Anticipation in Motion-based Games for Health

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Abstract. Digital motion-based games allow users to play computer games that are controlled with body movements. They can also be used as so called exergames, purposefully combining exercises and games. Such computer games are a relatively new phenomenon, based on enabling technology in low-cost tracking methods for game consoles that allow for affordable full body tracking. Exergames have three major benefits. First, they can raise the motivation addressing the homo ludens and the immersion of interactive computer software can lead to a sustainable motivation for doing exercises. Second, they can give users feedback on doing physiologically positive movements and aggregate performance over time. Third, they can be customized (by adapting) to individual users. The latter is not only a great chance but also a great challenge in developing exergames. When employing exergames as games for health, e.g. in physiotherapy, many patients (players) have quite individual pre-dispositions and abilities. Furthermore, depending on the reason for their condition, they might have phases with more or less restrictions. Anticipating and adapting to physical ability and individual training goals on various time scales requires subtle mechanisms that capture differences between individual users over time. We present a structured analysis of the requirements of adaptivity, approaches for implementations, and argue for the introduction of anticipatory techniques in this context.

Keywords: human computer interaction, games for health, exergames, adaptivity, anticipation, therapy, rehabilitation

1 Introduction

Motion-based games for health (MGH) are a kind of serious games aiming for involving users in gameplay that often use full-body input in order to implement interactive physical exercises. In recent years such games received growing scientific and commercial attention. These games can either address just general fitness of healthy players or specific needs for people who are in need of individual training or treatment [5, 21, 26, 32, 46].

One reason for the success of MGH is tied to the reason behind the fact that computer games are one of the most successful genres of digital media. They address the fundamental human desire to engage in playful activities. The concept of the homo ludens proposed by Huizinga [24] identifies game play not only as something that is innate to mankind but also as a principle that leads to cultural evolution. If we enter the magic circle of a game, we obviously follow a quite natural instinct [8]. The fun of gameplay can be turned into a motivational driver for involving people in activities with a serious background. Games for health and fitness (exergames) make use of this fact.

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In combination with new game console technology and advanced tracking methods, games for health and fitness have turned into a mass market phenomenon. In combination with the automated feedback and the evaluation of the objective activity of the player, custom programs and personalized sessions can be designed that act as a virtual personal trainer. With this technology, not only young and healthy gamers can be addressed. Rehabilitation patients, older adults, and people with special needs can benefit from custom exercises with individual monitoring and feedback, especially in situations where a therapist is not available and/or of prohibitive cost [39].

A central challenge for MGH is to adapt exergames to the specific abilities and needs of individual users from heterogeneous target groups (adaptability) [1, 42, 43]. Recent research and development aims for automated adaptation (adaptivity) [42]. An adaptive digital system can take numerous contextual factors into account, such as physiological, cognitive, and situational parameters. Adaptation for such games is required with respect to several different layers and time scales. First, there are principal, more or less constant differences between individual users and specific target groups that have to be addressed, e.g., the body height and other properties that do not change, or change very slowly (such as the biological age). Second, the system has to support medium-term changes, i.e., over several days, weeks or months, which are often aligned to typical recovery cycles, but may also result from acute disease or acute episodes of chronic maladies. Third, the system has to anticipate very dynamic short-term changes and fluctuations, i.e., daily changes in user performance (a tired day, forgotten to take a medicine, etc.). As an additional complication, these time scales apply to multiple layers of heterogeneity (which introduce variance) that can be classified as follows: (a) the heterogeneous general application areas (such as MGH for stroke patients, MGH for children with cerebral palsy, MGH for phantom pain, etc.), (b) the heterogeneity within those target groups (i.e. commercial mass market and pure entertainment games can afford to target a comparatively thin slice of a normal distribution of their potential users, but games for health cannot afford to leave somewhat deviating users behind and the variance with regard to individual capabilities and needs can be quite extreme), (c) the heterogeneity within any individual user / patient (e.g. with regard to varying capabilities and requirements at different times, as illustrated above).

