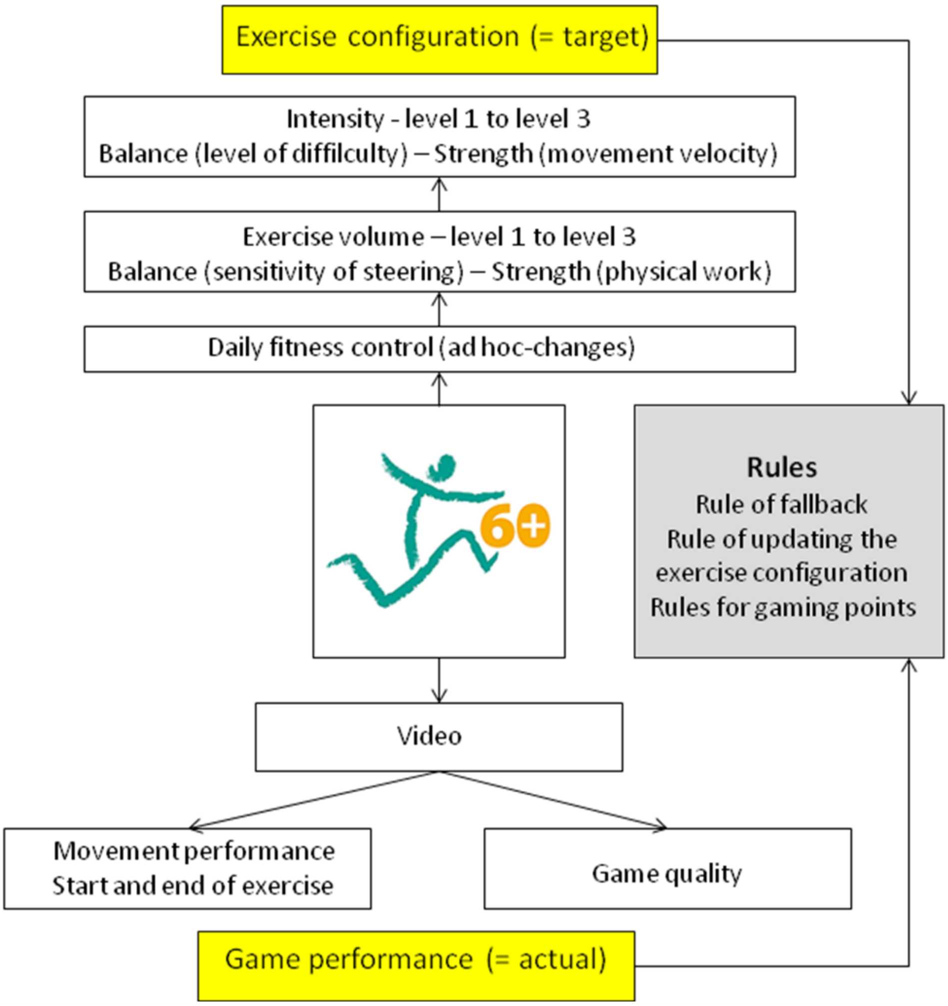


Figure 2. Multi-level control circuit for exercise configuration and quality control.

The exercise configuration unit is used to define the target exercise in three aspects:

- *Daily fitness control:* In the first frame individual intensity is adjusted by ad hoc-changes during a play-through. These are small adaptions to the user's daily conditions and efforts. For example ad hoc-changes in the mini-game "Chariot race" are produced by increasing or reducing the number of coins and rivals.
- *Exercise volume*: The second frame adjusts the volume of an exercise within the same game level when starting a new play-through. Increasing volume means increasing the number of movements or increasing the range of motion within a single movement. In the "Chariot race", the range of motion is increased by a less steering sensitivity. This means that the user has to conduct a stronger lateral bend in order to steer the chariot through the Colosseum.
- *Exercise intensity:* If the exercise was performed successfully with maximal volume, the level of difficulty is increased by a new game level with higher intensity, e.g. a more demanding foot position in "Chariot race", a higher movement speed in strength exercise.

A Kinect video-tracking system (Microsoft) is used to record data on actual performance. The actual game evaluation unit is used to analyze these data with regard to four tasks:

- Start, end and type of exercise is identified.
- Uninterrupted exercise time, total time per exercise, overall exercise time are recorded for purposes of training plan.
- Exercise quality is evaluated by predefined parameters. Data on movement correctness can be used to give feedback to the user.
- Game-related data is recorded (e.g. number of coins collected, number of birds eluded) in order to count successes, points and other rewards.

Comparing target exercise with actual movements, the base of rules is used to assure three features in order to make the system adaptive and flexible:

- In case of overtaxing the user automatically falls back to a lower level ("fall-back"). For example when the user commits too many mistakes that is in the case of "Chariot race" to miss too many coins or collide with too many rivals.
- In addition, the user has always the possibility to go back to a lower level by using the "smoother"- button.
- When the number of correct exercise units (exercise time) necessary for a configuration upgrade is reached, progress in the training plan (see configuration unit) is initiated.

## Discussion

Within the research and development project "Motivotion60+", an exergame system for elderly people was conceptualized. The technological implementation is appropriately done and significantly improved through Microsoft Kinect. Meanwhile, two prototypes are tested in a feasibility trial.

With regard to the theoretical design we can conclude, that "Motivotion60+" is still behind due to the insufficient theoretical knowledge in training science. While general principles are widely accepted, we did not find rules how to define concrete values for training progression with the target group. As a consequence, training parameters have to be substantiated through the experiences of the feasibility and acceptance trials. For this purpose, an authoring system (StoryTec) will be used. Changes in volume and intensity values, but also position coordinates and angles used to define movement quality will be easily changeable.

Considering the large differences in fitness status found in seniors, maybe automatic rules of training progression will be insufficient even after further research. If manual intervention will be necessary in the future, the open system approach used in design of this exergame could also be helpful in later use cases: Exercise experts or even geriatric carers could adjust and scale the system for target subgroups or individuals using the authoring system. Again, hints and directions for further research & development steps can be expected from user trials, but also from the scientific community.

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# Virtual Sports Teacher – A Serious Game in Higher Education

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## Abstract

*Virtual Sports Teacher* is a Serious Game which is being developed by sports scientists, computer scientists and media scientists, funded by the HMWK (hessian Ministry of science and art). The primary target group of the game are physical education teacher students. In the game they can practice the procedure of a typical sport lesson, learn how to treat pupils and arrange different sport exercises. A Game Master, the course teacher of a university tutorial, can adapt the game at runtime according to the player's performance. The Game Master is able to view important statistics, to modify difficulty or to trigger game events. In Section 1, we explain the need for new forms of teaching like Serious Games. In Section 2, we present the game *Virtual Sports Teacher*, followed by a detailed description of the didactical and Game Mastering concept in Section 3. In Section 4 we conclude with an overview of future work.

KEYWORDS: SERIOUS GAMES, HIGHER EDUCATION, PHYSICAL EDUCATION, TEACHER, SPORT

## Introduction

Educationalists are calling for a modern teaching that is closely related to life. Teaching should no longer ignore the new information and communication technologies because technology has now become an important part of the childrens' and young adults' life. Disregarding the new media means to exclude an aspect of the childlike everyday life. Thus, basic tasks and goals would be neglected. Rather than reject these technologies, such as for example video games, teachers should take advantage of them.

A digital game, that combines playing and learning is called a Serious Game. Unfortunately, so far, Serious Games have been mostly met with resistance or suspicion. They were not trusted to stimulate the learning process, although it is proven that playing and learning are closely interrelated in human development. The connection of both is a natural state and is later separated only by the institution of school (Breuer, 2010). McLuhan and Fiore (1968/1997, cited from Prensky, 2001) said "*Anyone who makes a distinction between games and education clearly does not know the first thing about either one*".

Despite of the negative prejudices, the concept of Serious Games has become more and more popular during the last decade. Serious Games offer various fields of application (Susi, Johanneson & Backlund, 2007; Sawyer & Smith, 2008), like Serious Games for sports and health (Baranowski, Buday, Thompson & Baranowski,2008; Wiemeyer & Goebel, 2010), prevention and rehabilitation (Griffith, 2004; Wiemeyer, 2010), energy awareness (e. g. Enercities[1]), political awareness (e. g. Global Conflicts series[2]), in the military sector (e. g. Americas Army[3]), and finally Serious Games for education (e. g. Scoyo[4]).

There are now a number of Serious Games available for elementary school and high school. For the higher education like university, there are fewer games, and for the teacher training, to the best of our knowledge, there are none (Mitchell & Savill-Smith, 2004; Egenfeldt-Nielsen, 2005). In the project "Virtual Sports Teacher" an educational Serious Game for the teacher education, specifically for the Physical Education (PE) teacher education is being developed. The project is funded by the Hessian Ministry of Science and Art (HMWK). The project partners are the Hessian telemedia technology competence centre (httc), the Technische Universität Darmstadt, the Hochschule Darmstadt, and the University of Gießen.

## The Project – Virtual Sports Teacher

"Virtual Sports Teacher" is a 3D game in which the player takes the role of a PE teacher practicing a typical sports lesson. The game can be played in a single-player and in a multi-player mode. The Game Engine Unity 3D[5] and the authoring tool StoryTec (Mehm, Göbel, Radke & Steinmetz, 2009) were used for developing the game.

The game "Virtual Sports Teacher" combines theory and practice of learning and teaching in sport. The player equips him- or herself with knowledge from sport science, and learns how to teach sports to students in an autodidactic way. The player learns to convey skills in a virtual environment by using different didactic methods. Phases of practice are followed by phases of reflection. The main purpose is to activate and integrate knowledge normally taught by isolated courses like sport psychology, sport pedagogy, and movement science within an authentic teaching context (gym of a school).

The (virtual) teacher is mainly acting in a gym, presented as a 3D environment. The 3D environment comprises the teachers' room, the principal's office, and the gym consisting of a main hall and an adjacent room containing the sports equipment.

The player's Graphical User Interface (GUI) contains an overview of the pupils' personality and skill level and a bar displaying the total activity and the total mood of the pupils (see Figure 1). For example, if a student gets an exercise that is too difficult or too easy his/her mood will be affected. If he/she has to wait at an exercise station for too long, because there are too many other students, the mood also drops. If the player takes too long to build and structure the apparatus or if a student gets hurt because of an incorrect set up of the apparatus the mood of all students will drop.

To ensure individual support, there are various buttons for interactions with the Game Master (GM), for chatting and for game-related actions. Under the tab of the folder, the player can get useful information about the topic of the lesson. The player can talk to the pupils via a set of predefined statements or look at a self-made summary sheet.

[1] www.enercities.eu/
[2] www.globalconflicts.eu/
[3] www.americasarmy.com/
[4] www-de.scoyo.com/
[5] www.unity3d.com/


Figure 1. Screenshot of the game Virtual Sports Teacher.

## Goal

The purpose of the project is to develop and evaluate an educational Serious Game in the form of a role play game. As a final result, the game will connect game aspects and learning aspects in a way that, ideally, while the player is caught in a flow, he/she acquires knowledge effectively and efficiently, and learns to apply this knowledge to practice. The user is intended to expand his/her competences to act successfully in the context of physical education.

## Target Group

Target group are students of sport science, particularly students of the PE teacher program and tutors in the sport and PE sector. The players' previous experiences in teaching are usually very heterogeneous; presumably, most players (students) have few practical experiences. Even the level of knowledge is likely to be very heterogeneous. In the game, this heterogeneity will be considered.

## Learning Goals

Concerning the learning effects of an educational Serious Game, players always learn something about the game itself. In addition to the explicit and implicit rules of the game, players will learn game-specific skills. Beyond that, digital games have effects on the users' knowledge and skills exceeding the scope of the game itself. Under certain circumstances, the acquired knowledge and skills can be transferred to other areas of life (Egenfeldt-Nielsen, 2005; Breuer, 2010).

By playing the game, the player can improve his or her teaching skills. He/she can get to know concepts, models, laws, etc. in the fields of physical education. He/she can enhance his/her self-efficacy relevant to act in front of a class, experience fun, acquire and apply knowledge and skills to increase his/her competences of successful teaching in PE. Foremost, the users should learn what he/she has to do in each situation and to consider what the rules are in dealing with students. To enhance teaching competences and to enhance self-efficacy the different tasks in the game have been constructed according to "scripts", i. e. a pre-structured order of actions the player has to initiate in order to solve the task. These scripts become increasingly complex according to the different levels of the game.

## Story (Narrative Framework)

The principal of a model school is in a bad situation, he is desperately looking for a good PE teacher. The best and most dedicated PE teacher of his school has been seriously injured and is unable to conduct his sports lessons. The player of the game is asked to replace the missing teacher. Proven to be a good PE teacher, the player may, according to the game level, raise in his/her position. Starting in the position of a substitute teacher, He/she can first receive a temporary and later on a permanent contract. The ultimate goal is to be appointed tenured German civil servant. To proceed from one level to the next, the player has to manage teaching assignments successfully, for instance, performance of a gymnastics lesson intended to teach a back extension role (backward role to handstand). This teaching assignment is performed in an authentic sports lesson. For a successful work with the pupils the player is awarded score points. If the students are unhappy, bored or unmotivated the player will lose score points.

While the game is played some foreseeable and unforeseeable incidents happen which the player has to master. As an example, pupils may get injured, argue or fight or the principal may appear spontaneously.

