Games for Health

Jan D. Smeddinck

Digital Media Lab, TZI, University of Bremen, Germany
smeddinck@tzi.de

Abstract. Health is an elementary foundation of prosperous human life. Average human life expectancy has never been as long as it is today and medical advances have greatly improved overall population health. However, modern societies are burdened by new complications in the form of lifestyle diseases which arise due to various aspects of modern life, such as sedentary behavior. The pressure on public health systems is ever increasing with the emergence of further complex and expensive treatment options, and due to the complications resulting from demographic change. The technological advancements of the industrial and information age, the computational revolution in general, and video games for entertainment specifically contribute to the prevalence of some prevalent lifestyle-related health issues. At the same time, computing devices and interactive applications also play an important role in improving all areas of individual and public health. Recent research and early commercial releases deliver convincing evidence that playful applications and games for health in particular offer approaches that can help overcome the motivational barriers which often restrain successful health treatments or preventive actions and behavior. This chapter provides an overview of the arguments that motivate the application of play and game techniques for personal and public health. It summarizes the basic promises and challenges of games for health research and development, provides starting points regarding their design and implementation, illustrates selected aspects along the lines of exemplary applications, and hints at pressing open challenges as well as promising avenues for further research and developments. A selection of quality references for further reading is included in the last section.

Keywords: serious games, games for health, exergames, motion-based games, health, game design, game user research

1 Introduction

Playful digital media applications for serious purposes in health, or *games for health* (GFH), have seen growing attention both in research and in industry, especially since ubiquitous connectivity and sensors have enabled a large number of promising use cases beyond mere information processing. Nowadays, games for health are created for a large variety of purposes ranging from the classic use cases in information processing and analysis, over individual and public education, to the active support of diagnostics or treatments [52].

In the area of physiotherapy, rehabilitation, and prevention (PRP) [136], for example, motion-based games for the support of existing treatments and exercises [119] have been explored for a wide range of target groups, such as older adults [10, 39, 53, 149, 155], people with Parkinson's disease [11, 110, 134], children with cerebral palsy [45, 68, 74], people in stroke recovery [6, 29, 38, 156], and more [52], with many positive indications [62, 72, 102, 124]. Other application scenarios cover a broad range from surgeon education [61], over public health information [47], to personal hygiene and nutrition [14], as well as cognition and mental health [7, 10, 51].

Independent of the specific application area, games for health offer three central pillars of potential [135] which also apply to serious games in general. Most prominently, they have the potential to (1) *motivate* players to perform tasks that they might otherwise be less motivated to perform by employing a playful, game-like, or fully game-style mixture of design, reward structures, game mechanics, and storytelling. However, due to their interactive nature, serious games can also offer (2) *guidance* and *feedback* regarding the task at hand that might otherwise not be available, thereby potentially improving task execution and minimizing the risk of mal-executions. Lastly, next to momentary feedback for guidance, serious games (e.g. for health) can also provide tools to support the (3) *analysis* of user performance over time, which can help with forming a more objective picture of individual progress.

In order to utilize these potentials, games for health need to be carefully designed to match the respective use case and target group. To this end, user-centered iterative design and participatory approaches are frequently applied. However, since iterative design usually targets average users from a larger group, and since the target groups of games for health are often composed of individuals with very heterogeneous abilities and needs, methods for personalization via adaptability and adaptivity are required if the use of the potentials is to be optimized (cf. also Streicher and Smeddinck on *Personalized and Adaptive Serious Games* in this volume). While adaptability and adaptivity [17] in the context of health applications are a topic that has been covered by research for many years, recent advancements in the mobility, ubiquitous availability, and inter-subjectivity of the analysis of sensor data and user performances allow for much more comprehensive and contextually grounded data analysis and user model construction. In turn, these developments facilitate more densely evidence-based and quantitatively stable decision-making.

Besides the potential of playful methods and games in health which motivates research and development, there is also considerable economic pressure that is visible in auspicious market estimations [124]. Despite the positive outlook, games for health developments are often held back by challenges such as the complexity of clinical validations, the need to compete with high-quality game productions, limited evaluation methods, regulatory hurdles, and limited acceptance of playfulness in professional and serious contexts. Due to the interdisciplinarity in the research and development of games for health, which involve game designers, researchers, and professionals, as well as due to the dual role of players that are often patients with primary and secondary interests that differ both from those of regular gamers and between individuals, various complex and interdependent challenges arise. At the same time, a wide range of design and research methods have been tested in the context of games for health and some guidelines are beginning to emerge together with informative application examples.

The remainder of this chapter will provide detailed discussions of the topics that were summarized in this introduction and aims to leave the reader with an initial broad understanding of the state of the art, the central challenges, technical and methodological approaches, and avenues for future work, allowing for directed further reading and exploration of this comparatively young and yet broad and challenging research area.

1.1 Chapter Overview

This chapter is structured as follows:

Foundations of Games for Health A summary of the foundations that support a further discussion of the topic, including the terminology, the relation to eHealth, the central promises of games for health, a brief discussion of theories of motivation that are closely tied to games for health and serious games as a whole, heterogeneity as a central challenge in the design, development, and evaluation of games for health, as well as an overview of considerations on types and classes of games for health.

Designing Games for Health A discussion of important aspects of the design of games for health, such as the importance of user and expert involvement, the perspective on player abilities as resources, considering levels of gamification and the importance of stories, as well as general approaches to evaluations.

Games for Health Examples and Illustration The section contains a summary of seminal work together with a discussion of the progression of three consecutive games for health projects that serves to illustrate practical challenges, approaches to these challenges, design and implementation strategies, intermediate evaluations, and the respective outcomes that occurred during the practical research and development of motion-based games for health projects.