2 State of the Art

Exergames for physiotherapy, rehabilitation and prevention (PRP) have been a prominent research topic for a decade now and the effort in scientific research is growing steadily. Systems focus on information, explanation and teaching or active support of physiotherapy, rehabilitation, and prevention (PRP) [15]. General exergames without PRP focus [47] are already available on the game market. A number of studies could prove the effectiveness of exergames for a number of target groups (e.g. stroke patients [3, 6], Parkinson’s disease patients [5] or older adults who face rather general age-related challenges [18]).

Exergames involve users in a dual-task scenarios [10, 11]: they have to both act cognitively in the game, learning the rules of that the game-mechanics entail, developing and enacting strategies, tactics, etc., and to practice physical exercises. In classical PRP such conditions are appreciated and considered to be especially effective. However, the mappings and appearance have to be designed with respect to the target group and the needs of the user [20]. For older adults, for instance, age-related constraints have to be taken into account [19]. Next to an individual adaptation to skills, the psycho-physiological condition of the user is of key interest for reaching a certain game experience for all users [12, 33]. Automatic adaptation using modern sensor technology can be used to achieve dual flow, i.e. matching both skills in the game and exertion to the difficulty level of the game and the exercises [40].

In contrast to conventional instructions in PRP by exercise instruction sheets, exergames have a number of advantages, in particular support for motivation, feedback, and analysis and can lead to a more efficient performance of the exercises [43, 45]. Some motivational dimensions and therapeutic effects have even been shown to be significantly in favor of MGH when comparing to instructions by a live physiotherapist [44]. Another benefit of MGH is that they are always available, unlike a real therapist and they may also serve to gather a consistent objective view of one's therapeutic progression. In contrast to a wide-spread misconception, playing computer games is not an activity only for young people, but also for older adults [27], who show growing interest in computer games that can contribute to their physical and cognitive well-being [37, 42].

The challenge in PRP is to keep a constantly high level of effective treatment quality. This is difficult due to several problems, in particular when patients practice their exercises without supervision. The self-controlled adherence to the correct execution and right number of repetitions is a dominant problem [7, 45]. Even life-threatening diagnoses do not ensure a high quota of adherence to the exercise plan as was shown with cardio patients [25]. Feedback, encouragement, social interaction and emotional engagement in particular can make a positive difference [41]. Hence, exergames can be ideal vehicles, as they can include such factors. The wealth of sensor devices for the game market such as vision- or motion-based controllers made it possible to use devices that were originally designed for entertainment purposes also for PRP with positive results [17].

Next to sensing and proper game control mappings, user- and context-dependent adaptation is necessary. Even though early adaptive systems were often received quite critically [23], today many software systems successfully employ subtle adaptation mechanisms. In particular in games, it is an aspect of *balancing*, that aims for levelling out differences of individual players [35] and allows for similar player experience even though the skills may vary [4]. Such concepts are also discussed for exergames [16, 38], where physiological data can be used for online adaptivity and customization [29, 30].

User models for continuous adaptation for individual players have been proposed [34] and used, e.g., for games for depression prevention [28]. More generic ways of adaptation for exergames have been discussed in recent research [21, 22], but the present approaches are still largely reactive in their adaptivity. The following section provides an example of a contemporary approach to adaptive exergames (or MGH).

3 Towards Adaptive and Personalized Interactive Motion-Based Games for Health

How should an ideal MGH adapt to a user? This is a complex questions and we want to illustrate this claim with the example of a rather simple exergame for Parkinson's disease patients [5]. In the game *Starmoney*, the patient stands in front of a monitor and is tracked with a vision-based sensor. The task is to make wide movements with the arm in order to follow a trace of stars that is dynamically generated. Each star that is hit can be caught and in turn can be collected as a point for the user's score.

Fig. 1. Exergame for PD patients: Starmoney

There are basically three game-related parameters that can be adjusted:

- The scaling of the mapping of the user´s hand to the position of the hand on the screen. This could, e.g., compensate for various arm and body sizes of the users.
- The size of the virtual hand. This would relate to the required accuracy for hitting the stars.
- The only dynamic parameter would be the timing, i.e., speed of the trail of stars.