By applying a realistic story with surprising incidents an increase in motivation, challenge and tension is expected. Score points and feedback are used as a rewarding system to confirm adequate actions and decisions in the game.

## Characters

The following playing characters are acting in the game:

- The PE teacher
  At the beginning, the player can choose his/ her character, the name of the character and its gender. The teacher is at the beginning of his/her career. Starting as a substitute teacher, he/she tries to shine with good performance and climb the ladder.
- The principal
  He cannot be played by the player him-/herself, but by the lecturer or the course teacher. The GM takes the role of the principal and can trigger several actions like an accident of a pupil.

There are also Non Playing Characters acting according to predefined scripts:

- Pupils/students
- Colleagues

## Goal of the Player

The player, in the role of a PE teacher, has to perform in an authentic teaching-learning situation. In this context the player has to make appropriate decisions about core aspects of motor learning with respect to the situation and target groups (i.e., the virtual pupils). Within this process, the player has to establish the integration of knowledge coming from different disciplines of sport science, e.g., movement science, sport psychology, and sport pedagogy. The player must observe and evaluate the movements of students and, if necessary, correct them by means of appropriate visual and verbal instructions or other methods. Besides the sports movements, the player analyzes situations, identifies problems and responds appropriately. Prior to the lesson, there are several organizational activities which have to be done by the player: structuring the lesson, selecting exercises and arranging the selected exercises and teaching methods in the correct order.

By playing the game, the player is intended to learn the following competences:

- How to structure and plan a sports lesson
- How to assemble the apparatus, which mats to choose and where to place them in order to avoid accidents (see Figure 2)
- Which methods and exercises to use to teach the students
- What are the main errors of a certain movement and how to correct them
- Which assistance to render for the exercise stations
- How to explain the assistance to the pupils
- How to arrange the order of the exercise stations
- How to motivate the students
- How to solve problems like arguments, fights, accidents, etc.

As mentioned above, these tasks can be successfully solved according to task-specific scripts. For example, to reach the main part of gym lesson, the player must process some actions in the correct order. He/she must gather and welcome the children first and then check presence and clothes before he/she can enter the room with the apparatuses. In the main part the player is subjected to very few restrictions. He/she can leave the room, interrupt the lesson or leave the students practicing alone, etc.

## Sequence of a Lesson

During the game, the user must meet various teaching assignments. He finds his next teaching assignment in his box in the teachers' room.

To give an example:

- Assignment: physical education with a 5th grade (10 students, 5 males and 5 females).
- Lesson content: Learning the back extension role.

As a next step, the player can prepare himself in the staff room by using sources provided in the game (e.g., learning courses) or he can directly enter the gym. After having entered the gym, the player first has to analyze the given situation. He must get an overview of the gym and his students. For instance, he has to check whether there are any apparatuses left from his predecessor or where the students are located and what they are doing. The system enquires whether the player has screened the entire gym. It is important for the progress that a certain order of procedure (script) is maintained. During the first part, the teacher has to convene and welcome his pupils. After this procedure, he has to check the presence of his students and make sure that the students wear appropriate workout clothes. If he omits this check, there is a risk that a child gets injured.

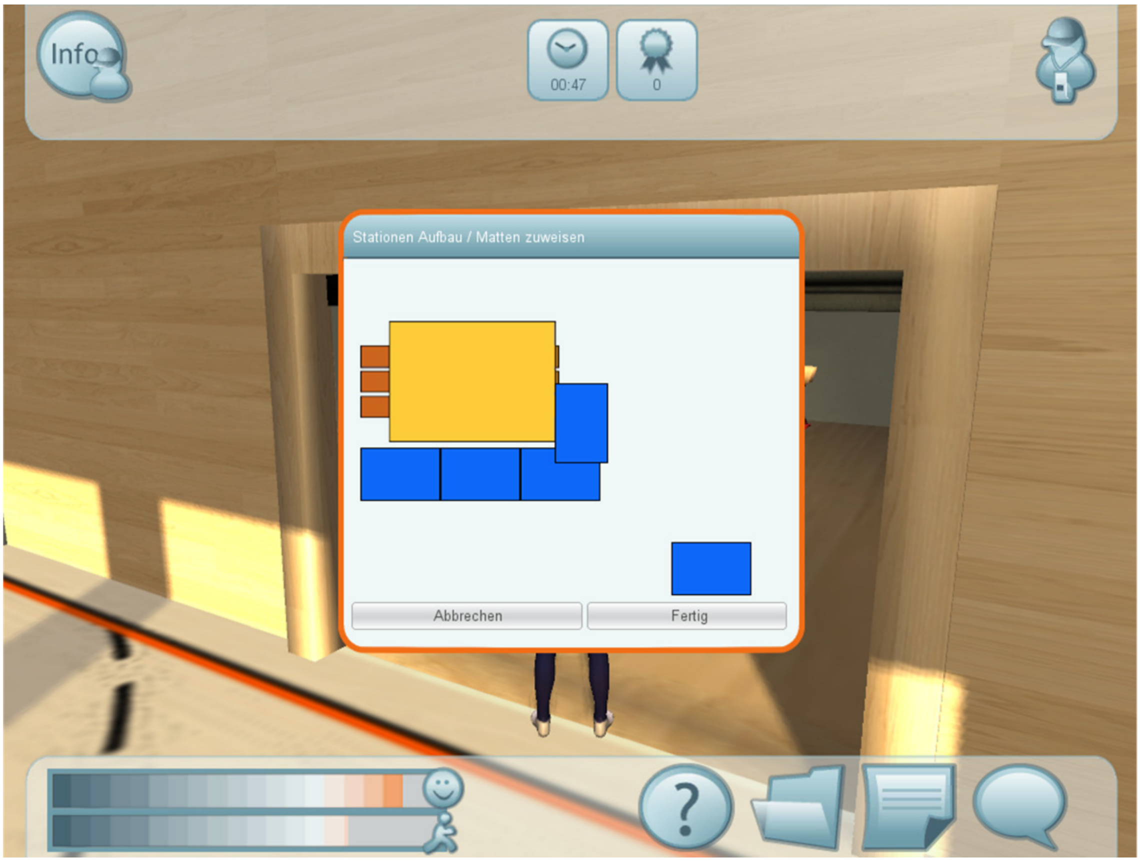


Figure 2. Screenshot of the game Virtual Sports Teacher, scene: placing the mats.

The second part of the lesson consists of the warm-up. The player must choose appropriate exercises according to the goal of the lesson and arrange them in proper order (exercises for general warming, stretching and coordinative practicing, matched to the lesson's content). After this he has to organize the build-up of the gymnastics apparatuses. The challenge is to equally engage all students in this process. If this is neglected, the students may start to dispute. After the devices have been located, the mats have to be placed in the correct position. If the player chooses too little mats or wrong mats, students may hurt themselves when practicing.

During the main part of the lesson, the teacher is more flexible in her/his actions. He/she has to fulfil the following requirements:

- He/she must assign the students to several exercise stations, depending on their skill level.
- At each station, the player must choose the adequate helping or securing position.
- His/her main task is to review gymnastic motions and to correct errors of his/her students.

- Doing this, the player must not lose sight of his/her pupils out of view. He/she must place him-/herself in a way that he/she can always see most of the students. If the player is positioned inadequately, some students may start to scuffle.

Furthermore, the player must cope with and solve disturbances that may occur during class. Typical situations are, for example, an argument or fight between some of the students or an accident caused by a defective apparatus. By chance, the principal (played by the course teacher) may come along and pose difficult questions about the teaching methods, biomechanics of the skill or first aid.

Towards the end of the lesson, the player must organize the decomposition of the devices, so that every student is involved. Finally, the player says goodbye to his students.

Preparation, organization and structure of the lesson and the actions of the teacher during the lesson will be evaluated, so that the player can obtain a detailed feedback

## Effectors and Tools

### *Summary Sheet*

Any player can create his/her own summary sheet. Before the player starts with his/her PE lessons in the gym he/she can gather information from different sources provided in the teacher's room and include them in his summary sheet. Information is provided by integrated digitized books, the World Wide Web and web-based training (WBT), consisting of e-learning classes (e. g. biomechanics, functional analyses, educational teaching, etc.) (see Wiemeyer & Hansen, 2010). The player can take the sheet to the gym and use it any time.

### *Folder*

The folder is the guidance for the player, left by his/her predecessor, the injured teacher. In this folder, the player can get specific information from the disciplines of sports medicine, training science, movement science, physical education and sports psychology. This information is precisely matched with every teaching assignment.

The folder is always visible to the player. Related links are integrated into the individual files of the folder. To click them and get further information, the player must pay some of his/her score points.

In skill questions, the player can use the acquired knowledge and win back points. With the correct answers, the player gets more points than he/she has previously invested.

### *The Principal and Further Players*

In the single-player version the principal can help the player with predefined hints. In the multi-player version the principal, played by a course teacher in a university tutorial, can help with individualised aid. The principal can communicate with the player, direct his/her teaching process and help him/her in critical situations. The multi-player mode enables cooperative and communicative phases between the principal and the player, but also between individual players. Thus, the course teacher can pose questions or tasks which the player has to answer or solve directly, or the players can interact with each other to find solutions or alternatives.

## Game Mastering Concept

The concept of Game Master is rooted in pen&paper roleplay games (Tychsen, Hitchens, Brolund & Kavakli, 2005). In such games, the task of the GM is to create a suspenseful story while keeping the game and thus the story open to influences of the players. The GM has to react to ideas and actions of his/her players in a way such that the story is not disrupted too much by unforeseen actions but also has to take care that the players do not get the feeling that their actions do not matter. To achieve this, the GM has to be able to always react to the players' actions having in mind the overall goal of the story.

In "Virtual Sports Teacher", we adopt this principle. However, the GM's primary task is not to adjust the game in order to create suspenseful story but to help the player/learner having a perfect learning experience. Therefore, the GM needs to influence the game in terms of difficulty and speed and alter it if necessary.

To do so, the GM needs a comprehensive in-game overview of the player's performance. So the question arises how to provide the GM with the necessary information, i.e. what parameters must be visible to the lecturer in order for him/her to be able to judge the game and learning situation correctly.

Moreover, we provide the GM with a toolset to adjust, modify, and adapt the game at runtime. So, the second question is how to provide the instructor with appropriate methods and tools to adjust the game according to her estimation of the situation.

## In-Game Assessment

The Game Master needs to know what the player is doing at every time. For this purpose, we allow the GM to view the complete gym. The GM is not bound to an avatar, but instead he/she is bodiless and can oversee the whole scene. However, if desired, the GM can take the role of the school principal to actively take part in the game. This is a method of taking influence on the game without interrupting the gaming experience in an unnatural way (seamless learning, see Wendel, Göbel & Steinmetz, 2011).

In addition, the GM needs a special interface providing information about the current state in the gym. This information includes:

- The game time
- The pupils' mood
- The pupils' activity
- The state of each pupil
- All current actions of the player
- Events to occur in near future

The simulation/game time is simply displayed by a timer. The overall mood and activity bars are displayed in the same way as for the player. The state of a pupil includes information about the pupil's current activity, his/her current mood, and other static information, like character traits. All player actions are logged internally for an automatic evaluation of the player's performance. The GM is able to view the logged actions in-game. Furthermore, the GM can see all the player's interaction windows when they appear.

## In-Game Reaction

In addition to the need for assessment, the GM also needs to be able to react to the player's actions. Therefore, we provide him with an integrated toolset enabling him to influence/adjust the game ad-hoc if necessary. The GM can trigger unexpected events, like a child having an accident, in order to increase the difficulty. On the other hand, he/she can prevent the game from triggering such actions automatically. When the virtual students are performing exercises, the GM is furthermore able to have them make exactly the errors he/she wants in order to focus on the errors he/she regards as important.

Just like in real class, the instructor will occasionally want to give hints or correct the learner if necessary. For this reason, the GM in "Virtual Sports Teacher" is not only a spectator who can trigger events, but he/she is also able to communicate directly with the player in form of a dedicated in-game chat.

In order to enable the GM to interact with the game in a more realistic and direct way, he/she can also take on an in-game role, the role of the school principal. If the GM chooses to do so, he/she plays the NPC of the school principal, illustrated by an own avatar in the game world. Being the principal, the GM has the same assessment and control options, but is illustrated as a real in-game person so he/she can actually "play" the role of the principal, giving special tasks to the player or inquiring knowledge in-game, thus improving the degree of realism.

## Hypotheses of Advantages of this Serious Game

We expect the following advantages by playing Virtual Sports Teacher (see also Hays, 2005):

- Individual motivation by challenge, control and curiosity: The game offers an increasing level of difficulty, different learning contexts – meaning different sport skills – and takes learning preferences and gender issues into account.
- Sustainability: The game can be used not only during university courses but also be played and practised at home.
- Scalability/ social interaction/ interpersonal motivation: It is keen because more players can play this game than students can be taught in a course. Social interactions are supported in the multi-player mode.
- Economy: It is cheaper and less time-consuming because it is impossible to allocate classes with pupils for every PE student to practice and to arrange all possible situations in a systematic way.
- Transition from university to school (self-efficacy): A 'practice shock' can be avoided. The PE students are better prepared for the tasks of a teacher. By experiencing success in the game their self-efficacy will be enhanced.