Challenges with Designing and Researching GFH A summary of common challenges that occur when researching, designing, and implementing games for health, ranging from interdisciplinary and multiple party interests, over heterogeneous target groups and the need for adaptability and adaptivity, to safety, practical integration, long-term situated evaluation, and ethics, data privacy, as well as regulatory concerns.

Current Trends and Open Research Questions A brief outlook on promising avenues for currently breaking and future work.

Conclusion, Outlook, and Further Reading This chapter closes with a general summary of the content and the outlook, together with a brief list of recommended related work for further reading and online resources that contain further information on the topic of games for health.

2 Foundations of Games for Health

Games and playful elements have been used for serious purposes in health even before the appearance of computer or video games. Examples range from colorful illustrations in eye-sight tests for children to analogies such as "holding one's arms up like branches of a tree", or "hopping like a frog" in kinesiatric therapy. The potential transfer from employing the motivational power of traditional (non-video) games and playful elements for health purposes to employing computer or video games instead has been recognized even in very early video game research literature. Crawford [35], for example, highlights physical or mental exercise as a secondary motivation to play games that is rooted in the evolutionary benefits of engaging in such exercises.

Since the early conceptual references, *games for health* has not been the only term used to describe the application of computer or video games for serious purposes related to health. An overview of common terminology, including definitions that this chapter relies upon and relating the most central terms to each other, thus lays the foundation for the following sections on *the foundations of games for health*. The central promises of games for health are covered in a separate section, as well as the foundations from motivational psychology that are frequently employed in serious games and general game research and design. The central challenges stemming from the heterogeneous abilities and needs of target groups of games for health, the interdisciplinary nature of games for health research, design, and development, as well as the interests of various parties involved with creating and using games for health are also discussed. Furthermore, general eHealth is discussed as a larger related context for games for health together with central approaches in GFH, a structure for the types and classes of GFH, and a gamification continuum to provide a further delimitation of GFH from related approaches.

2.1 Terminology

The *Games for Health Project*[1] defines *games for health* simply as "game technologies that improve health and the delivery of health care" [115]. GFH are sometimes referred to as *serious games for health*. Since the term *serious* is

[1] Games for Health Project: http://www.gamesforhealth.org/

redundant, the addition can be abandoned. The term *health games* is used synonymously. Other less common terms that are used synonymously are *eHealth games* [34], *digital health games* [18, 24], *healthy gaming* [25], and more. In order to avoid fragmentation of the field, it appears advisable to consider whether the term *games for health* may be used in future discourse. Other terms such as *exergames*, *fitness games*, *virtual rehabilitation*, *kinesiatric games*, *motion-based games for health*, *mental health games*, or *cognition games* are sometimes used synonymously, although they can arguably be seen to describe specific subclasses of GFH (here: different physical and mental health targets).

The terms *gamified health*, *health gamification*, or alternatively *gHealth* bring the aspect of *gamification* into the terminology and are not easily dismissed since they do arguably match the definition provided for GFH above. Since the debate on gamification and games is not the topic of this chapter, this text operates on the premise that both approaches reflect different angles of the same concept of using game technologies [44] to improve health and the delivery of health care: While gamified health highlights the underlying serious purpose and application as the origin to which gamification elements can be added to a variable degree, GFH highlights the motivational potential of fully fledged games which can encompass a certain range of serious health purposes.

While games for health can often also be *games for behavior change* [48, 65] or *persuasive games* [111], those two classes encompass many other application areas. Moreover, GFH can also be non-persuasive and not tailored towards behavior change (as for example in many GFH that support the education or training of health care professionals [14]). There is, however, considerable overlap between *education* or *learning games* that target professional or public education in health related areas and *educational* or *learning games for health* that is difficult to avoid since the framing usually depends on the professional backgrounds of the researchers or game designers. It is therefore important to be aware of the various angles that different researchers, designers, developers, and GFH projects can take regarding the same core subject matter.

2.2 Background in eHealth

Games for health are rooted in both (serious) games and health information technology applications. The latter are also frequently referred to as *eHealth*. The eHealth field is currently growing rapidly, fueled by an increased connectivity of devices and services, as well as by growth in the areas of mobile devices and other affordable multi-sensor devices with access to powerful data processing. Mobile eHealth applications exist for a large range of application areas ranging from diagnostics, over education and information or health service localization and promotion, to activity tracking and the active support of treatments. Although the integration in widespread public health treatment is often still experimental [100], more than 31,000 applications were reportedly available on app markets by 2014 [97]. In an example of a rather developed eHealth market segment, a number of tracking platforms for exercising and fitness have been established (e.g.

Strava, RunTastic, RunKeeper, Nike Plus, MyFitnessPal, etc.) [88]. These applications support a wide range of different sports and health activities, but they usually do not incorporate specific health treatments and they are limited to the support of selected consumer tracking devices. However, many applications tailored to specific and often complex medical devices, such as robotic walking aids or exoskeletal hands for rehabilitation [116], are currently being researched and developed. The notable involvement in existing or upcoming eHealth platforms of all big players in digital technology, namely Apple, Google, and Microsoft [94] shows that eHealth is a considerable market.

While digital health applications are already being used by more than 30% of all US adults [88], there is still a lack of clinical research, especially regarding the usage of the platforms that encompass multiple health related activities [21, 88]. Despite this widespread lack of clear scientific evidence, many consumers are willing to pay for existing applications, even in cases where manual data entry is required [94]. Due to the growing number of integrated sensors and their processing and connective capabilities, smartphones (and to a certain extent tablets and digital watches) are becoming the primary devices for eHealth platforms and their interfaces. This, of course, raises a need of ethical and lawful data storage and processing [118], which also applies to most GFH.