Starmoney is a simple game with only very limited game mechanics. Other games might have a multitude of adaptable parameters. If we consider a certain user we could one measure the arm length or better the area that can be reached, response time and accuracy and set the parameters accordingly. However, this will not suffice if we consider dynamic aspects. These play a role on various time scales [42]:

- During a game session: in many exercise sessions it takes some warm-up or activation times until patients reach their level of physical ability. In particular PD patients often suffer from a remarkable stiffness that is reduced after some activation exercises
- Positive effect due to training: If the PRP is successful, the exergames can lead to an increased performance from session to session.
- Negative effect due to aging or progression of a disease: In particular for PD but also for aging we have to expect a progressive decline of physical ability on a long term time scale.
- Individual performance variances: due to many factors the day-to-day performance can vary a lot. This can be due to infections, other treatments, medications etc.

These temporal aspects show that dynamical variations are a challenge for automatically adapting exergames. In particular since the users themselves adapt and anticipate the dynamics of the system. Such co-adaption of both users and systems can lead to mutually unpredictable effects that can be positive or negative [13, 31]. Human adaptation to exergames has been observed in a number of commercial sports games, e.g., for Wii Tennis, where some users after a while do not perform full arm movements anymore, but rather just move the hand with the controller resulting in the same in-game effect. Thus, if users – either consciously or unconsciously – learn that the system adapts to a low performance by lowering the physical demand of an exercise, they might trigger a spiral of succeeding easier exercises.

This negative dual-adaptive process, however, has not been observed in our studies with adaptive exergames. In contrast to sports games that focus on a game and not on a sustainable training effect of the physical movements, exergames with clear physiological goals seem to be less prone to this effect. Patients typically state that they are aware of the "serious" aspect of their interaction with the system. They can therefore be more willing to accept sub-optimal scores [42] and may be hesitant to exploit adaptive systems. However, since it is likely that not all users are like this, it seems advisable to implement maximal relative offsets per adjustment cycle [44] and to boost / slow-down extreme positive or negative developments with the motivational tool-set of game design. It also seems likely that therapists will continue to play at least a role as sporadic advisors / supervisors in adaptive systems for MGH in order to prevent undesired positive or negative spirals.

4 Components of Adaptive Exergames

Considering a simple overarching model and building on the work of Adams et al. [2], in order to realize an adaptive exergame, we need to consider the following elements:

- Sensors
- Models for estimating the user's psycho-physical state
- Adaption strategies

4.1 Sensor technologies for adaptive exergames

In order to build an adaptive exergame, the system must reliably detect the state of the user and assess the user's performance and fitness. Many exergames are vision-based and thus the visual input is the key for tracking the user and the exercises. Alternative tracking is often done with motion sensors (e.g. with Wii controllers or mobile phones). Less common are sensor mats or devices like the Wii balance board. Even less common are complex medical devices, such as gait rehabilitation devices or rehabilitation-robotics. Additional sensors can also be used to directly get data related to the user's physical condition. Such sensors can be, e.g., heart rate or blood pressure monitors, multiple degree-of-freedom motion-trackers, and more. In principle many combinations of sensors are possible and as a result of sensor data fusion, the user's state can be measured more and more comprehensively.

4.2 Psycho-physical user models

User modeling has been a research topic for the last 20 years. Usually, user modeling aims for classifying users in groups according to user data such as demographic attributes (age, gender, …) or behavioral patterns (activities with an interactive system). Such methods use -for instance- classification techniques like cluster algorithms, nearest neighbor classifiers, or neural networks. For exergames such user models can be a starting point. However, they have to be extended with respect to physiological and psychological aspects both reflecting static as well as dynamic aspects. These aspects can cover as rather static factors e.g.:

- Physical abilities and limitations (e.g, arm flexibility, vision, …)
- Diagnosed diseases (e.g., PD, Diabetes, …)
- Risks (e.g. high blood pressure)
- Treatment/Therapy (e.g. Exercises against back pain)
- Training goals
- Game-related factors (e.g., highscore)

More dynamic aspects are:

- Accuracy of the exercises (on the basis of the tracking data)
- Physiological data (e.g., heart rate)
- Exertion (relative to personal condition)
- Performed repetitions
- Game-related factors (e.g., score)

According to these factors the user can be both related to other users (or prototypical users) or to historical data and to pathological models, in order to assess training progress. In many models the user model consists of rather simple data sets. More subtle models would not just collect flat data but include deep models. E.g. therapy or treatment could be an elaborate model of an actual physiotherapeutic treatment for the individual user.