## Future Work

A prototype of the game is just being subjected a formative evaluation. As a next step, when the game is finished, there will be an extensive evaluation. We therefore plan to deploy the game in a real university class of PE students. The following parameters will be evaluated: effectiveness and efficiency of learning, game experience, e.g., motivation, fun (e.g., Nacke, 2009) and immersion, the use of the GM role and replay-ability. Also, the question has to be addressed, if the content to be taught is visible as such. The evaluation of the use/role of the GM will include comparisons of gaming sessions with and without a GM. The evaluation of game experience like motivation, fun, immersion and replay-ability will be done by a qualitative player interview and specific surveys. The usefulness of motion capture will be tested in a game usability laboratory by means of eye-tracking, mouse tracking and by a user experience and game experience questionnaire.

After analyzing the test results, the revealed shortcomings are to be eliminated and further evaluation will be performed.

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# Remedial Games – Tools for Therapy

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## Abstract

Ranj Serious Games developed 'Juf-in-a-Box', an innovative system to train young children with fine motor skills disorder and method for preparatory writing based on gaming principles. Juf-in-a-Box is an educational, therapeutic computer game, developed in collaboration with experts in the field of pediatric physiotherapy, designed to offer a solution to fine motor skills disorder and writing problems within primary education.

KEYWORDS: SERIOUS GAMES, PAEDIATRIC PHYSIOTHERAPY, NEUROMOTOR TASK TRAINING (NTT)

## Introduction

Writing has become a major issue in primary education. Motor writing problems are common. Figures in the literature range from 5-25% (Hamstra-Bletz, 1993; Smits-Engelsman, 1995; Mojet, 1991). Despite the growing importance of the computer, it is still a sizeable problem. Learning to write well by hand actually influences language development, reading comprehension and the development of fine motor skills.

## Starting Point

In today's primary education, too little time is spent on training the motor writing skills, when in fact it requires a lot of practice before a motion is stored in the motor memory. In theory, half an hour per day is reserved at primary schools for classroom writing teaching, but in practice this is often much less. Thus, apart from the fact that children practice far too little, they don't get the immediate feedback they need during classroom writing and insufficient account is taken of their individual development.

Children with fine motor disorder usually get professional pediatric physiotherapy treatment. Equal to the education the time a young patient spends exercising and the immediate feedback are crucial for the therapeutic success. Many children find doing writing exercises is far too boring. There is something to be said for that. Finally, there really are far more exciting things to come up with than just endlessly practicing the same movements.

## Juf-in-a-Box

The solution to these problems is a technology that combines an accepted treatment methodology and gaming techniques in one system. A system that supports pediatric physiotherapists and teachers by taking over a number of tasks in the area of fine motor skills disorder and teaching writing. An application that allows the children to practice over a long time at their own level and continuously guides them in this process.

But how do you get children motivated to do the same writing exercises over a long period of time? The exercises should then be more exciting, more challenging and more fun, like in a game. Playing is innately human. Through play we not only learn to understand our environment, to acquire social skills and to use language, but also to move ourselves. In recent decades, partly due to cultural changes and new multimedia opportunities, children's play has gone through an enormous development. Children are becoming more used to playing games on the computer. Educational games are becoming increasingly popular and research shows that they actually are instructive. Yet there is still skepticism by education professionals about their educational value, or uncertainty about implementation within the school timetable. The fact remains that children throw themselves into games with a fanaticism and focus that the average teacher would be jealous of. *Serious games* combine this motivating factor with the achievement of specific learning goals. And so Ranj Serious Games came up with the idea for Juf-in-a-Box: a writing method based on gaming combined with a system that measures and analyses the child's actions, and thus can make course corrections exactly where it's necessary.

## Methods

Juf-in-a-Box uses easy to understand software and hardware. Using a stylus similar in size to a normal pen, the pupil writes on a writing tablet that is also a monitor. The visual display on the screen follows the movement without delay. In addition, the surface of the writing tablet is provided with a coating, making the writing with a stylus on the tablet feel just like writing with a pen on paper. The child receives exercises that train the fine motor system at his or her own level and immediate feedback, while the game elements ensure that the child remains motivated. That way, there is enough time given to the tasks in order for the movements to be stored in the motor memory.

Due to the graphical interface, the game is instinctively understood. Through this, the system is suitable for children from 4 years, hence also for children who cannot yet read.

## Neuro-Motor Task Training (NTT)

Fundament of the Juf-in-a-box system is the underlying methodology. While the child is playing the game, he or she is actually engaged in exercises that train each of the fine motor skills and form a preparation for the ultimate writing of letters. All exercises in the game are created by working closely with experts in the field of pediatric physiotherapy. In addition the scientifically proven *Neuromotor Task Training* (NTT) is used (Niemeijer, 2007). The NTT writing methodology is based on a task analysis of the writing movement. This has led to a specific methodology of writing exercises, whereby in the preparatory writing skill, the neurological writing conditions are first trained, then the basic strokes and finally, the series of strokes (Smits-Engelsman & van Tuijl, 1999).

An important feature of the game is that the preparatory writing movements are guided by the animations (environmental conditions). This means that the child writes more spontaneously and thus doesn't always have to think about movement control, which results in them learning implicitly.

Figure 1. Example of a neuro-motor condition NTT exercises.

With the NTT, the work is more task-oriented than process-oriented. Previously, general motor processes such as hand-eye coordination, the balance or muscle strength were addressed in the assumption that an improvement of the writing would follow naturally. Not anymore. Research has shown that it has too little effect. Letting children roll on a big ball or sway to and fro on a swing for the purpose of stimulating writing is simply not effective. In a task-oriented approach for teaching writing, the attention is focused on writing tasks that the children need and looks within the writing tasks at the components that the child has not yet mastered. The skill is analyzed in many increments and consideration is given as to whether it makes sense to exercise those aspects as part of the whole. Furthermore a lot of attention is paid to the *transferability* of exercises: the translation to use in daily life.

The NTT is based on the knowledge acquired in recent years about the neural development of young children, the way children practice their motor skills and the effect of the method of instruction.

Figure 2. Example of exercise translation into game play.

## Translation of the Methodology into Game Play

In Juf-in-a-Box, the player finds themselves in a strange sort of zoo. Unlike a normal zoo, you won't find any elephants and tigers here, but a motley collection of fantasy creatures and kindly monsters. By using the stylus, the player must ensure that they help keep the zoo clean and tidy by doing all sorts of jobs. For example, the highly explosive *Boembollen (Boom Bulbs)* should be planted in the right flower boxes and the *Plensplanten (Splash plants)* must be watered, but then without the monsters in the vicinity being sprayed with water. The many monsters that live in the zoo could also use some help from the player. There's the vain *Loenskukel (Cross-eyed Cuckooloodle)* who's completely lost her hum because her eyelashes are all mixed up. By redrawing the eyelashes, the player can make this strange bird with its eyes out on stalks, cheerful once again. Or the *Muggenzifter (Gnatty-nitpicker)* a mosquito-eating, whale-like monster that needs help in restoring order to his whalebones. By drawing slanting lines with the stylus you help him back on the road. And then there's the *Scharluinen (Scarlet beasties)*. The shells of these monsters could well use a brush-up! By making circles with the stylus, the player can make the shell shine beautifully again.

The player is lead through all these tasks by a little elf. This cheerful little character explains exactly what needs to be done with each exercise and gives specific feedback on the input the player gives during the game. The elf helps the player where necessary, will encourage him or her to improve themselves and introduce new exercises when the player is ready for it.

Figure 3. Example of Juf-in-a-Box game characters.

## Usability and Target Group Tests

Of course, during the development process work is not only done with experts in the field of pediatric physiotherapy. While making the game an important role is laid out for teachers and children. They are the ones who actually have to use the game later, hence it has to meet their wishes and needs as best as possible. Therefore regular testing sessions are held in which parts of the game are presented to teachers and player. The reactions that emerge from these test sessions are then included in the further development of the game.

Figure 4. Usability test during development.

## The Role of the Teacher

The fact that children can work independently with 'Juf-in-a-box' does not however mean that the teacher has become an insignificant link in the learning process! On the contrary: Juf-in-a-Box is a powerful tool but still requires the guidance of a qualified teacher. Because it allows each child to work at his or her own pace, the teacher can then also pay more attention to the children who need it. The teacher can also log in and review each pupil's progress within the game, see what problems are occurring in which components and serve up specific exercises to the pupil.

## Value Add for the Pediatric Physiotherapist

Juf-in-a-box follows the principles of the NTT methodology as they are used in the pediatric physiotherapy treatment for children with fine motor deficits. The system analyses and monitors the actions of the young patient and stores this information. This gives the pediatric physiotherapist a full insight in the development, individual strengths and weaknesses of the young patient.

Another important advantage of the Juf-in-a-Box system is that gaming the reward system motivate the patient to perform the necessary actions and therefore process the training.

## Conclusion

The current issues in education and healthcare call for the development of new methods and the use of new technologies. Juf-in-a-Box is an exceptional tool for the treatment of fine motor skills disorder and offers an innovative answer to the writing issues within primary education. The development of the system can't stand still. Finally, an innovative method like Juf-in-a-Box must remain innovative. Reactions from pediatric physiotherapists, occupational therapists, teachers and pupils who will soon use the game also serve as input for improvements and expansions.

In addition, developments in education are not standing still and the current rapid developments in the field of tablets are bringing many new opportunities, ones that are interesting for future versions of Juf-in-a-Box.

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# Ant-based Approach for Dynamic Difficulty Adaptation in Post-Stroke Therapeutic Games

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## Abstract

Post-stroke therapeutic games can be considered as a promising rehabilitation tool since they provide personalized rehabilitation sessions in which training intensity and challenge can be manipulated and adapted to each patient. In this short paper, we describe an adaptation framework dedicated to pointing games. This approach has been implemented and tested with the RehabCraft game as a case study. Besides, we describe an on-going experimental evaluation of the proposed framework.

KEYWORDS: THERAPEUTIC GAME, DIFFICULTY ADAPTATION, POST-STROKE

## Introduction

A stroke after a cerebrovascular accident (CVA) is a medical emergency that can cause inability: to move one or more limbs on one side of the body, to understand or formulate speech, and to focus one side of the visual field (i.e. neglect effect). The specific abilities affected by stroke depend on the location, type and size of the lesion. Each patient is then characterized by a specific combination of deficits. Several studies suggest that intensive training (many repetitions) with positive feedbacks and motivation improves recovery (Cirstea & Levin, 2007; Levin, Sveistrup & Subramanian, 2010). Therapeutic games can be considered as a useful rehabilitation tool since they enable personalizing rehabilitation sessions according to the patients' abilities and training needs. In fact, the gaming environment allows manipulating training intensity, difficulty, duration and frequency. It offers also the opportunity for therapists to monitor and analyse rehabilitation sessions at real time and offline. Game based therapy has also to fulfil game design principles and rules in order to be entertaining, engaging, and fun while serving its therapeutic objectives. The aim of this paper is to present an adaptation framework to dynamically adjust difficulty of pointing tasks in games while taking into account patient's current motivation.

## Related Work

Several works have already used games in the field of post stroke rehabilitation. (Broeren, Claesson, Goude, Rydmark & Sunnehagen, 2008) have conducted an experimental study that demonstrated usefulness of computer games in training motor performance. The training sessions included several games with different difficulty levels. The difficulty level of each game was preset manually by the therapist and could not be changed during the game session. We suggest an automatic and fine-grained adaptation of pointing tasks difficulty within games.

(Burke, McNeill, Charles, Morrow, Crosbie & McDonough, 2009) and (Crosbie, McNeill, Burkem & McDonough, 2009) have proposed a low cost webcam system where the player has to touch widgets such as arrows and buttons to control its actions within the game. In this work, the emphasis is made on meaningfulness of games and feedback to engage patients. Although an initial range of motion is assessed, controls are placed without taking into account the current motivation level of patients. By contrast to this statical approach, we suggest a dynamical adaptation of game objects positions to either challenge or support the patient depending on his/her motivation.

(Ma, Charles, McDonough, Crosbie, Oliver & McGoldrick, 2007) propose an adaptive post-stroke rehabilitation system based on a virtual reality game. The therapeutic game aims to improve functional arm capabilities, visual discrimination and selective attention using three difficulty levels: beginner, intermediate and expert. Based on a clinical evaluation such as motricity index (Demeurisse, 1980) the system suggests an appropriate difficulty level of the game. Using clinical metrics such as the motricity index is an interesting approach however in practice few therapists are ready to accept performing large number of assessments. To avoid this acceptance problem, we suggest assessing automatically patient's motor skills without requiring intervention of therapists.

(Cameirao, Badia, Oller & Verschure, 2010) propose a personalized training game called Spheroids. The adaptation consists in providing an appropriate task difficulty by capturing specific features of the movements of the arms. The adaptation technique adjusts frequency, speed and size of spheres based on a statistical analysis. The statistical model developed is too specific to the Spheroid gameplay where the player has to catch incoming spheres. The goal of our proposed framework is to be generic so it can be used in several games where the gameplay is based on pointing tasks.

Finally, we can notice that all presented works make a strong link between adaptation aspects and gaming aspects. Therefore, games are dependent and constrained by the difficulty adjustment technique. Consequently, most of reviewed games can be considered as exercises rather than games with a significant lifetime. We propose to make a clear separation between the adaptation of pointing tasks aspect and the gaming aspect. The benefit of such separation is to decrease technical constraints on the game design. By analogy to "path finding" in games, the adaptation of pointing tasks is considered only as a generic technical tool that does not interfere with the game design.