2.3 Promises of Games for Health

In the context of motion-based games for the support of physiotherapy, rehabilitation, and prevention, three central areas of potential benefits of employing game technology have been identified in a classification that arguably generalizes to motion-based games for health (MGH), GFH, and even serious games as a whole. These three "promises" are motivation, guidance, and analysis [103, 135].

Motivation: Game technology enables entertaining and captivating experiences that can motivate players to perform actions, even if these actions are repetitive, strenuous, or straight out undesirable to a considerable extent. This is clearly evidenced by behaviors such as grinding in games, where players willingly accept long stretches of tiring and repetitive activities due to the promise of following rewards. In GFH this can mean, for example, that patients can be motivated to perform the often strenuous and repetitive exercises that are required for successful physiotherapy or rehabilitation. In the context of health professional education, games or a playful approach can motivate surgeons to perform a large number of simulator trials whilst staying focused despite being aware of the unreal nature of the procedure. A specific example of a GFH that makes use of a broad range of motivating game elements is Valedo [81].

Guidance: The interactive nature of digital applications paired with sensing and feedback modalities as well as analytic abilities allow for guiding the players regarding the quality and safety of their target activity performance. In the context of MGH this can mean that players are informed when they fail to assume the proper stance or pose during a physiotherapy exercise and that corrections can be offered, potentially avoiding mal-executions and injuries, especially in situations where no professional support would otherwise be available, such as in the frequent use case of exercising at home. The same principle can apply to a professional health game for surgeon training that could facilitate training with less (or without immediate) supervision. Specific examples can be found in the visual body representations with highlights and shapes outlining go-to positions or postures in the VirtualRehab Body [150] and Reflexion Health [1] systems.

Analysis: GFH are usually deployed on platforms with rich information processing capabilities and Internet connectivity, making data aggregation across sessions (and potentially also across different users) possible. Thus, the regular and prolonged usage of GFH allows for the objective analysis of the development of individuals with regard to specific game performances, and sometimes even regarding general abilities, which can be useful for individual users and professional personnel alike. In the context of motion-based games for the support of physiotherapy, for example, it is usually difficult for patients and therapists to gain an objective impression of patient performance and development between practice visits. MGH can deliver objective data for the time between practice visits, where therapists previously had to rely solely on patients' self-reports [148]. Users of professional learning GFH and their educators can likewise benefit from developmental overviews and grounded projections. Practical examples can be found in many patient and professional information interfaces for games for health and in personalized reports, such as the development reports targeting parents that are available in the game *Meister Cody* (transl.: Master Cody) by Kasaa Health, which focuses on children with dyscalculia [90, 91].

Fig. 1. Three central areas of potential benefits of GFH; after [103, 135].

Considering the wide scope of these promises, it is important to recognize that any specific GFH does not have to implement all of them to the full extent, since GFH are already successful in beating many baselines that are defined by the most common approaches to real-world situated health applications. For example, as Uzor et al. show [148], the current standard in many kinesiatric therapy applications for practicing at home is to provide patients with a sheet of paper with some instructive images and a description of how to perform exercises. It was shown that this practice leads to patients performing exercises in a suboptimal or even malicious manner, miscounting their repetitions, forgetting whole sets of exercises, misreporting to therapists, etc. [148]. It is clearly apparent that the potential in data recording and analysis of MGH offer opportunities for improvements regarding these problems. On a similar note, the inter-rater variance of movement quality judgements between therapists has been shown to be considerably high [114], meaning that different therapists, for reasons such as different schooling or professional foci, may judge the quality of a certain movement execution by a patient considerably differently. The objective data gathered by GFH and analyses based on such data have the potential to offer improvements with regard to such issues as well.

While these potential areas of benefit certainly validate research and development efforts in GFH, it is important to underline that the potentials are frequently abused to exaggerate the practical benefits of GFH and even to challenge the relevance of human health professionals. As the following sections regarding challenges of GFH will show, it is much more reasonable to approach research and development regarding GFH with an aim at augmenting the available palette of tools for supporting health and the delivery of health care. Health professionals will likely continue to play a central role in steering the general direction of treatments and in assuring the adequacy of using specific GFH with apt configurations. In any case, the research and development of GFH involves considerable challenges. In the context of the foundations of GFH, an awareness of the psychological basis of motivation and employing existing theories based on an understanding of the implications of widely varying individual abilities, needs, and the resulting game and exercise performance skills, is key to successful GFH projects.

2.4 Theories on Motivation and Games for Health

Related work in GFH references the same foundations that are frequently relied upon in general serious games and game user research. Perhaps most prominently, the theory of *flow* is used to explain how games can motivate players to become so engaged that they are apparently completely drawn 'out of their bodies' and 'into a play session' [36]. While flow theory encompasses analog play and many other activities that can induce the arguably highly intrinsically motivated state of flow that supports the execution of evolutionarily beneficial activities [36], it has been connected to digital games both by Csikszentmihalyi [37] and other authors (e.g. [32]). From a number of requirements that can facilitate a state of flow [36], the balance between the skills of a player and the challenges presented (by the game), is most frequently employed in order to illustrate the game design challenge of creating adequate tasks and exercises that match a given player at a given time.

Concerning GFH, Sinclair et al. [129] have presented the important argument that in motion-based applications for exercise and health, the balance between player skills and game challenges exceeds the traditional focus on digital game design and mechanics, and the balance between physical abilities of a player and the challenges presented plays an equally important role (see figure 2) [130]. It is also due to the interwoven nature of cognitive and physical activity in motion-based games for health that they are almost intrinsically of a dual-task nature [113]. Dual-tasks have been shown to be more beneficial than either cognitive or motor training alone [27]. The dual-flow approach to the balance of skills and challenges can be generalized to highlight the need to consider any physicality or otherwise expressed ability or skill that is directly linked to the effectiveness of an intended outcome of any GFH (not only motion-based) or serious game. For example, if mental skills are the serious focus in a GFH, the balance between player skill and presented challenges regarding these skills must be considered in addition to any balance of challenges and skills related to the playful or game elements employed in the GFH. Arguably, in many well integrated GFH there is an overlap between these two areas; however, both views are important angles of consideration during game design and for game user research in the context of games with serious purposes that are to be implemented in an effective manner while maintaining the motivating power of (adequately challenging) game play.