4.3 Adaption strategy

The adaption of motion-based games for health needs to be discussed along a number of basic dimensions such as:

- Automated vs. manual adaptation
- Adaptation with regard to exercise and game
- Temporal aspects of adaptation
- Granularity of adaptation, complexity, etc.

With manual adaptation, users have full control on all settings. Moreover, additional persons like physicians or therapists can use adaption interfaces in order to customize exergames for their patients. But even though adapting parameters by hand allows for control of all settings, it has two main disadvantages: it can be cumbersome if too many parameters have to be adjusted and dynamic changes cannot be followed easily, thus requiring frequent updates [44]. The first issue may lead to the permissive usage of default parameter settings and thus the power of adaptability is wasted. The second issue can lead to precise settings at the beginning but might entail a continuous drift towards a misfit of the parameters. Therefore, automatic adaption methods are necessary. They can, in turn, be combined with manual methods. Often this combination is used such that in early phases manual methods are used, which are replaced over time by automated techniques that are based on observations. In particular direct manual adaption can often be interpreted as corrections and can be used as reward / punishment cues for machine learning methods that improve the automated system.

The adaptation can influence both the physical exercises and the game play. For automated adaptivity, it is necessary to define goals towards which parameters and settings are adjusted. Such goals can accordingly relate to both the game play and the exercises. In many games the designers likely want to achieve a good balancing such that the difficulty of the game matches the player's skills. This relates to the flow theory [9], which assumes that players reach a flow state that correlates with a good player experience when skills and difficulty are well-balanced. Similarly, for exercises, exertion level and exercise intensity have to be balanced in order to avoid overexertion or ineffective training. The demand to balance both aspects has been formulated as the dual-flow theory [40]. Obviously both aspects are independent when contrasting any two persons. A player can be physically very fit but novice to the game or vice versa.

Modeling the complex dynamic fluctuations of user performance is a very difficult task. Advanced models will take medical knowledge into account that would for instance describe the flexibility and fitness of users depending on age and diseases during individual sessions (e.g. before and after warm-up) and between sessions (e.g. wrt. to training goals). But even simple models that merely aim to keep the user roughly in the double-flow state can be helpful [42].

Lastly, the goal of motion-based games for health is usually not only to motivate the players to perform exercises momentarily, but to support triggering lasting behavior change. In the terms of the well-established *Fogg Behavior Model* [14], MGH can support both the factor of *motivation*, and the factor of *ability*, if players are frequently momentarily motivated to exercise, which contribute towards moving individuals across their "action line" which facilitates lasting behavior change.

5 Building Adaptive Exergames

The ultimate goal of adaptive games for health would be to integrate all aspects and components discussed above. This has not been achieved for several reasons. In particular there are not yet models that cover all temporal, physiological and psychological aspects. The good news, however, is that not everything has to be done automatically and even simple models can serve as proof-of-concept. In an adaptive version of the *Starmoney* game for PD patients (Fig.1), we considered adaption of timing, accuracy and the distance that can be reached by the patient's arm (Fig. 2). Using a simple threshold heuristics for the motion (amplitude) of the arms, we wanted to see in particular, how the effect of an adaptive game would be over a longer period of time [42].

Fig. 2. Adaption possibilities for the Star Money game: timing, accuracy, range of reach

With a small number of participants but a study over 3 weeks, we could show that the system works and was well received. Adaptation did not confuse the users. The perceived difficulty correlates with performance. The patients expected a high level of challenge and were not very confident in their own success. The study showed that the amplitude (range of motion) actually developed positively over successive game round and we observed an objective increase for all participants.

In a more recent development, results from a medium-term study of exergames for physiotherapy and rehabilitation with 30 participants in the situated context of a physiotherapy practice indicated that automated adaptive versions of exergames, even when building on simple rubber-banding heuristics, can be roughly on a par with manually adaptable versions regarding the user performances and experience. At the same time, therapists appreciate the adaptive versions due to the lessened need of manual effort [44].