## Proposition

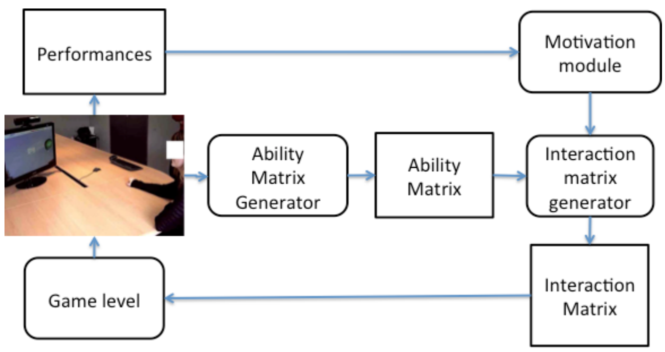


Figure 1. Overall process of dynamic difficulty adaptation.

The overall process is presented in Figure 1. The patient interacts with game objects by moving his/her hands on a work plan (a table). Due to stroke, he/she finds it more or less difficult to reach certain areas of the work plan. The first step assesses patient's movement abilities. This allows building a model about patient's movement abilities called *ability matrix*. The actual game needs some information to steer interaction with the player to certain areas (hotspots) of the work plan. This is provided by a structure called *interaction matrix.* The interaction matrix generator takes into account patient's ability matrix and a recommendation from the motivation module to either increase decrease or maintain the difficulty level of pointing tasks. We describe in the following paragraphs more in details this process.

## Ability Zone

*Definition: An ability zone* $A(m,n)$ *is a matrix of dimension* $m \times n$ *where m represents the number of rows and n the number of columns. Each cell* $A[m,n] \in \mathbb{R}$ *represents an easiness score for the patient to reach the mapped area of the work plan.*

The ability zone models patient's movement capabilities within a 2D work plan. The goal of constructing such model is to build an instantaneous image of the patient's movement capabilities.

### *Building the Ability Zone*

Ant algorithm was originally introduced by (Dorigo, 2004) as a metaheuritic to solve problems such as finding an optimal path in a graph. In our context, principles of the ant algorithm are used to construct the patient's ability zone as follow: (i) an ant is virtually located on the patient's hand; (ii) by moving his/her hand, the patient makes the ant exploring the work plan; (iii) the ant deposits a digital pheromone following the movement path of the patient. The rationale behind of this approach is to consider that all areas that have been reached several times by the patient as easy areas and unexplored areas as difficult.

*Propagation law:* the propagation law is an important feature of the digital pheromone since it allows approximation of difficulty of nearest cells without requiring the patient to actually explore them. In fact, it is reasonable, to some extent, to assume that the patient could reach a cell near to already reached cells. However, the farther the cell is the less confident we are about this statement. Consequently, the pheromone signal has to be decreased with distance.

*Evaporation law:* the evaporation law is as important as the propagation law since it allows forgetting areas that have been reached by chance. In fact, since the patient's movements are not totally controlled, the patient can reach involuntarily some areas of the work plan. Thanks to the volatile nature of the digital pheromone these areas are ignored by time.

## Interaction Matrix

*Definition: An interaction matrix of dimension* $m \times n$ *is defined as* $I(m,n)$ *where m represents the number of rows and n the number of columns. Each cell* $I[m,n] \in \{0,1\}$ *contains a binary value indicating whether or not an interaction with the player is desired within this cell.*

The interaction matrix is used to orient interaction with the patient toward specific areas. The interaction matrix can be used to either: (i) increase, (ii) decrease, (iii) or maintain the current difficulty level. In fact, depending on successes or failures of the patient, a motivation module has been developed in (Hocine, Gouaich, Di Loreto & Joab, 2011) to provide one of the following recommendations:

- Increase difficulty level: this happens when the player is in a situation of consecutive successes so he/she may find the game too easy. To maintain his/her engagement and avoid boringness difficulty is increased.
- Decrease difficulty level: this happens when the player meets a situation of consecutive failures. In this situation, difficulty level is decreased to reengage the player within the game.
- Maintain difficulty level: the player is reaching a steady state that should be maintained.

*Case 1: Increase difficulty*

When the motivation module suggests increasing the difficulty this means that the player is succeeding too easily which may produce boringness and decreases his/her engagement. The goal is then to explore more difficult cells. However, it is important to create a constructive dissatisfaction thus it is not recommended to select too difficult areas of the plan. These requirements are translated as selecting outside frontier of the ability zone. A simple gradient based algorithm is used where the gradient of each cell indicates direction of increase or decrease of the pheromone:

$$grad(A_{i,j}) = \sum_{k,l \in i-1..i+1, j-1..j+1} (A_{i,j} - A_{k,l})$$

In this case the interaction matrix is constructed by a *challenge* function that simply keeps only cells with negative gradient:

$$\text{Challenge}(X)_{i,j} = \begin{cases} 1, & grad(X_{i,j}) < 0 \\ 0, \text{otherwise} & \end{cases}$$

*Case 2: Decrease difficulty*

When the motivation module suggests decreasing difficulty this means that the player is failing too much. This suggests that reachable work plan is too large regarding the player's current capabilities. The solution is then to come back to known areas where the player was succeeding. This is performed by selecting the inner frontier of the ability zone. In this case the interaction matrix is constructed by a *support* function that keeps only cells with a positive gradient:

$$\text{Support}(X)_{i,j} = \begin{cases} 1, & grad(X_{i,j}) > 0 \\ 0, \text{otherwise} & \end{cases}$$

*Case 3: Maintain difficulty*

In this case the motivation module recommends maintaining current task's difficulty level. Consequently, the previous interaction matrix is maintained.

## Case Study: RehabCraft Serious Game


Figure 2: RehabCraft game.

(a) RehabCraft game environment

(b) player build virtual objects by following the construction step

(c) Example of an object construction

This section illustrates how the proposed approach is integrated with a rehabilitation game named: RehabCraft (Figure 2). The patient plays a role of a artisan working at a workshop to build virtual artefacts. All artefacts could be sent by the patient to relatives as gifts to promote social interaction and inclusion of the patient. The patient receives requests to build artefacts (see Figure 2 (b)). Each request contains a blueprint that steers the construction of the objet.

All actions in RehabCraft follow the point and click pattern (see Figure 2 (c)). Although the patient cannot actually click, she/he has simply to wait a certain amount of time to simulate a click. The adaptation module is integrated with the game engine and is asked to generate the interaction matrix. The interaction matrix of the player is used to place all points (hotspots) in the game scene. The player is then asked to reach these points to complete actions such as cutting woods, painting and so on. The adaptation module is used as an external tool or library to steer the interaction within the game.

## Conclusion

In this short paper, we described a generic difficulty adaptation framework for pointing tasks in therapeutic games. As stroke patients' failure rate is usually high, our adaptation technique allows adjusting the difficulty of pointing tasks to meet patient's abilities and increase their motivation. A simple case study has illustrated how this adaptation framework has been integrated to RehabCraft game.

To experiment with the presented framework, we are conducting a pilot study with healthy players. In fact, before experimenting with patients and disturb their classical rehabilitation program (planned for at least five weeks), it is necessary to experiment with healthy persons. Nonetheless, the experiment scheme with healthy players has to simulate difficulty of pointing tasks. The experiment follows a repeated-measures design where each player plays with a random strategy (session A) of difficulty adaptation and our proposition for difficulty adaptation (session B). Player reports on his own perceived difficulty, frustration and fatigue using the DP-15 scale (Delignieeres, 1996) for both sessions A and B. We have expressed the following experimental hypothesis:

H0: There is no difference between session A and session B concerning the success rate of pointing tasks

Our goal is to demonstrate experimentally that players will succeed more frequently using our adaptation framework. Interviews and open questions are also programmed to get players' feedbacks and perceptions.

The presented approach is generic and can be applied to a family of games based on point-and-click. The DDA server is accessible as an open source project (GPLv3) at http://gforge-lirmm.lirmm.fr/svn/mags/dda/

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# Teaching High School Physics with a Serious Game

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## Abstract

This study explores the research domain of using serious games to support learning processes. In particular, we examined the effect of a serious game on teaching high school students electrical engineering theory. We compared the abilities of two groups of high school students to answer questions on this subject immediately after they received instructions on it. The first group received its instructions by means of a serious game, the second group by means of a text. We discovered that the group that received its instructions via a serious game performed significantly better than the text group in solving the assignments. Surprisingly, the group that received its instructions via a text indicated that they were better motivated. Further analysis revealed gender differences: males benefitted most from instruction via a serious game, while females were better motivated by a text. From our results we conclude that, at least in our application domain, serious games can be more effective in supporting the learning process than written texts, but that they do not necessarily motivate students better than a textbook.

KEYWORDS: SERIOUS GAMES, TEXTBOOKS, HIGH SCHOOL PHYSICS

## Introduction

The term “edutainment” refers to entertainment games that have the ability to educate players. Such games are also referred to as “serious games”. Similar to serious games are so-called “educational games”. Both types of games are focused on developing the skills and knowledge of their players. However, serious games can be distinguished from educational games in that they are designed to look more like commercial videogames than their counterparts. The educational content of serious games is implicit in the gameplay, rather than an explicit component as found in educational games (Johnson, Vihjalmsson & Marsella, 2005). Winn (2008) states that serious games play as entertainment games, but have been designed to serve a purpose beyond just entertainment.

Some work has been done to investigate the effectiveness of educational games for learning processes (Bourgonjon, Rutten, Vanhooren & Soetaert, 2010; Gibbs, 1992; Kim & Chang, 2010; Lieberman, 2006; Pandey & Zimitat, 2007; Squire, 2003; Virvou, Katsionis & Manos, 2005; Zepp, 2005). Egenfeldt-Nielsen (2007) provides an extensive overview of such research. A general conclusion from this work is that playing games motivates the students, and better motivated students achieve better results. In a literature search we could find some – but not much – work that had examined whether the results achieved for educational games could also be applied to serious games (Van Eck, 2006; Squire, 2005). In general, in educational games knowledge is represented explicitly, while in serious games knowledge is represented implicitly in the game mechanics. Therefore we cannot assume that serious games are as effective in the classroom as educational games. The aim of the present research is to investigate how effective a particular serious game can be in transferring knowledge in comparison with the use of a textbook.

We use the serious game *E and Eve's Electrical Endeavors*, which is designed to instruct high-school students on electrical engineering. We compare the effectiveness of using this game to teach the students about transistors with a textbook that provides the same information. We are interested in the question which students are able to answer questions about electrical engineering more effectively, and in a comparison of the motivational effects of both instruction techniques.

In this paper we first provide brief background information on serious games. We then describe our experiment, discuss the achieved results, and derive our conclusions.

## Serious Games

Serious games are games that have a purpose beyond entertainment, e.g., education, training, advertising, or supporting social change (Winn, 2008). Such a combination is no guarantee for success (Van Eck, 2006). Brody (1993) notes that the combination of entertainment and education in computer games has produced some not-very-educational games and some not-very-entertaining learning activities.

For a long time, educators tended to ignore computer games as a source of education (Van Eck, 2006). Nowadays, however, the role of games in education is increasing (Squire, 2003; De Freitas & Oliver, 2006). It is surprising that in general it is assumed that games will have a positive influence on education, but there is very little research that supports that position. One aspect of educational computer games that has been investigated are graphics. Benjamin (2010) showed that realistic graphics in a game are beneficial for the educational value of the game. He concluded that realism in educational games has a positive influence on knowledge transfer, as long as some room for imagination is being left. Bourgonjon et al. (2008) found that games may help students in developing collaboration skills.

A possible reason why serious games are assumed to be beneficial for education is that students are often motivated to play games. Svinicki (1999) showed that traditional schooling methods do not tend to motivate students. It is generally assumed that well-motivated students learn better. Winn (2008) showed that games are effective at engaging students which makes them active learners. Virvou et al. (2005) showed that certain hard-to-teach students showed improved concentration when playing an educational game. Such results lead to the common assumption that an educational game, which by its nature should motivate, is better at transferring knowledge than the methods used in traditional schooling. Of course, the pitfall is that a game might be a less suitable medium for transferring knowledge, leading to a motivating but ultimately less effective educational experience.

## Experimental Setup

To investigate the effect of using a serious game in the classroom, we ran an experiment in which we let a group of high-school students play a game that taught them electrical engineering theory, in particular the use of transistors. A second group of students was given a text which taught exactly the same material, using the traditional method of providing theory using a text, followed by example questions for practicing. We then compared the abilities of both groups in answering questions on transistor theory, and examined their motivation in working with the learning material. We now describe the game that we used, the participants, and the experimental procedure.

### Game

The game we used is called *E and Eve's Electrical Endeavors*. It is an online serious game that was developed by the Eindhoven University of Technology. The purpose of the game is helping players to develop skills and acquire general knowledge about electrical engineering.

The game starts with a brief introduction in which the player is shown that the playable character is trapped in electrical wires. The character has to move through the wires in order to escape. The player has to solve issues with resistances, transistors, and power shares, while moving through the wires (see Figure 1).


Figure 1. Screenshot of E and Eve's Electrical Endeavors. In the lower middle area of the screen the playable character is moving trough electrical wires. On the left of the screen a transistor is seen.

After every completed level the issues encountered are explained. The game consists of four chapters with ten levels each (except for the fourth chapter, which consists of only one level). In our experiment the students played only the first two chapters. In the first chapter the player is introduced to the controls and playing techniques. The second chapter teaches the player about transistors.