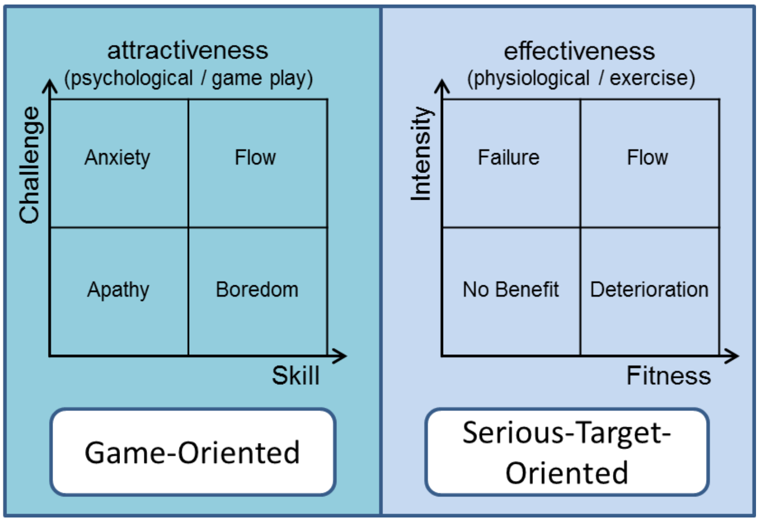

Fig. 2. The dual-flow model for exergames; a generalized adaptation of the model after Sinclair et al. [130].

In these terms, it is also apparent that this perspective can be connected to the three central promises of GFH, where motivation corresponds to attractiveness, and guidance and analysis are linked to effectiveness (momentary and prolonged).

As another approach on motivation, *self-determination theory* (SDT) [41] is increasingly being used in the context of games, serious games, and GFH. Summarizing in plain terms, SDT as a need satisfaction theory states that three basic human needs must be fulfilled in order to support intrinsic motivation via a self-determination motive: *competence* (the need to feel competent at things we do), *autonomy* (the need to feel free in our decisions and goal selection), and *relatedness* (the need to feel related and socially connected to other people). Rigby and Ryan [121, 123] have convincingly established the application of SDT in games, while SDT has also been successfully employed in the context of sports / exercising and general health behavior motivation. It is therefore a very interesting tool in the context of GFH and MGH. Psychometric instruments constructed on the basis of SDT, such as the *intrinsic motivation inventory* [104] or the *player experience of need satisfaction* questionnaire [122] can not only supply game researchers and designers with validated measures of motivation, but also shed light on the subscales of motivation that often show additional telling trends under experimental manipulation [19, 20, 136].

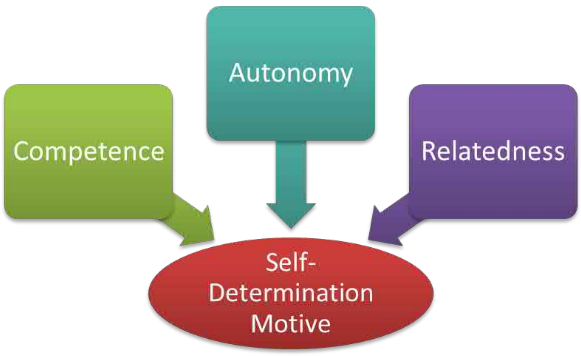

Fig. 3. Competence, autonomy, and relatedness needs satisfaction combined facilitate the self-determination motive. After Deci et al. [41].

While stemming from different schools, flow theory and SDT do recognize each other and research could benefit from the simultaneous use of both theories despite their similar foci. While SDT focuses mainly on the basic premises that shape a self-determination motive that enables intrinsic motivation in the first place, flow theory is mostly concerned with questions around how a momentary situation of very strong intrinsic motivation arises and how it can be maintained

[139]. Thus, both approaches can make important contributions to dissecting the overall perception of motivation in research on GFH. Likewise, Denis and Jouvelot [42] have suggested a model that relies on SDT, however, they establish motivation in the context of games as a balance of challenge and skills in a manner akin to the application of flow theory in the context of games [32].

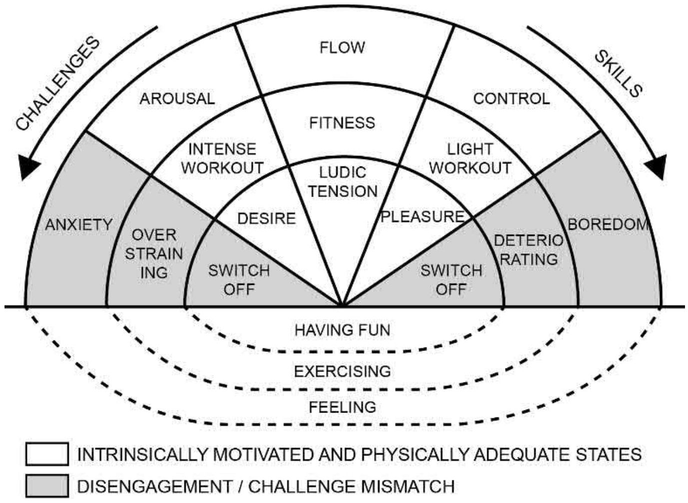

Fig. 4. Intrinsic motivation as a balance between challenges and skills. Adapted from learning games to exergames, following the original model by Denis and Jouvelot [42].