6 Towards Anticipatory Exergames

The approaches that we summarized in the state of the art sections and the examples that we introduced from our own practical implementations have in common that these contemporary adaptive exergames are still largely performance-based and reactive. This means that the system reacts after deviations from a more optimal course of developments are detected. In many cases this means that a system even made an adjustment that worsened the situation, only in order to then readjust. Binging true anticipation into practical adaptive MGH (e.g. by relying on more predictive user and/or group models, likely in combination with known models for average therapy / rehabilitation progressions and context models), might help to eliminate this systematic over- or under-shooting and produce settings progressions that meet the patients' needs much more precisely. From the perspective of a general model, this means moving from a system based on a *performance evaluation* and an *adjustment mechanism* that takes only the most recent performance evaluation into account to an adjustment mechanism that also takes an anticipated reaction to upcoming changes and anticipated development into account. This follows the main aim of preventing overstraining or under challenging the players (cf. Fig. 3).

Anticipation in relation to games for health has been discussed by Nadin et al. in the context of the project Seneludens[1] [36]. Following the focus of that work, anticipation is a human capacity, an indicator of the fitness to adapt to changes that is reduced with increasing age. Motion-based games can arguably play a beneficial role in retaining or improving the anticipatory profiles of individual players. The view presented in this paper highlights the potential an anticipatory component in the adaptivity of a motion-based game system to the needs and capabilities of a user, thereby providing an additional perspective on the role of anticipation in the context of games for health.

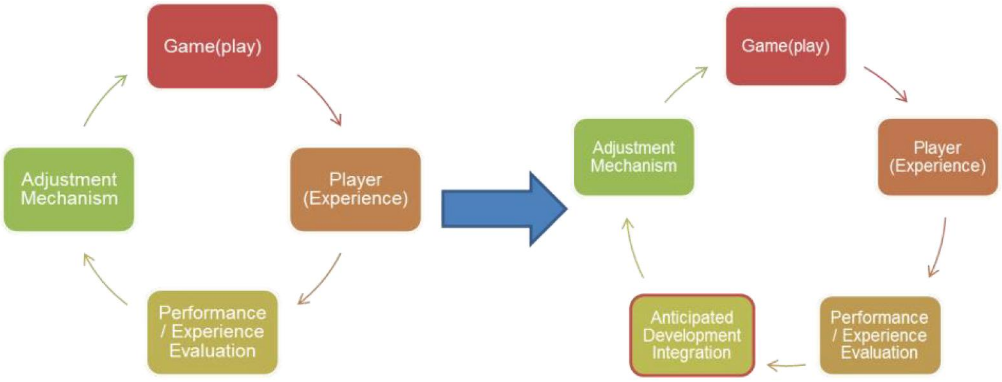

Fig. 3. Moving from reactive adaptivity to anticipatory customization.

7 Conclusions and Discussion

Exergames are a very promising approach to increase the motivation and adherence of people needing to perform exercises on a regular basis and to increase the likelihood of achieving effective and safe exercising. The users can be healthy individuals with general fitness goals or patients who need to do exercises as part of some rehabilita-

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[1] http://seneludens.utdallas.edu, last viewed: 2016-04-05

tion or physiotherapy program. Exergames generally have the potential to provide three positive aspects, namely motivation, feedback, and customization. Due to the playful character, motivation can be increased and thus may lead to a more sustainable training program and long-lasting adherence to the scheduled exercises. Tracking with modern sensor technology allows for precise guidance on how to perform certain exercises correctly. Moreover the system can use the tracking for feedback. This can be live feedback during a training session, reflective feedback after a session and development feedback on the long-term change in performance over longer time periods.

Adaptive exergames are an important step forward in personalizing exergames to the needs of users. In principle, many temporal, contextual, physiological and other personal parameters can be used to either manually or automatically adapt the game and/or the exercise program. So far we have seen some first adaptive exergames. More subtle models will allow for more complex adaption strategies. In the long run, we expect exergames to become reliable personal trainers that may anticipate many factors in order to guide users through a personalized and optimized training program avoiding the "need of prior mistakes" that is inherent to many contemporary adaptation strategies.