### Participants

In our experiment 187 third-grade Dutch high-school students of two different schools participated. Both these schools were of the highest level of Dutch secondary schooling (Voortgezet Wetenschappelijk Onderwijs: VWO). 47% of the participants were male, 53%

were female. 7 participants did not indicate their gender (see Table 1). The average age of the participants was 14.6 years. 97.8% had the Dutch nationality. 78.7% indicated that they had previous gaming experience. None of the participants was previously instructed at school about transistor theory.

In each repetition of the experiment, the participants were randomly divided into two groups by either the teacher or the investigator. One group was called the “game group”; the students in this group were assigned to play the game. The other group was called the “text group”; the students in this group were assigned to study the text. In total 97 participants (52%) were placed in the game group, and 90 participants (48%) were placed in the text group. Of the game group, 48 participants were male, 44 female, and 5 did not report their gender. Of the text group, 37 participants were male, 51 female, and 2 did not report their gender.

### *Procedure*

The experiment took place in a computer room of the participants’ high school. One classroom had been reserved for this experiment. The experimental procedure followed a schedule that took one hour to complete (see Table 1).

Table 1. Experimental procedure.

| *phase* | *time limit* | *game group* | *text group* |
|---|---|---|---|
| introduction | 5 min. | instructions and assigning groups | |
| learning | 20 min. | playing the game | reading the text |
| testing | 20 min. | solving assignments | |
| survey | 10 min. | filling out the survey | |
| closing | 5 min. | powering down computers and leaving the room | |
| total | 60 min. | | |

The classroom was divided into two sides, and each of the students was randomly assigned to one of the sides. On each desk a computer with an internet connection was installed. It was not previously determined which side of the room would play the computer game and which side would read the text. After the teacher or investigator had randomly decided which side of the room would be the game group, and which side would be the text group, the investigator introduced the purpose of the research and the overall process of the experiment to the participants [introduction].

The students received written instructions. The instructions for both versions were similarly structured, but referred to either the computer game or the text. The printed instructions of the text group were followed by the actual text and training exercises. The students started working after receiving the instructions. The game group played the computer game, and the text group read the prepared text equivalent and worked on the example exercises. None of the students had previously received instructions by their teacher on the subject matter. They were allowed to collaborate with other students in their group during this phase [learning].

After the students had finished playing the game or studying the text, or 20 minutes had passed, the students were asked to stop working on the learning phase. They had to close down the game (game group) or hand in the text (text group), after which they received a set of 6 multiple-choice questions on transistor theory. They had 20 minutes to answer the questions.

Two example questions are displayed in Appendix A [testing].

Next, the students completed a short personal survey (see Appendix B), in which they were also asked about their motivation during the experiment. 10 minutes were available for this phase [survey].

Finally, the students were asked to power down their computers and leave the room [closing].

## Results

We now discuss our results, in sequence: (1) the effectiveness of the students in the game group and text group in answering questions on the theory; (2) the proclaimed motivation of each of the groups; (3) gender differences; and (4) the students' opinion on the use of serious games in the classroom. An alpha level of .05 was used for all statistical tests.

### *Acquired Knowledge*

To measure the difference between the game group and text group in total number of correctly answered questions an independent ANOVA was conducted. The results are displayed in Tables 2 and 3. Note that two participants did not hand in their test results; these were left out of the analysis.

Table 2. Group statistics for total correct answers.

| group | *N* | *M* | *SD* | *SE* |
|---|---|---|---|---|
| game | 96 | 3.31 | 1.182 | 0.121 |
| text | 89 | 2.96 | 1.215 | 0.129 |
| total | 185 | 3.14 | 1.208 | 0.089 |

Table 3. Results of ANOVA between group and mean of correct answers.

| variance | *SS* | *df* | *MS* | *F* | *p* |
|---|---|---|---|---|---|
| between groups | 5.901 | 1 | 5.901 | 4.115 | .044 |
| within groups | 262.445 | 183 | 1.434 | | |
| total | 268.346 | 184 | | | |

There was a significant effect of the assigned group on the number of correctly answered questions ($F(1,183) = 4.115$, $p = .044$). These results indicate that, on average, the participants of the game group provide significantly more correct answers on the assignments than their counterparts of the text group.

We wanted to exclude the possibility of the game group containing more students who were doing well at physics anyway, so we measured the difference between the game group and text group's means of their most recent physics grade. We found no significant difference between the groups' means of physics grades ($F(1,183) = .031$, $p = .861$).

Therefore we may conclude that the game we used is better able to transfer knowledge than the corresponding text which provides the same information. It is interesting to note that according to Pearson correlation there was no significant relation between the students' most recent physics grade and the score on our test ($r$ = .127, $p$ = .088), though the significance value indicates that there was a small trend that showed that doing well at physics increases the test score.

### Motivation

The participants were asked whether they enjoyed their assigned task (Appendix B, question 3). To measure the difference between the game group and text group in motivation (enjoyment) an independent ANOVA was conducted. The results are displayed in Tables 4 and 5. Note that one participant did not answer this question; this person was left out of the analysis.

Table 4. Group statistics for motivation.

| group | *N* | *M* | *SD* | *SE* |
|---|---|---|---|---|
| game | 96 | 2.82 | .833 | 0.085 |
| text | 90 | 3.12 | .776 | 0.082 |
| total | 186 | 2.97 | .818 | 0.060 |

Table 5. Results of ANOVA between group and motivation.

| variance | *SS* | *df* | *MS* | *F* | *p* |
|---|---|---|---|---|---|
| between groups | 4.161 | 1 | 4.161 | 6.400 | .012 |
| within groups | 119.645 | 184 | .650 | | |
| total | 123.806 | 185 | | | |

There was a significant effect of group on motivation ($F(1,184)$ = 6.400, $p$ = .012). These results indicate that the participants of the text group reported a significantly higher motivation for their assigned task. This result is surprising, as games are assumed to provide higher motivation than texts.

In previous research we noted clear gender differences when computer games are used. We therefore repeated the previous test for the two genders separately. For the male participants, we discovered that there was no significant effect of group on motivation ($F(1,82)$ = .603, $p$ = .440). For the female participants, however, the analysis showed a significant effect of group on motivation ($F(1,93)$ = 3.975, $p$ = .049). Therefore we may conclude that the female students were better motivated by the text than by the game.

### Gender Differences

Since we already noted gender differences for motivation, we decided to examine gender differences in our experiment in more detail. We started by measuring whether there was an effect of gender on number of correct answers on our test, using an independent ANOVA. The results are displayed in Table 6 and 7. Note that nine participants did not specify gender or did not hand in their test results; these were left out of the analysis.

Table 6. Gender statistics for number of correct answers.

| gender | *N* | *M* | *SD* | *SE* |
|---|---|---|---|---|
| male | 84 | 3.49 | 1.227 | 0.134 |
| female | 94 | 2.86 | 1.142 | 0.118 |
| total | 178 | 3.16 | 1.220 | 0.091 |

Table 7. Results of ANOVA between gender and number of correct answers.

| variance | *SS* | *df* | *MS* | *F* | *p* |
|---|---|---|---|---|---|
| between groups | 17.405 | 1 | 17.405 | 12.443 | .001 |
| within groups | 246.190 | 176 | 1.399 | | |
| total | 263.596 | 177 | | | |

There was a significant effect of gender on number of correct answers, indicating that males performed better than females ($F(1,176) = 12.443$, $p = .001$). We also found that males claimed to spend significantly more of their free time on gaming than females ($F(1,177) = 53.008$, $p < .001$; Appendix B, question 7). Considering that the subject matter is physics, these results are rather stereotypical, so not unexpected. However, while the number of males in the game group was close to the number of females, for the text group the number of females was 40% higher than the number of males. As males seem to do better at physics than females, and males reported more game experience, this raises the question whether the better results of the game group on our test can be explained by the ratio of males and females being askew.

We already noted that there was no significant difference between group and mean of last physics grade. But as males do better on our test than females, we decided to measure whether there was a difference between the groups in the number of correct answers that each of the genders gave. The results for males are displayed in Tables 8 and 9.

Table 8: Male group statistics for number of correct answers.

| group | *N* | *M* | *SD* | *SE* |
|---|---|---|---|---|
| game | 48 | 3.73 | 1.144 | 0.165 |
| text | 36 | 3.17 | 1.276 | 0.213 |
| total | 84 | 3.49 | 1.227 | 0.134 |

Table 9: Results of ANOVA between males of each group and number of correct answers.

| variance | *SS* | *df* | *MS* | *F* | *p* |
|---|---|---|---|---|---|
| between groups | 6.509 | 1 | 6.509 | 4.505 | .037 |
| within groups | 118.479 | 82 | 1.445 | | |
| total | 124.988 | 83 | | | |

We found that for males, the mean of number of correct answers for the game group was significantly higher than for the text group ($F(1,82) = 4.505$, $p = .037$). For the females, we found no such significant difference ($F(1,92) = .283$, $p = .596$).

We therefore conclude that the serious game we used seemed to teach the male students the theory more effectively than the text, but that the female students gained no benefit from the game over the text.

### *Games in the Classroom*

When the participants were asked whether they would like to play serious games in the classroom more often (Appendix B, question 8), 78.7% answered positively. This opinion seems to contradict our conclusions on motivation. There was no significant association between gender and whether or not students would like to play serious games in the classroom ($\chi^2(1) = 1.158$, $p = .282$). However, the text group professed a higher preference for games in the classroom than the game group ($\chi^2(1) = 7.257$, $p = .007$).

## Discussion

Our results show that serious games can be a supporting factor in learning processes, though they are not necessarily more motivating than texts. These results contradict previous research conducted by Squire (2005), Virvou (2005), Gibbs (1992) and Mujis and Reynolds (2001). Their studies show that computer games in education do motivate the students better than traditional schooling methods.

Before discussing these results in more detail, we need to point out that this study contained at least three weaknesses in its design. Firstly, no pre-test was done to determine the students' knowledge on transistor theory before they played the game or read the text. While the teachers indicated that transistor theory was a completely new subject for them, we cannot exclude that some of them acquired knowledge about this subject area through other means. Secondly, we did not include a control group that completed the assignments without playing the game or reading the text. Therefore we cannot be sure that the students gained any new knowledge at all, or how much knowledge they gained. Thirdly, for practical reasons we allowed the students to collaborate during the training phase if they wished to do so. Therefore any knowledge gained cannot be attributed to the game or the text with certainty. Because of these weaknesses, our conclusions should be regarded mainly as hints for future research.

We found that the female participants evaluated the computer game as less motivating than the text. We offer two possible explanations for this result. Firstly, the theory concerned electrical engineering, which in The Netherlands is considered typically a male subject. It is possible that a lack of interest in the subject material had an adverse effect on the female students' opinion on the game. Secondly, in general females tend to show less interest in computer games than males (Lucas & Sherry, 2004).

Even though the survey showed that the game did not have a motivational effect on the participants, the investigator who observed the participants during the experiment noticed that the game group immediately started playing the game, while the text group was not motivated to start reading the text at all. The text group had more complaints and asked more questions. Although the participants were randomly divided into the two groups, many students indicated that they would rather play the computer game than read the text (no notice was taken of gender differences in this respect). It should be noted that the behavior of the students in the text group might have influenced their effective learning time negatively.

The results on motivation are so contrasting with other research, that in hindsight it is deplorable that we did not set up our experiments to investigate this variable in more detail, so that we could offer stronger explanations for our findings. In the present research, we just asked one question on the enjoyment of the task (Appendix B, question 3). In future research, we will at least update our survey in this regard.

This study focused on one particular serious game. The research could be extended by studying different serious games. *E and Eve's Electrical Endeavors* is a computer game concerning physics. Serious games concerning language development, training skills (for example for defense) and general knowledge should be examined as well.

In this research only short term memory has been tested. The participants immediately answered the questions after playing the game or reading the text. It would be interesting to compare the effects of a serious game with textbook learning on long term retention of knowledge.

Finally, we wish to stress that we only compared the use of a serious game with the use of a textbook. The teacher was not involved in instructing the students in this experiment. It is very much an open debate whether serious games can approach a teacher's effectiveness in transferring knowledge.

## Conclusion

In this research we investigated the difference between teaching high school students electrical engineering theory by means of a serious game and by means of a text. We found that the males who acquired their knowledge through playing the game were more effective in answering questions on the theory than the males who studied the text. For the females, we found no difference between using a game or a text to acquire knowledge. Somewhat surprisingly, the females who played the game indicated that they were less motivated than those who used the text, while the motivational effects of the game and the text were equal for males. Whether this is the result of a lack of female interest in electrical engineering or in computer games in general is an open question. We may cautiously conclude, however, that serious games (at least the one we used in our research) have the potential to be more effective in education than textbooks, in particular for male students.

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## Appendix A

These are two of the six questions that the students were to answer after playing the game or studying the text (translated from Dutch). Both questions concern Figure 2.

Q1: If the transistor is 'closed' (current flows in the right side of the diagram), what would happen if resistance $R_2$ decreases very much?

A. The situation remains the same, the transistor remains ‘closed’.

B. The transistor will open so that the current in the right side of the diagram gets interrupted.

C. The situation depends on resistance $R_3$.

Q2: The transistor is ‘closed’, so current flows in the right side of the diagram. What will happen to the current in the right side of the diagram when resistance $R_3$ decreases?