Drawing from the classification of motivational qualities into (a) *intrinsic motivation*, which relates to the push to act freely and on one's own volition, (b) *extrinsic motivation*, which relates to factors external to the activity itself, leading an actor to be willing to perform an activity, and (c), *amotivation*, which describes the absence of motivation [40], Denis and Jouvelot construct a model that suggests a central corridor of intrinsically motivated states which only arise in a state of balance between challenges and skills. Prepending the notion of the duality of dual-flow, the model can also be expanded into a dual-balance model where a second corridor is constructed around the physical activity (replacing learning with exercising, as indicated in figure 4), for the case of motion-based GFH, or around the respective serious target outcome in the case of other GFH or serious games.

A third prominent motivational theory that is employed in the context of serious games is *self-efficacy* [12]. Self-efficacy, or the extent of one's belief in one's own ability to complete tasks and reach goals, has been linked as a predictor to completing health related tasks and goals, and has also been used in the context of games [141]. While the construct is helpful in principle, it does not lend itself to comparative reasoning as readily as SDT, since it is recommended to construct customized measures for independent use cases [13]. However, since motivation and feedback play explicit roles in self-efficacy, it can provide insightful perspectives in GFH research and development.

While motivation is important, the challenge of researching and creating successful GFH exceeds the aspect of momentary or prolonged motivation to engage with activities that have some direct or indirect health benefit. The goal is often to *persuade* users into first starting a treatment or change, and to trigger lasting *behavior change*. Models and approaches from persuasive applications design [112] and behavior change [48] have been used in the context of serious games [14, 147] and provide further background on these broader concerns. We do not provide a more detailed discussion of these approaches, since they are discussed in other chapters of this volume.

2.5 The Central Challenge of Games for Health

Due to heterogeneity on multiple levels, in addition to user and use case centered design, flexible yet efficient adaptability and adaptivity to create optimized experiences for groups or personalized experiences and outcomes for individuals, is the arguably most central challenge around GFH. It is also the reason why commercial mass market games can only rarely be used successfully as GFH. Typical monolithic and coarse difficulty settings like "easy", "medium", and "hard" do not allow for the required level of flexibility. This challenge stems from the strong differences in capabilities and needs of GFH users, which - in turn - result from a number of aspects.

Heterogeneous Application Areas. As argued above, GFH are being researched and developed for use in widely different application areas. Still, GFH often target multiple application scenarios within the same application area, which can require notable adjustments.

Heterogeneous Target Groups. Sometimes, application areas or scenarios are tied to a very specific demographic sub-group, such as people within a certain age range (young children, children, adolescents, young adults, or older adults [109], or frail older adults [55]), or people of a specific social, cultural, or economic status. Oftentimes, however, a GFH will be aiming to encompass multiple of these groups with the resulting requirement to allow for enough flexibility to cater to the respective abilities and needs of their individual members.

Heterogeneous Individuals. Even within specific target groups and sub-groups, individuals frequently have strongly different abilities and needs. For example, due to increasing variance in age-related afflictions and related physical and mental abilities, older adults of similar age can be very different from one another. In another example, strong differences e.g. in the range of motion of different players of a game for the support of therapy for Parkinson's disease patients were recorded and discussed (cf. figure 5 which illustrates differences in motion dynamics and range of motion in two players)[134].

Fig. 5. A series of images of participants in a study of motion-based games for the support of physiotherapy for Parkinson's disease patients [134]. One participant (left) shows a notably smaller range of motion, and less dynamic movement than the other (right).

Games have been shown to have the potential of positive impacts on *intergenerational acceptance* [146] and *social integration* [26, 101]. Social interaction around games and multiplayer situations between members of heterogeneous target groups require careful consideration and often times additional flexibility, or even different approaches to adaptability and adaptivity altogether. This was reported, for example, in a study by Gerling et al. [56], which gives insight into how visible adaptations for balancing between two players of a local multiplayer game led to adverse results in homogeneous player pairs. Further results indicate that such adjustments are much more readily accepted in notably heterogeneous player pairs (in this case wheelchair users playing with non-wheelchair users; cf. figure 6).

Fig. 6. Two photos taken as part of a study of the impact of different levels of visibility of difficulty adjustments on player performance and experience with different results in dyads of players with more homogeneous abilities (right), compared to dyads of players with rather heterogeneous abilities (left).

Heterogeneous Interested Parties. In addition to the challenges mentioned above, a number of different parties act with different interests, needs and abilities in the larger ecosystems that GFH must function in. Next to the players or patients (a complex duality in and of itself), professionals, such as doctors, therapists, care givers, or professional educators, may interact with the games or with information and settings interfaces for the games. Family members and other relatives, such as parents, or other guardians of the core users are often involved. Lastly, game makers, developers, designers, artists, system administrators, and researchers (from a wide range of disciplines, such as game design, computer science, medical science, therapy, sports science, psychology, storytelling, etc.) are also part of the development and release ecosystem of GFH.

Drawn together, in many cases, GFH need to cater to very specific needs and abilities of their players due to a broad range of heterogeneous target groups which are themselves typically composed of people with considerable variance regarding abilities and needs in terms of both the interaction with the game and the interactions linked to the targeted serious outcome, as well as variance regarding prior knowledge, and expectations of games. Next to the impact of the application target, the social status, age, technological affinity, and further factors, such as the interests of many different user groups, must be considered when designing, implementing, and researching GFH. Even given a proper approach to design (cf. to section 3 on designing games for health in this chapter), this leads to *manual adaptability* and *automated adaptivity* as central challenges (the chapter on *Personalized and Adaptive Serious Games* by Streicher and Smeddinck in this volume provides a detailed discussion).