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References

1. Aarhus, R. et al.: Turning training into play: Embodied gaming, seniors, physical training and motivation. Gerontechnology. 10, 2, (2011).
2. Adams, E.: Fundamentals of Game Design. New Riders (2010).
3. Alankus, G. et al.: Stroke Therapy through Motion-Based Games : A Case Study. Therapy. 219–226 (2010).
4. Andrade, G. et al.: Dynamic Game Balancing: An Evaluation of User Satisfaction. In: AIIDE'06. pp. 3–8 (2006).
5. Assad, O. et al.: Motion-Based Games for Parkinson's Disease Patients. Entertain. Comput. 2011. 47–58 (2011).
6. Burke, J.W. et al.: Optimising engagement for stroke rehabilitation using serious games. Vis. Comput. 25, 12, 1085–1099 (2009).
7. Ch, S. et al.: Home exercise and compliance in inflammatory rheumatic diseases--a prospective clinical trial. J. Rheumatol. 24, 3, 470–476 (1997).
8. Crawford, C.: The art of computer game design. (1984).

9. Csikszentmihalyi, M.: Flow: The Psychology of Optimal Experience. Harper & Row, New York (1990).
10. . de Bruin, E.D. et al.: Feasibility of Strength-Balance Training Extended with Computer Game Dancing in Older People; Does it Affect Dual Task Costs of Walking? J. Nov. Physiother. 01, 01, (2011).
11. . de Bruin, E.D. et al.: Feasibility of Strength-Balance Training Extended with Computer Game Dancing in Older People; Does it Affect Dual Task Costs of Walking? J. Nov. Physiother. 01, 01, (2011).
12. Drachen, A. et al.: Correlation between heart rate, electrodermal activity and player experience in First-Person Shooter games. In: Proceedings of the 5th ACM SIGGRAPH Symposium on Video Games. pp. 49–54 (2010).
13. Fischer, G.: User modeling in human–computer interaction. User Model. User-Adapt. Interact. 11, 1, 65–86 (2001).
14. Fogg, B.: A Behavior Model for Persuasive Design. In: Proceedings of the 4th International Conference on Persuasive Technology. pp. 40:1–40:7 ACM, New York, NY, USA (2009).
15. Gekker, A.: Health Games. In: Ma, M. et al. (eds.) Serious Games Development and Applications. pp. 13–30 Springer Berlin / Heidelberg (2012).
16. Gerling, K.M. et al.: Effects of Balancing for Physical Abilities on Player Performance, Experience and Self-Esteem in Exergames. In: CHI'14: Proceedings of the 2014 CHI Conference on Human Factors in Computing Systems. (2014).
17. Gerling, K.M. et al.: Exergame design for elderly users: the case study of SilverBalance. In: Proceedings of the 7th International Conference on Advances in Computer Entertainment Technology. pp. 66–69 (2010).
18. Gerling, K.M. et al.: Full-Body Motion-Based Game Interaction for Older Adults. In: CHI'12: Proceedings of the 30th international conference on Human factors in computing systems. (2012).
19. Gerling, K.M. et al.: Game Design for Older Adults: Effects of Age-Related Changes on Structural Elements of Digital Games. In: Herrlich, M. et al. (eds.) Entertainment Computing - ICEC 2012. pp. 235–242 Springer Berlin Heidelberg (2012).
20. Geurts, L. et al.: Digital games for physical therapy: fulfilling the need for calibration and adaptation. In: Proceedings of the fifth international conference on Tangible, embedded, and embodied interaction. pp. 117–124 (2011).
21. Göbel, S. et al.: Serious games for health: personalized exergames. In: Proceedings of the international conference on Multimedia. pp. 1663–1666 ACM, Firenze, Italy (2010).
22. Hardy, S. et al.: Adaptation Model for Indoor Exergames. Int. J. Comput. Sci. Sport. 11, 1, (2012).
23. Horvitz, E. et al.: The Lumiere project: Bayesian user modeling for inferring the goals and needs of software users. In: Proceedings of the fourteenth Conference on Uncertainty in Artificial Intelligence. pp. 256–265 (1998).
24. Huizinga, J.: Homo ludens: proeve eener bepaling van het spel-element der cultuur. Amsterdam University Press (2008).
25. Ice, R.: Long-Term Compliance. Phys. Ther. 65, 12, 1832–1839 (1985).
26. Ijsselsteijn, W. et al.: Digital game design for elderly users. In: Proceedings of the 2007 conference on Future Play. pp. 17–22 (2007).