A. The current in the right side will increase.

B. There will still be current in the right side, but weaker.

C. The current will no longer flow in the right side.

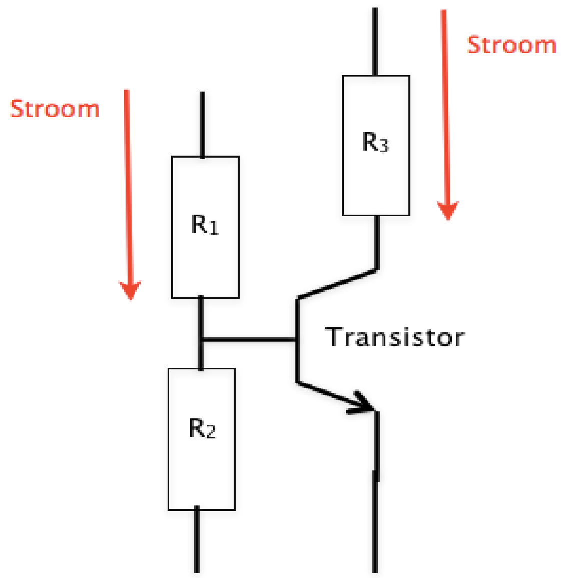


Figure 2: Schematic representation of 3 resistances and 1 transistor. The arrows indicate the flow of the current.

The answers are: Q1:B, Q2:A.

## Appendix B

The students completed a short survey. The survey asked the particpants to enter their gender (male/female), date of birth, and nationality, and to answer the following eight questions (translated from Dutch; where indicated, the students got a version with “game” or “text” appropriate to the group that they were assigned):

Below we ask several questions about physics as taught in school.

1. In comparison with other subjects, I consider physics:
   no fun at all  no fun  average fun  fun  a lot of fun
   (please circle your answer)
2. What grade did you receive for your last physics test (for which you received a grade):
   0 1 2 3 4 5 6 7 8 9 10
   (please circle your answer)

Below we ask several questions about the [game you just played / text you just read] and the assignments.

3. I consider the [playing of this game / reading of this text]:
   no fun at all no fun average fun fun a lot of fun
   (please circle your answer)
4. I consider this [game / text]:
   very hard to understand hard to understand understandable easy to understand very easy to understand
   (please circle your answer)
5. Can you indicate why you did or did not find the [game / text] understandable?
   (open question)
6. If you could change anything about the [game you just played / text you just read], what would it be?
   (open question)
7. How many hours per day do you play computer games?
   I never play computer games 0 to 1 1 to 2 2 to 4 more than 4
   (please circle your answer)
8. Would you like to get physics theory explained using computer games more often?
   □ Yes, because...
   □ No, because...
   (please check your answer)

### Acknowledgements

*E and Eve's Electrical Endeavors* can be found at `http://www.eeee.tue.nl`. A more detailed description of the research discussed in this paper is given by Stege (2011). This paper is an extended version of a paper by Stege, Van Lankveld, & Spronck (2011). We thank the reviewers for their extensive comments on the paper which have improved the final version considerably.

# Technology-Mediated Experience of Space while Playing Digital Sports Games

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## Abstract

The general aim of the research project presented in this paper is to analyze the different interactions between human, technology and space within existing theoretical frameworks from different disciplines and to apply these approaches to digital sports games. One particular aim is to investigate the impact of playing expertise or a manipulation of game situations, as well as the use of different technical devices on game experience and how game experiences in the 'virtual' world transfer to the 'real' world. The core assumption is that the interposition of technology brings up specific transformations in the coupling of perception and action that do not exist in real sports situations. The project is based on a generic framework relating theory and empirical results.

In the exploratory phase guideline-based qualitative interviews were applied after playing a dance game. Results confirm the feasibility of the theoretical approach. There is, e.g., a correlation between high scores and the feeling of spatial presence. Participants with previous dancing experience felt more involved in the game. Further studies in the experimental phase are planned to reveal more details.

KEYWORDS: DIGITAL SPORTS GAMES, TECHNOLOGIC-MEDIATED GAME EXPERIENCE, SPATIAL INTERACTIONS, SPATIAL PERCEPTION, HCI

## Introduction

The rapid progress in information technologies opens up new options for real-time interactions with artificial worlds being presented in a realistic way. This statement also holds for digital games (Distler, 2003). The proposed paper focuses on the new interaction devices in digital games and their impact on spatial perception and experiences of space. Different approaches address the experience of spatial presence (Wirth, Schramm, Böcking, Gysbers, Hartmann, Klimmt & Vorderer, 2008), the game experience (Ijsselsteijn, Poels & de Kort, 2008; Poels, de Kort & Ijsselsteijn, 2008) and the experience with digital sports games in general. The research project is located within the general framework of the interdisciplinary Graduate School "Topology of Technology" at the Technical University of Darmstadt which focuses on the relationship of humans, technology and space.

First, we will explain the theoretical background by introducing a generic framework that characterizes the interactions when playing digital games, followed by an overview of existing approaches and theories from different disciplines, which are related to particular components of the generic framework. Furthermore, the generic framework allows the deduction of research questions to be addressed by empirical studies. Finally, first results are discussed and an outlook to the further research is given.

## Theoretical Background and Empirical Evidence

### *Generic Framework*

The further development of game technology expands the options of the players to move in 'virtual' spaces. The complex interactions of the player, the technology (interface) and the game are illustrated by the following generic framework (Figure 1):

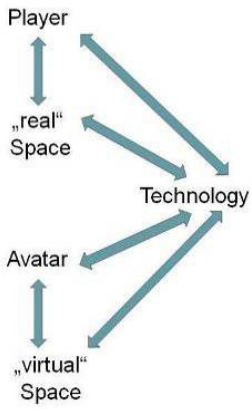


Figure 1. Generic framework of interactions between player, technology and gameplay in digital games. Bidirectional arrows denote interactions (see text for explanations).

While playing digital games the player experiences a technology-mediated environment ('virtual' space) in addition to her immediate environment ('real' space). Therefore, a specific quality of spatial perception is evoked. The player's actions in 'real' space are transformed into interactions between the avatar and its virtual environment in 'virtual' space. The technical device as a mediator makes it possible for the player to influence the 'virtual' world by her actions in 'real' space (Figure 2). The transformation rules of the player's own movements to movements of the avatar and the resulting virtual feedback need to be experienced to control the game. With the introduction of new controllers allowing a more intuitive whole-body interaction with the game the general question arises how the complex interactions illustrated in Figure 1 are experienced by the player.

Figure 2. Technology-based transformation of movement from the 'real' into the 'virtual' space (Source: Martin).

Table 1. Theoretical approaches to the interactions of player, interface technology and gameplay.

| *Movement & Space* | *Movement & Technology* | *Sensory interactions* | *Game experience* |
|---|---|---|---|
| • Action chains<br>• Gestalt theory<br>• Ecological approach<br>• Information processing approach | • Augmented Reality (AR) and Virtual Reality (VR)<br>• Human-computer Interaction (HCI)<br>• Biomechanical real-time feedback systems | • Sensory-tonic field theory<br>• Intersensory integration | • Flow, game-flow<br>• Immersion<br>• (Spatial) Presence<br>• Challenge<br>• Tension<br>• Curiosity<br>• Phantasy<br>• Emotion<br>• Motivation<br>• Arousal |

Several theoretical approaches from cognitive psychology, computer science, and movement science are relevant to the generic framework (see Table 1). In the following section only those approaches are discussed in more detail that are relevant for the empirical part.

### Gestalt Theory

Gestalt theory deals with the emergence of order in mental processes (e.g., perception, cognition, feeling, and acting; Goldstein, 1997). Gestalt theory posits that the single parts of the whole are influenced by structural laws (Wertheimer, 1925). These Gestalt laws are divided into different categories: Conciseness, similarity, Gestalt-orientated line management, neighborhood, common destiny and familiarity (Goldstein, 1997). Kohl applied the Gestalt theory to the attentional focus in sports (Kohl, 1956). He distinguished an ego-centered, an environment-centered and a balanced mode of attention. The results of his phenomenological studies show that during learning there is a shift from an ego-centered or environment-centered to a balanced mode of attention. Applying this result to playing digital sports games one may expect that an inexperienced player probably focuses either on the technical device, the avatar or his own movements. With increasing game expertise the player will develop a balanced mode of attention integrating the events in 'real' and 'virtual' space. But this balanced mode of attention can be disturbed by a surprising event like the unexpected vibration of the controller or an error. As a consequence, the focus of attention immediately switches back to the ego-centered or environment-centered mode.

### Inter- and Intrasensory Integration

Game technology can either support or impair the gaming experience. Including the new 'virtual' game technologies in the complex interactions of various sensory systems (visual, acoustic, proprioceptive) gives spatial orientation a completely new quality. Intra- and intersensory integration becomes on the one hand more intuitive and straight-forward and on the other hand contradictory since the player perceives a sum of different stimuli from his own movements and the movements in the game. For example, the player may stand relatively stable while the avatar is running through the virtual space or he may just stand up while the avatar is jumping. According to Mester (1988) these situations of ’sensory disorientation‘ are called a ’sensory mismatch‘. This mismatch can lead to ’motion sickness’ due to the divergent, multi-sensory perception in Virtual Reality environments. Furthermore, the player can either use a controller as substitute for a tennis racket or, in general, can move differently as compared to actual movements in sport reality. As a conclusion, the ’interposition‘ of technology within the coupling of perception and action while playing digital sports games brings up new transformations that do not exist in real sports situations.

### *Human-Computer Interaction*

Human-computer Interaction (HCI) conducts research on the user-friendly design of interactive information-based systems. Within these systems, man, machine and the interface form a man-machine system. In digital games, the various technical devices (controller, camera, etc.) are the interface between man and machine, which enable the player to interact with the machine-generated ’virtual’ space. The player can interact with the game by means of movements, while the game can interact with the player by visual, acoustical or haptic feedback.

To cover the subjective human experience of space in technology-mediated gaming environments models from Human-computer Interaction (HCI) have been applied dealing with the relationship between player and game. Two of them are picked out and presented below.

### *The User-System-Experience (USE) model*

Cowley, Charles, Black & Hickey (2006) applied a USE model illustrated in Figure 3 to game experience. The USE model consists of three segments being explained below.

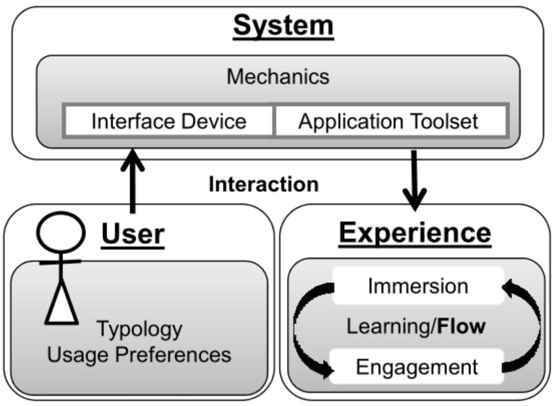


Figure 3. The USE model (adapted from Cowley et al., 2006, p. 20:2).

The System segment of the model helps showing the structure of a game. The formal system works with input and output mechanics. The input is delivered to an interface device like the controller and the output comes via ‘virtual’ world or application toolset like the scores displayed on the screen. The game is constrained by constituative, operative and implicit rules. They are considered as hierarchical loops of nouns and verbs like e.g. ‘The human player’ (Noun: A player-controlled avatar(s) – the focus of player agency; Verb: The player’s actions set in the game) and the practical experience (in terms of timing) (Cowley, Charles, Black & Hickey, 2008).

Furthermore there is the User segment of the model. The player needs to be classified as well as the game and the experiences. Each type of player alters the requirements for an experience to deliver flow, because every player interacts in a different way first with the game technology and in succession with the game. So these ways of interaction and the grade of possible flow depend on the type and the preferences of the player. For example, a 'manager' would differ from a 'wanderer' (Cowley et al., 2008).

The Experience segment represents the inter-relationship among several constructs describing experience. Taken together these constructs cover the range of feelings one might have when playing a game (Cowley et al., 2008). If there's a balance between immersion (perceived skills) and engagement (challenge) during gaming, flow will emerge and learning processes may result (because flow experience supports learning processes).

### *The Exertion Framework*

Mueller, Edge, Vetere, Gibbs, Agamanolis, Bongers & Sheridan (2011) developed a theoretical framework for interactions in exertion games and examined the experience of users engaging with new interactive exertion systems. They proposed a framework that can be useful in many parts of game-design (especially in the design of exertion games).

The initial point is to look at the exercising body from a "four-lense perspective" (Figure 4). The framework distinguishes four layers important for interactive technology: The responding body, the moving body, the sensing body and the relating body.

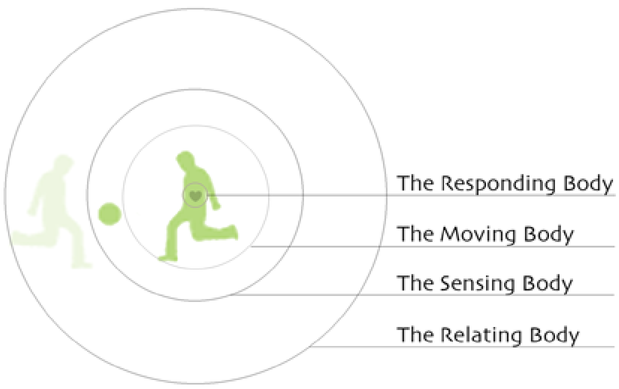


Figure 4. The Four Lenses of Exertion Interactions (Mueller et al., 2011, p. 3).