2.6 Types and Classes of Games for Health

Considering the broad range of application scenarios and potential user groups, a structured approach to the types and classes of GFH is helpful to allow for a systematic discussion of design and development methods, as well as research efforts. One approach are grids with game characteristics, such as the summary presented by Rego et al. [119] for serious games for rehabilitation. They sample related work to retrieve characteristics such as application area (motor or cognitive), interaction technology (motion tracking, keyboard, etc.), as well as game interface, number of players, competitive or collaborative nature, game genre, adaptability (yes / no), progress monitoring, performance feedback, and portability. Other, more top-down approaches generate a structure along (usage) fields and areas of application (cf. Table 1) [125, 52]. This taxonomy is especially helpful when planning the design of GFH or research about GFH, since it induces a conscious reflection about the potential interests in other usage fields and helps with clearly defining areas of application.

In combination, both approaches can inform decisions and help shape discourse. The layers of of *active* GFH (i.e. used to work on a specific health issue) or *supportive* GFH (employed for related serious targets around a specific health issue) could make a useful addition. Within a motion-based GFH category, reasonable sub-classes are *pervasive / location-based games* vs. *partial-body*, or *full-body motion-based games*. Sawyer and Smith's class of *assessment* should be read to explicitly include diagnostics [85, 143], and a sub-class of *structural support* (memorizing medication schedules, playful day planning, etc.) could be added

Table 1. A taxonomy for games for health as suggested by Sawyer and Smith [125].

Fields -> / Areas of Application	*Personal*	*Professional Practice*	*Research/ Academia*	*PublicHealth*
Preventative	Exergaming Stress	Patient Communication	Data Collection	Public Health Messaging
Therapeutic	Rehabilitainment Disease Management	Pain Distraction Cyber Physiology Disease Management	Virtual Humans	First Responders
Assessment	Self-Ranking	Measurement	Inducement	Interface / Visualization
Educational	First Aid Medical Information	Skills / Training	Recruitment	Management Simulations
Informatics	Personal Health Records	Electronic Health Records	Visualization	Epidemiology

to the informatics area of application. While these taxonomy and classification efforts can help shape a more grounded dialogue about GFH and hopefully support the transfer of findings, it is important to note that many GFH and GFH systems will represent a mixture of multiple classes, and that characteristics will be expressed to variable degrees.

3 Designing Games for Health

The usual steps of a design process as illustrated in the general context of serious games (please confer to the respective chapters in this volume) also form the basis of GFH design. However, as indicated in the preceding sections, GFH introduce challenging additional aspects that require consideration. During the design process, after having determined the target group and serious purpose, a reflection of the application area is helpful. Brox et al. [25] have structured this consideration into design for education, or persuasion, or exercising. Following the classes by Sawyer and Smith to discuss and determine primary and secondary targets would be another option.

3.1 The Importance of User and Expert Involvement

In addition to reviewing related literature, explorative methods, such as target group surveys, interviews, expert involvement, paper prototyping, or participatory design play an important role with GFH design, since these methods make requirements and challenges evident that designers and developers might otherwise overlook.

Participatory design workshops can deliver insights into unexpected target group preferences or whole alternative game concepts. For example, in a participatory design workshop that was carried out in the context of the project Adaptify while planning the development of games for the support of back pain physiotherapy (see figure 7), older participants were found to largely avoid comparative score or ranking displays, while younger participants highlighted their

Fig. 7. The images show older adults during a participatory design workshop on motion-based games for health that was carried out as a formative measure in the currently ongoing project Adaptify [2]. The picture on the left shows participants composing own game screen designs and the picture on the right shows a final design. The study served the purpose of determining preferred game screen elements and approaches to embedding instructor figures and player characters.

importance when asked to compose their own game screens using a large number of pre-printed typical game assets and pens for the inclusion of own ideas. The same series of workshops also produced alternative approaches to interspersing play sessions with storytelling content that had not been considered by the project designers or researchers prior to the workshops.

Fig. 8. A participant enacting movement capability adjustments either on a physical or digital manikin during a series of two studies performed in the context of the project Adaptify. The study explored approaches to realizing efficient and well-integrated patient movement capability configurations for physiotherapists [138].

In another example from the same project, therapists were involved in the early planning stage of an application for tablet devices for configuring motion-based games for health. Even before a first digital interactive prototype was produced, therapists were asked to enact movement capability configurations on a wooden figure in order to explore their bimanual interaction and how they comment on which aspects of the movement capability configurations are important to them (see figure 8). While a following study with an early interactive prototype (see figure 8) found that a mixture of direct manipulation of a 3D avatar with traditional input elements and clearly separated movement axes worked best for the therapists, the early involvement of the therapist led to the unexpected finding that the therapists highlighted the usefulness of such a tool for communicating with other therapists and with patients about movement capabilities and the development of individual patients [138].

Fig. 9. The figure illustrates that non-gamer experts and gaming experts can both be involved to cover different aspects of GFH development (here with the example of motion-based games for health for older adults) [59].

As the game development progresses, and input from non-gaming experts becomes available, the involvement of gaming experts can help interpreting that information [59]. Following the application use case of MGH for older adults, figure 9 illustrates that non-gamer experts, such as doctors, therapists, and nurses, can provide valuable contributions with their insights into common age-related changes and impairments, giving recommendations that help designers implement beneficial movement-based game input, and supporting game developers throughout evaluation processes. Gamer experts, such as interaction and game designers, can also make valuable contributions by providing insights regarding enjoyable game mechanics, appropriate interaction schemes, etc.

3.2 Patient Abilities as Resources

Based on the model of digital games produced by Adams [5] and Fullerton et al. [49], related work has discussed the perspective that player resources can require special consideration with target groups such as older adults [58]. Similarly, with games for health, players may have limited attention spans, abilities, or special requirements that can be seen as a depletable resource in game design (see figure 10). This lens is often helpful when planning interactions around the serious target of the game. In a game for mental rehabilitation, for example, the duration for which a player can be very focused, can be seen as a resource that may be limited, changes over time, and may yet be a central target for change due to interacting with the game.