27. Ijsselsteijn, W. et al.: Digital game design for elderly users. In: Proceedings of the 2007 conference on Future Play. pp. 17–22 (2007).
28. Janssen, C.P. et al.: User modeling for training recommendation in a depression prevention game. In: Proceedings of the first NSVKI student conference. pp. 29–35 (2007).
29. Lindley, C.A., Sennersten, C.C.: Game play schemas: from player analysis to adaptive game mechanics. In: Proceedings of the 2006 international conference on Game research and development. pp. 47–53 (2006).
30. Liu, C. et al.: Dynamic Difficulty Adjustment in Computer Games Through Real-Time Anxiety-Based Affective Feedback. Int. J. Hum.-Comput. Interact. 25, 6, 506–529 (2009).
31. Mackay, W.E.: Responding to cognitive overload: Co-adaptation between users and technology. Intellectica. 30, 1, 177–193 (2000).
32. Malaka, R.: How Computer Games Can Improve Your Health and Fitness. In: Games for Training, Education, Health and Sports. pp. 1–7 Springer (2014).
33. Mandryk, R.L. et al.: Using psychophysiological techniques to measure user experience with entertainment technologies. Behav. Inf. Technol. 25, 2, 141–158 (2006).
34. Missura, O., Gärtner, T.: Player Modeling for Intelligent Difficulty Adjustment. In: Gama, J. et al. (eds.) Discovery Science. pp. 197–211 Springer Berlin Heidelberg, Berlin, Heidelberg (2009).
35. Mueller, F. et al.: Balancing exertion experiences. In: Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems. pp. 1853–1862 (2012).
36. Nadin, M.: Play's the Thing: A Wager on Healthy Aging. In: Cannon-Bowers, J. and Bowers, C. (eds.) Serious Game Design and Development. pp. 150–177 IGI Global, Hershey, NY (2010).
37. Nap, H.H. et al.: Senior gamers: Preferences, motivations and needs. Gerontechnology. 8, 247–262 (2009).
38. Rego, P. et al.: Serious games for rehabilitation: A survey and a classification towards a taxonomy. In: Information Systems and Technologies (CISTI), 2010 5th Iberian Conference on. pp. 1–6.
39. Schuler, T. et al.: Abstract virtual environment for motor rehabilitation of stroke patients with upper limb dysfunction. A pilot study. In: Virtual Rehabilitation (ICVR), 2013 International Conference on. pp. 184–185 IEEE (2013).
40. Sinclair, J. et al.: Exergame development using the dual flow model. In: Proceedings of the Sixth Australasian Conference on Interactive Entertainment. pp. 11:1–11:7 ACM, New York, NY, USA (2009).
41. Sluijs, E.M. et al.: Correlates of Exercise Compliance in. Phys. Ther. 73, 11, 771–782 (1993).
42. Smeddinck, J. et al.: Adaptive Difficulty in Exergames for Parkinson's disease Patients. In: Proceedings of Graphics Interface 2013. , Regina, SK, Canada (2013).
43. Smeddinck, J. et al.: Anpassbare Computerspiele für Senioren. Inform. Spektrum. Special Issue on Entertainment Computing, (2014).
44. Smeddinck, J.D. et al.: Exergames for Physiotherapy and Rehabilitation: A Medium-term Situated Study of Motivational Aspects and Impact on Functional

Reach. In: Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems. pp. 4143–4146 ACM, New York, NY, USA (2015).

45. Uzor, S., Baillie, L.: Exploring & designing tools to enhance falls rehabilitation in the home. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. pp. 1233–1242 ACM, New York, NY, USA (2013).
46. Walther-Franks, B. et al.: Exercise My Game: Turning Off-The-Shelf Games into Exergames. In: Anacleto, J.C. et al. (eds.) Entertainment Computing – ICEC 2013. pp. 126–131 Springer Berlin Heidelberg (2013).
47. Yim, J., Graham, T.C.N.: Using games to increase exercise motivation. In: Proceedings of the 2007 conference on Future Play. pp. 166–173 ACM, New York, NY, USA (2007).