The "Responding body" refers to the fact that the human body shows internal (physiological) short-term and long-term reactions like an increase of heart rate to exercise or adaptations of the cardio-vascular system. The "Moving body" refers to the control of the muscles to establish spatio-temporal changes of the body or body segments. The "Sensing body" focuses on the human senses (e.g., vision, hearing, proprioception) conveying information and experiences about the interactions of the body and the environment. This interaction is often mediated by specific sport, exercise or game equipment. By stimulating the senses in a unique way (exertion) games can convey attractive sensory and perceptual experiences to the exercising human. The outer layer of "Relating body" refers to social interactions of human players. Social interactions are important mediators facilitating or inhibiting exercise participation.

By combining the four segments of exertion interactions and the three game characteristics of rule, play and context (Figure 5) six concepts are distinguished which are also relevant to game experience in general: awareness, uncertainty, expression, rhythm, risk, and understanding (of exertion).

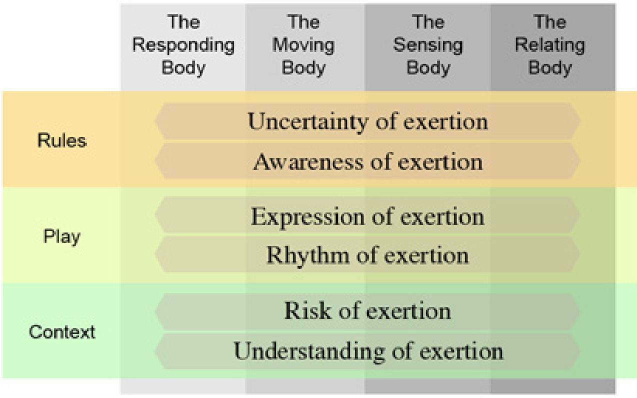


Figure 5. The Exertion Framework (Mueller et al., 2011, p. 5).

Uncertainty causes suspension. Of course, there is an optimum of uncertainty. If, for example, the interface does not transform the movement of the player in a reliable way, disappointment, anxiety or anger may result. Awareness comprises own internal states and spatial locations. Expression refers to the capability of the human body to express current states by postures, gestures and mimics. Every movement has a rhythm but also the process of user-game interaction can follow a specific rhythm co-determined by the complex interactions shown in Figure 1. Risk means that every game action bears a certain probability to fail. This experience has consequences for game experience like flow and presence. Finally understanding means that players increase their knowledge by engaging in the game. This also changes subjective experience, if, for example, the player becomes accustomed to the specificity of the game controllers.

Compared to the generic framework of interactions between player, technology and game-play in digital (sports) games which is the basis of the current project, the two models proposed by Cowley et al. and Mueller et al. have a different focus and contribute specifically to the generic framework. Our model puts a special emphasis on the spatial aspects of the interaction of player and game technology (especially due to the projects' location in the interdisciplinary Graduate School „Topology of Technology"). Parts of the USE model (particularly interface, user types, and experience segment) and the exertion framework (particularly awareness, uncertainty, rhythm, risk and understanding) can be integrated into the complex interactions of the generic framework.

### *Empirical Research in HCI*

Empirical research combining HCI approaches and game experience revealed the following results: Gerling, Klauser & Niesenhaus (2011) compared the impact of different controllers (PC mouse and keyboard versus analog stick controls) on game experience in first person shooter games. Whereas the authors found no differences between the controllers, experience with controllers had a significant impact on game experience. Regardless of the controller the participants reported a greater challenge, more engagement and more usability issues when playing with their non-preferred controller. Nacke (2010) compared two different controllers (Sony gamepad versus Wiimote) in a third person shooter. He found a higher level of self-location (Measurement, Effects, Condition - Spatial Presence Questionnaire'; see next section) under the Wiimote condition but no difference in the Game Experience Questionnaire (GEQ; see next section). Furthermore he found relations between selected EEG parameters and spatial presence both in the Sony and the Wiimote conditions. Whereas EEG was related to possible actions in the Sony condition, EEG was related to self-location in the Wiimote condition.

In exergames as well as digital sports games things seem to be a bit different. Interacting with those games includes more than associating the pushed controller button with the forward movement of the avatar. Games of these genres require investing physical effort (Mueller et al., 2011) and combine exerting body movements with computer or console gaming (Mueller & Bianchi-Berthouze, 2010). This is mediated by different motion-sensing controllers like e. g. the new Sony Move controllers (PlayStation 3) or the Microsoft kinect camera (Xbox 360). Limperos et al. (2011) compared PS 2 and Wii controllers in a football game. They found a difference in favor of the PS 2 controller enjoyment and feeling of control. This surprising finding confirm that finding an adequate correspondence of movements in the 'real' world and in the 'virtual' world is not all a trivial issue.

### Game Experience

Game experience is a complex concept comprising immersion, tension, competence, flow, emotions or affects, and challenge (Bernhaupt, Ijsselsteijn, Mueller, Tscheligi & Wixon, 2008; Nacke, 2009; Poels et al., 2008). The "Game Experience Questionnaire" (GEQ) can be used to assess these components (Poels et al., 2008). 'Flow' means the experience of total absorption by an activity (Csikszentmihalyi, 1990). The focus of attention is centered in this activity. Flow happens within a corridor of an optimal combination of challenge and skill, i.e., between boredom and anxiety. Everybody experiences the flow in an individual way, although there are some general principles (Csikszentmihalyi, 1990; Jackson & Marsh, 1996). Sweetser and Wyeth (2005) established the concept of game flow. According to this approach, the game flow is the result of concentration, challenge, skills, control, clear goals, feedback, immersion and social interaction (Sweetser & Wyeth, 2005). Because these factors are not stable during a game session, the flow experience can vary. For exergames, Sinclair, Hingston, and Masek (2007) suggested a dual-flow model taking into consideration a skill-challenge and a fitness-intensity relationship.

The flow is also coupled to the focus of attention (Wulf, 2007) and the spatial presence (Wirth et al., 2008). Presence denotes the subjective feeling of 'being there' in an environment (Freeman & Avons, 2000; overview: Lombard & Ditton, 1997). Wirth et al. (2008) proposed a two-level Process Model of Spatial Presence (PMSP) which addresses antecedents and dimensions of spatial presence. According to the PMSP spatial presence emerges in three steps: The process starts with the players forming of a mental model of the game-mediated environment by looking at various cues (images, movement, sounds, and so forth). Once that mental model of the game world is created, the player must decide, either consciously or unconsciously, whether she feels like she's 'in that imagined world or in the 'real space'. The PMSP is the basis of the so called "Measurement, Effects, Condition - Spatial Presence Questionnaire" (MEC-SPQ). The MEC-SPQ consists of 8 dimensions: Focus of attention, spatial situation model, spatial presence/ self-location, spatial presence/ possible actions, suspension of disbelief, involvement, domain-specific interest, and visual-spatial imagery (Wirth et al., 2008).

To conclude, issues of game experience depending on the particularity of the respective technology-mediated interactions addressed by the generic framework have already been partially focused by research. Research is still in its infancy. Spatial aspects of game experience have only rarely been addressed. The respective results are promising and call for a more differentiated approach to spatial aspects of game experience.

## Method

The current research project analyses issues regarding spatial presence experience, game flow, attentional focus, as well as perceptual-motor processes. The aim is to find out if increasing playing expertise and the manipulation of game conditions (e.g. switching first-person into third-person view, etc.) change the above-mentioned components of game experience and if there is a transfer effect between ’virtual‘ and ’real‘ world. First, a guideline for interviews was developed based on the generic framework, the theoretical approaches, and the questionnaires addressing spatial presence experience (MEC-SPQ) and game experience (GEQ). The guideline consists of the following questions:

- What is your most concise experience?
- Did you feel that you are actually in the environment?
- Were there moments when the two spaces overlapped?
- Did you feel like moving in space?
- Did you have the feeling of moving with the avatar or to control and move the avatar?
- How did you feel while playing?
- Were there moments when you felt uncertain?
- How present was the game technology while playing? Was there a change? Did technology disturb you? Did you have to focus on technology directly?
- What do you think about the instructions and the feedback in the game?
- How was your feeling of performance?
- Did you feel correct and skilful in your movements? Was there a change? Did the execution of movements get better in your mind? Do you remember each step of the learned choreography?
- Did you like the way of instruction in the game? Was it easy to follow?
- What did you like most in the game?
- Which one of the two choreographies did you like most?
- Did you like the game genre?

Furthermore all participants were asked about former experiences in dancing and other sports as well as in playing games (in general and specific).

Based on the results of the interviews a questionnaire is created which will be used in the experiment. In addition, biomechanical data and the focus of attention are assessed.

In the exploratory phase, a group of 14 participants (6 males, 8 females) in the age of 20 to 76 years ($M$ = 33.3 years) were examined. The great range of participants’ age was deliberately chosen to explore a possible impact of age on game experience.

The participants had to play the dance game “Dance Central” (Figure 6) on the XBox 360 kinect. A projector was used to display the game on the wall of the laboratory.

Figure 6. Dance Central Tutorial and Performance (Source: Martin).

The participants differed in game and dance experience. None of them had previous experience with game interfaces running without a controller. All persons underwent the same procedure in two sessions. After a short introduction they started with a short adaptation phase to get accustomed to the functionality of the game technology and the content of the game. In the following exercising period, the participants performed one of two different choreographies in each session which they learned in a tutorial before. Both game sessions were recorded by a video camera and the performance scores of each session were registered. Finally, a guideline-based, qualitative interview was performed.

For data analysis, appropriate qualitative and quantitative methods were used. Due to the small sample size non-parametric tests (Wilcoxon tests, Spearman correlations) were applied.

## Preliminary Results and Discussion

The reliability of game performance was poor and not significant (correlation 1st - 2nd session: $r$ (Pearson) =.26, $2p$ =.37). This indicates a low level of expertise.

In the interviews, all participants with dance experience (DE) reported a spatial presence experience (SpE) during the session (see Table 2). SpE was disturbed in the freestyle part of the performance where the screen changed and participants saw a representation of their own body. In this phase the participants had to dance without a special model instruction. At this point of time most participants felt slightly uncertain and kind of ashamed although they had former dance experience.

All participants reported that they first had to focus very strongly on the usage of the kinect interface (e.g., navigating through the menu by moving one arm up and down and logging in with a wiping movement of the hand) and forgot about it very soon when the instructions started. The same change happened again when they had to switch from tutorial to the performance level. In the performance level the awareness about the game technology reappeared when the freestyle part started, but only for a rather short moment. During the rest of the play time most participants felt a kind of overlapping of the ‘real space’ surrounding them and the ‘virtual space’ of the game. They did not reach a feeling of being completely in the scenario (a kind of backyard where some young people meet to dance in a so called “battle” style). Most participants predominantly focused on the avatar. Some participants reported also a change of focus with growing game expertise. In these cases the attentional focus switched from the avatar to the little pictograms on the left side of the screen which showed the upcoming moves and steps a few seconds before they were to be performed (see Figure 6). All participants with dance experience felt moving the same way as the avatar. Some of them even had the impression of controlling the avatar with their movements, which is actually not the case in the game. Others reported that the little latency of the dancing avatar and the music was a bit confusing. These participants reported also that it was difficult to restrain from transforming the presented movements into the opposite direction (e. g., when the avatar steps to the left on the screen from the perspective of the observer, a dance-experienced person would transform this movement to a step to the right). All participants except one liked the game genre and reported fun experience. The participant who disliked the game was very low motivated to finish the game successfully. Most participants reported that they liked both choreographies the same and nobody estimated the game difficulty as easy.

There was no correlation between the game experience (GE) and presence experience (see Table 2). All participants without game experience reported presence experience (see Table 2). The game performance showed no significant change from the first to the second session (Wilcoxon test: $N$ = 14, $z$ =-0.031, $2p$ =. 975). However, subjective impression indicated an improvement of movement quality, reactivity and cognitive performance.

In both sessions, the three worst game performances corresponded to a lack of presence experience (Spearman correlation of performance score and spatial presence experience - 1st session: $rho$ =.713, $2p$ =. 004, 2nd session: $rho$ =.713, $2p$ =. 004).

Table 2. Dance experience and experience of spatial presence (DE – Dance experience; GE – Game experience; SpE – Spatial presence experience).

| | DE | No DE | GE | No GE |
|---|---|---|---|---|
| SpE | 7 | 4 | 9 | 2 |
| No SpE | - | 3 | 3 | - |

The present exploratory study provides some preliminary evidence concerning experience of the complex interactions within the proposed general framework. Awareness of technology mediating the interactions of ‘virtual’ and ‘real’ space seems to change according to increasing practice and changing game contexts. Referring to the bidirectional arrows in Figure 1 one could say that arrows seem to be present in the beginning, but they seem to disappear during practice. After a change of context (i. e., from tutorial to performance level) the arrows seem to reappear.

Results also indicate that dance experience may be a better predictor of presence experience than game experience. If this preliminary result is confirmed then the experience of spatial presence may depend rather an domain-specific than on general experience.

A second tendency to be confirmed is the relation of spatial presence and game performance. The flow concept postulates that flow experience only occurs with an appropriate correspondence of skill and challenge. This may also hold for spatial presence.

## Outlook

Currently, further studies address the influence of different technical game devices on the spatial presence experience. Furthermore, an experimental phase will follow examining spatial presence experience and game experience of seniors while playing a self-developed serious game (the "Greenhouse-project") in cooperation with the ETH Zurich.