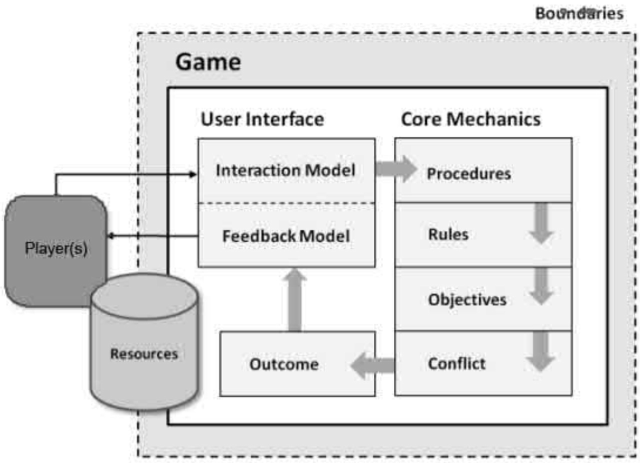

Fig. 10. An extended model of digital games after Fullerton et al. [49] and Adams [5] via [58].

3.3 Evaluation Criteria in Usability, User Experience, Playability, Player Experience, and Accessibility

Most importantly, next to traditional game user experience outcomes, the specific health outcomes of a GFH matter. This duality of target outcomes suggests that both should be considered in design and testing. As noted before, a theoretical approach to this end is presented by Sinclair et al. [130] with the dual-flow framework. This work suggests a split of the general concept of flow into psychological flow and physiological flow, which is relevant for any motion-based playful application. The physical fitness and abilities of any given user present a physiological counterpart to the aspect of skill (which would likely contain elements of hand-eye coordination, fine-grained muscle control, and reflexes with any sedentary game as well) and have to be balanced with the level of physical challenges that are presented by the game. If the challenges exceed the physical fitness or abilities of a player, there is an increased risk of overstraining and injury. If the challenges notably undercut the physical fitness or abilities of the player, there is a risk of deteriorative effects due to a lack of training intensity, or at least of a lack of an impact regarding the targeted health outcomes. This has to be considered in game design, implementation, and testing, but it also has to be taken into account by adaptive systems for motion-based GFH. Next to the temporal fluctuations, the general interpersonal difference in abilities also entail that accessibility plays an important role in the design of (motion-based) games for health. The question whether the game system at hand contains barriers that could prevent users from the target group from reaping the potential benefits of the application is even pre-conditional to the questions of playability and player experience that are commonly discussed in game design literature [135]. If the games are not accessible, any theoretical playability or player experience and any resulting motivation to be active or any resulting positive impact on health cannot come to fruition.

Given that aspects of accessibility are explicitly encompassed, user-centered design, repeated prototype testing and early pilot studies play an important role, if the complex challenges outlined in the preceding sections are to be tackled. GFH teams will benefit from following the classic user-centered design cycle [64] of analysis, design, implementation, and evaluation. However, it is important to point out that the iterations evolve around *multiple evaluative criteria* (see figure 11).

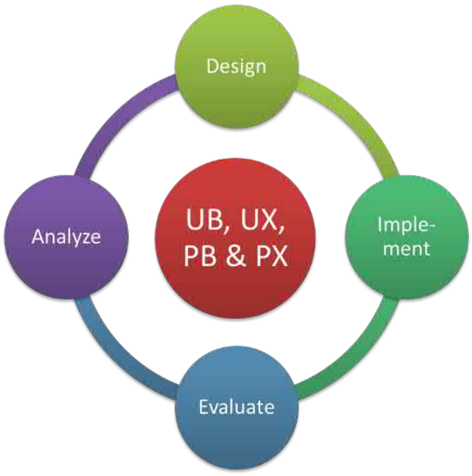

Fig. 11. The figure illustrates how user-centered iterative design in GFH revolves around the four cornerstones of usability (UB), user experience (UX), playability (PB), and player experience (PX).

Usability matters in games, because they come with menus, settings, and controllers that are not necessarily part of the game design in terms of mechanics or aesthetics, yet are elementary for facilitating unhindered game play. It is thus useful to evaluate them with classic usability criteria such as efficiency, ease of use, performance, etc. Additionally, the *user experience* that is perceived by the players in the interactions with the application surrounding the core game is important. Unlike non-game applications, games, serious games, and GFH must be designed for a good player experience as well. *Player experience* results from the interaction with the core game, the game mechanics, the rewards, potential social interactions, etc. and is measured with different tools (see for example the section on *Theories on Motivation and Games for Health* in this chapter) than usability (e.g. SUS [23]) or user experience (e.g. [93]). As a fourth evaluative focus, *playability* regarding the interaction with the core game itself should be considered separately from the usability of the immediately surrounding interactions, and it is important to note that, while inefficiencies and challenges in use will only be tolerated to a certain level, they do not always exert a clearly negative impact as they would be from the perspective of usability, since challenge and inefficient behaviors are important elements of many games [139]. Lastly, it is also helpful to recall the different parties of interest introduced in the preceding sections, which should be considered separately with regard to how important usability (UB), user experience (UX), playability (PB), and player experience (PX) in a specific GFH are, or are likely to be, to them. This overview clearly illustrates the complexity of the iterative user-centered design approach with GFH. Given an awareness of these challenges, however, these considerations can help prioritize evaluations and design targets in GFH where both patients and therapists are important target groups. While playability and player experience are usually most important to the patients, the usability and user experience of the interactions surrounding the core game play are of usually most important to the therapists or other professionals.