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# Spatial Perception and Spatial Experience in 3D Worlds

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## Abstract

In 3D worlds, the added dimension gives users the feeling of perceiving a more realistic presentation. Therefore, 3D is very attractive for different research and development areas like in the field of Games and Serious Games. The spatial perception and spatial presence experience of the user are different when using 3D in contrast to 2D applications. In the context of the project 'Sports in three dimensional television - Effects on spatial perception and spatial experience' the quantitative mechanisms of depth perception and the qualitative experience of spatial presence are discussed. The differences of 2D and 3D sport presentations and scenic presentations within one (and between different) sport discipline(s) are studied in detail in the context of a multilevel analysis. The purpose of this paper is to introduce first the theoretical framework of the project and second the empirical approach. As the project is in an early stage only few results of conducted qualitative interviews are presented. Transfer effects from 3DTV to the Game Industry are outlined, such as useful aspects which can enhance the 3D effect.

KEYWORDS: SPATIAL PERCEPTION, SPATIAL EXPERIENCE, PRESENCE, DEPTH PERCEPTION, 3D

## Introduction

The 3D technology gains more and more attention not only in the field of television, but also in the field of Computer graphics, Architecture and the Computer Game Industry. The third dimension is capable of imitating the real world in a more realistic way than any other technology before. Therefore, 3D illustration is a very interesting area for research and development. The current change of technology from 2D to 3D offers a unique historical chance for research. In 3D users' spatial perception and spatial experience is different compared to 2D presentations. This is exactly the focus of the research project "Sports in three dimensional television – Effects on spatial perception and spatial experience". The research project is part of the DFG-funded graduate program "Topology of Technology", which analyses relations between technology and space.

As numerous computer games are played using a television screen, this research project promises substantial transfers from 3DTVs to 3D games and Serious Games. An online market research in the USA (Dubravac, Wertheimer & Lelyveld, 2010) confirms the close connection between 3DTV and computer games and reveals that video game consoles are the key for future 3DTV adoption. Hence, spatial perception and spatial experience of the users are very attractive for the Game Industry.

This research project investigates the differences of spatial perception and spatial experience between 2D worlds vs. 3D worlds. In addition, the differences of scenic presentations within one sport discipline and between different sport disciplines are studied in detail.

## Theory

For exploring spatial perception and spatial experience it is necessary to consider the mechanisms of depth perception as well as (spatial) presence experience.

### *Depth Rerception*

Depth perception is a precondition for the perception of 3D presentations. Different depth cues are distinguished:

- Monocular depth cues
- Depth from motion
- Binocular depth cues
- Oculomotor depth cues

The monocular depth cues require the input from a single eye. Figure 1 includes the following monocular information: occlusion, relative size, relative height, aerial perspective, familiar size and linear perspective.

Figure 1. Monoscopic depth cues in a 2D picture (see text for an explanation).

Depth from motion arises not only from the movement of external objects but also from the movement of the observer, this is the reason why motion parallax and motion perspective are distinguished. Binocular depth cues (also called stereoscopic depth cues) arise due to the use of both eyes and are therefore an important source of the perception of 3D worlds. Because of the different location of both eyes, the human brain perceives two different pictures of the same observed object (diplopia). This difference of perceived pictures is also called 'binocular disparity' and is translated by the visual system to an impression of spatial depth (stereopsis). When focusing an object, there exist several corresponding retinal points (points that are connected with the same part in the visual cortex) which enable a single vision, not corresponding retinal points cause double vision. Panum's fusional space is the region of space, within which single vision is possible. The degree of the visual angle conveys information about the spatial distance of objects: "[…] disparity increases with the amount of depth, but decreases rapidly with increasing viewing distance" (Bruce, Green & Georgeson, 2003, p. 171). Moreover, oculomotor depth cues are important for the creation of a 3D effect. These cues comprise accommodation (modification of the focal width of the lenses while focusing on an object) and convergence (inner and outer rotation of both eyes).

All the above-mentioned depth cues – with special regard to oculomotor and binocular depth cues – are relevant to the perception of depth during a 3D television presentation or during playing a 3D videogame. As a consequence, presentations in 3D use two different viewing angles to create a 3D effect.

### *Technical Requirements for the Perception of 3D Worlds*

Usually, (active or passive) glasses are used to synchronize and filter the presented pictures. Autostereoscopic displays are currently under construction, which allow the perception of three-dimensional presentations without wearing any glasses.

### *Differences between "Real" and Simulated 3D Perception*

In contrast to the three-dimensional perception in "real life", the simulated 3D effects from "new" technologies arise through the accommodation to a projected area (screen). Based on the fixed distance to the projected area, objects can appear before, on and behind the screen, which leads to a discrepancy between accommodation and convergence. This discrepancy appears because the eyes accommodate on the screen and converge on the presented distance. This problem cannot be avoided by technology and may result for example in user's eye strain.

### *The Experience of Spatial Presence*

Whereas spatial perception deals with elementary and quantitative mechanisms, the experience of (spatial) presence is an holistic and qualitative concept and is therefore another important factor to analyse user's perception in 3D worlds. Presence is often referred to "a sense of being there". A two-level process model proposed by Wirth et al. (2007) emphasises the strong spatial impact of presence and is the basis for the spatial presence questionnaire MEC SPQ. The authors distinguish between different components that influence the emergence of spatial presence, namely

- domain specific interest
- visual spatial interest
- attention allocation
- spatial situation model
- possible actions
- absorption
- cognitive involvement
- suspension of disbelief
- self-location

These components include media factors, process components and user factors. They can affect the outcome of spatial presence. In addition, Schubert (2009) discusses a new conception of spatial presence by conceptualising spatial presence as a cognitive feeling. Lombard and Ditton (1997) give an overview of presence concepts and illustrate the versatility of presence. The authors distinguish between presence as realism (degree to which a medium can produce accurate representations of objects), presence as immersion (the senses are immersed in the portrayed world), presence as social actor within medium (media is seen as a social agent) and further concepts. As origins of presence, dimensionality and camera techniques are discussed together with characteristics of the visual display like image size, for example. Moreover, psychological effects like enjoyment and participation are distinguished.

This theoretical framework leads to the conclusion that 3D presentations generate a stronger depth perception and presence experience compared to 2D presentations. In particular, scenes in a close-up range are estimated to strengthen the feeling of being there and likewise enhance the depth perception. Therefore, sport disciplines, which allow such scenes in a close-up range are notably adequate for the presentation in 3D worlds. However, not all sport disciplines allow a close-up range. In fact, sport disciplines differ from each other in several ways. They vary for instance in the use of space (e.g. width: soccer field vs. judo mat, height: pole vault vs. running) and the number of players (e.g. two in boxing vs. 22 in soccer). These differences between sport disciplines are also estimated to have an impact on spatial perception and spatial experience. Furthermore, gender differences and also differences between persons with 3D experience and without 3D experience are expected. Voyer, Voyer and Bryden (1995) show that gender differences partly exist connected with spatial abilities - in favour of males. The authors suggest that there are several gender differences concerning spatial abilities in different areas. The American online market research (Dubravac et al., 2010) asked U.S. adults about their 3D expectations. The results show that persons associated negative aspects with 3D before they were able to watch a 3D presentation. These persons were – at least to a certain degree – less irritated after the 3D presentation as they expected beforehand. This leads to the hypothesis that impressions from persons with vs. without 3D experience differ from each other.

Considering all these factors, different research questions (Q1, Q2) and hypotheses (H1, H2) emerge:

Q1: How do presence experience and depth perception differ in 3D vs. 2D presentations?

Q2: Are there any gender differences concerning spatial perception and spatial experience when watching 3D presentations?

H1: Depth perception and presence experience differ depending on the particular sport discipline.

H2: Depth perception and (spatial) presence experience differ depending on the degree of 3D (sport) experience.

## Methods

In order to address the research questions and to test the hypotheses, a multilevel analysis is planned applying qualitative interviews, experiments with a subjective assessment of 3D and 2D scenes (evaluated by a questionnaire) and performance tests.

### *Qualitative Interviews*

Qualitative interviews with two different groups of persons will be performed with:

1) Persons producing 3D presentations
2) Persons using 3D presentations (persons with vs. without 3D experience are investigated separately)

The findings of these interviews are used to prepare a questionnaire for the experimental phase and moreover to help selecting suitable scenes for the subjective assessment. On the basis of the results of the interviews, experiments are constructed.

### *Experiments*

Particularly subjective assessment methods are used to assess user's perception in 3D worlds, such as the double-stimulus impairment scale method, the double-stimulus continuous quality-scale method as well as single-stimulus methods and stimulus-comparison methods. Eventually, the use of a single-stimulus method and a stimulus-comparison method is planned. In the single-stimulus method, test subjects will assess individually one attribute of single images. Moving stimuli from one sport discipline, varying in 2D and 3D, will be used to explore the differences of spatial perception and spatial experience in 2D worlds vs. 3D worlds. Soccer qualifies as subject matter because of the numerous existing material and the great variety of valuable scenes. The presented images will take account of spatial aspects such as close-up scenes, scenes from a bird's eye view or scenes varying in distances between players.

The stimulus-comparison method will be used to explore how similar scenes (regarding their spatial information) differentiate from spatial perception and spatial experience between different sport disciplines. Here, two images are presented and the test subject gives an index of the relation between both images. The initial conditions of 2D and 3D will vary. Sport disciplines available in 3D will be used as subject matter. The experiments will be performed as individual studies, persons will experience one factor per day. The sample will consist of an equal number of males and females and of persons with vs. without 3D experience. The underlying questionnaire is constructed on the basis of existing questionnaires like MEC SPQ (Wirth et al., 2008), which tests spatial presence, and recommendations by the International Telecommunication Union (ITU, 2002) for the assessment of depth perception. Beyond subjective assessment methods, additional objective assessment methods can be used to confirm the results. Ijsselsteijn, de Ridder, Freeman & Avons (2000) distinguish between postural responses, physiological measures, dual task measures and social responses. The additional use of the physiological indicator such as heart rate is considered as well as further tests using an eye-tracking system. Before the experiments vision tests are required to check the visual acuity and the stereoscopic vision of the test subjects.

### *Performance Tests*

In addition, performance tests are planned to assess the spatial perception of the test subjects. A computer software will be developed in order to test the spatial reproduction of player positions on the field after watching 2D or 3D scenes.

## Current State of the Project

In the research project qualitative guideline-based interviews have already been applied with producers in line with a 3D field production and an in-house production of a soccer game. Seven producers were interviewed about the 3D technology (in comparison to 2D). They are working in different 3D areas as product executive content, director, journalist, TV host, graphic designer or as product managers (2). The interviews were conducted during working hours of the producers and lasted up to 21 minutes. The aim was getting expert information about the 3D technology and sport as a 3D content. The interview guideline consisted of four major parts: 3D and sports, technical aspects, viewers and critical success factors. The questions dealt with the applicability of sport disciplines as 3DTV content and suitable or non-suitable sport disciplines, scenes and shots. Moreover, challenges in connection with 3D were addressed as well as current findings and standards of the technology. Further questions were asked about the perception of a 3D user compared to a 2D user.

The interviews were analysed by using a summarised qualitative content analyses in order to take account of all material. The material was systematically reduced to the substantial parts. The interpretation rules suggested by Mayring (2010, p. 70) were modified:

Paraphrase ⇨ Generalise ⇨ Categorise

In a first step (paraphrase), unimportant and repetitive parts of the interviews were deleted and important parts were transformed to a grammatical short form. In a second step (generalise), synonymous and minor important paraphrases were deleted. Substantial paraphrases were selected and adopted. In a last step (categorise), paraphrases with similar content were combined. Paraphrases with multiple statements to one subject were summarised (integration and construction).

First results show that a sport discipline is suitable as a 3D content, when a manageable, one dimensional space (e.g. width) is used like in boxing. Interviewee agree that suitable 3D scenes comprise spatial proximity (close and flat shots), spatial reference points like a foreground and a background as well as static shots with moving content (e.g. in direction of the user). However, too fast camera movements and too close shots without spatial information should be avoided. According to different interviewee, less appropriate sport disciplines are characterised by the use of multidimensional space and/or cannot be projected in a close-up range as the clarity is reduced or it is too dangerous getting close-up scenes. Soccer is discussed highly controversially. A clear distinction of sport disciplines suitable vs. non-suitable for 3D is impossible. Interviewee agree that 3D provides additional value vs. 2D due to technical aspects and a differentiated perception. Users need to change their viewing habits because of different cuts and stylistic devices. In return, 3D strengthens the aesthetic impressions of a sport discipline and the user feels more involved in the action and has more fun. Moreover, the perception of spatial depth helps resolving critical scenes (e.g. committed fouls). However, the limited space in stadiums and available 3D content, higher costs and technical development are considered as critical success factors. Users have to deal with 3D glasses and a reduced clarity during watching sports on a large field.

These first results allow transfer effects for Games and Serious Games. First, game characters should be presented at the level of the user to strengthen the 3D effect. Second, game fields should be clear and not too big, otherwise the 3D effect will be reduced. Spatial cues help the user to orientate in a Game. In fact, spatial depth cues should be constructed on purpose with foregrounds and backgrounds. As 3D enhances the presence experience, it might also benefit the occurrence of a flow-feeling. The more realistic presentation and the stronger fun factor of 3D presentations might lead to a better learning effect during playing Serious Games. At the moment, the qualitative interviews with producers are further processed and guidelines for qualitative interviews with users are constructed. The experimental phase of this research is being gradually elaborated.

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