Balancing Challenges and Ease of Use. When a game is reliably accessible, playability frames the next set of pre-conditional design criteria that resemble critical elements of usability. It is important to notice that classic criteria from usability often do play a role in games, for example in interfaces, but also concerning the game controls, although maximum efficiency and effectiveness (as exemplary aspects of usability) are usually not the focus of the core game mechanics [139]. To the contrary, since playful and/or game mechanics often evolve around purposefully challenging the user, they can oppose the judgement by such usability criteria. Games for health are interesting in this regard, since the serious purpose often results in designers having to find compromises between providing enjoyable game experiences and supporting the serious goals. Arguably, good GFH designs feature core mechanics that support the serious outcomes as directly as possible. However, such solutions cannot always be found and are often not cost-effective. Alternatively, approaches with a less direct integration of game mechanics and health-related activities, such as episodic game play or game narrative interwoven with temporally distinct episodes of health-related activities, also have the potential to support improved beneficial health outcomes compared to non-game-based interventions.

3.4 Levels of Gamification and the Importance of Story

As indicated in section 2.2 on the relation of games for health to general eHealth applications, there is no clear line that separates playful eHealth applications from GFH. One can envision a continuous scale of gamification ranging from fully serious applications to fully entertaining games, where, depending on the point of origin, game elements or serious application elements are added or removed. The understanding of gamification is often limited to rewards that are not closely related to the remaining activities in an application. However, game mechanics, design aesthetics, and storytelling, as viable game elements for games for health, should all be considered during conceptualization and design. While the simple addition of a reward layer, such as the one illustrated in figure 12 in playful applications has been shown to provide measurable benefits [137], it can be expected that the introduction of a broader repertoire of game elements, if done in a harmonious fashion, can lead to more far-reaching positive impacts on game experience and both game and health related performance.

Fig. 12. The figure shows two examplary screenshots of a gamified information application for users of electro muscle stimulation training [137]. The screen on the left shows stimulation intensities of different body parts in the last training session compared to a reference session and date picker UI components for selecting the respective sessions. The right screen shows a reward screen with a gallery of achievement badges and a total score. Augmenting trainer discussions with small interaction sessions with such performance-oriented applications was shown to lead to improvements in some motivational measures.

Evidence for this hypothesis can be found, for example, in a comparative study of different levels of visual fidelity about the impact on game experience and performance in a game to support physical activity in older adults (see figure 13). Notable differences only occurred when the visual fidelity was reduced to a level that made the micro-story that was inherent in the fishing scenario of the game disappear [132].

Given the complexity of GFH design and research, the sections in this chapter merely scratched the surface of the approaches and methods that have been discussed. Additional design and evaluation approaches are the topic in related work on games for health in general [16] and in related work on the various subclasses of GFH, such as motion-based games for health (or exergames) [108]. Many practical materials and more recent approaches and methods are shared and discussed in various online communities on GFH (see section 8 on further reading below).

4 Games for Health Examples and Illustration

In this chapter we do not present a survey of GFH with a strict sampling and analysis method, since such surveys have recently been produced with a range

Fig. 13. Four levels of visual complexity of the same game, where the abstract version (top left) was shown to have inferior effects on player experience compared to the other versions.

of foci. Ricciardi et al. [120] provide a survey of serious games in health professions, while Baranowski et al. [14] provide an overview of games with a focus on health-related behavior change, and Kato [83] reports on various examples of games in professional health care applications. Notably, all of these surveys report numerous positive indications.

4.1 Seminal Work

In order to name some specific projects for further reading, this section highlights GFH work of seminal character. This means that each project has considerable novelty (usually due to the serious target), features a convincing production quality, and is in the best case accompanied by research to supply evidence in favor of the approach. Validated with clinical trials, the games *Re-Mission* one and two, where players enter "their own bodies" to take on the fight against malicious cells, help improve drug administration adherence and indicators of cancer-related self-efficacy and knowledge in adolescents and young adults diagnosed with different types of cancers [84]. The playful VR experience *SnowWorld* [71, 72], where patients visit a world full of shades of light blue and other colors associated with cold and imagery of snow and ice, has been shown to be a potentially viable adjunctive nonpharmacologic analgesia both in the context of wound treatment for burn victims and in dental pain control. The game *Relive* [47] focuses on cardiopulmonary resuscitation (CPR) training and puts players into a compelling space station scenario with a high production quality. It features competitive multiplayer and has been released as a free game on the distribution platform Steam where it competes with many commercial titles. In *Project:EVO*, a game created to detect and track the development of Alzheimer's disease, players play a flying race type of game, in order to improve cognitive control via interference processing [10]. In the creature-care game *Monster Manor*, children with type 1 diabetes are encouraged to take responsibility of controlling their own blood sugar levels, earning them upgrades and support items for a monster they take care of [82]. *Meister Cody* [90] is a game to support children with dyscalculia [91], which features diagnostics, rich adaptability, adaptivity, as well as therapist and parental information and control; it is currently undergoing a large-scale trial. As an example from the large subgroup of motion-based games for health, *Valedo* is a gaming system where two motion-sensors are attached to a patient's body in order to enable full-body control of a suite of well-designed mini games for the support of back pain movement exercises [81].

4.2 Motion-based Games for Health

The following sections illustrate the evolution of motion-based games for health (MGH) in the exemplary therapeutic application area of physiotherapy, rehabilitation, and prevention (also sometimes referred to as kinesiatric games), along the lines for three quasi-consecutive projects that were carried out at the Digital Media Lab of the Center for Computing and Communication Technologies (TZI) of the University of Bremen, Germany, in cooperation with students, as well as partners from research and industry. The discussion in this chapter focuses on approaches to – and challenges in – the general design, implementation, and evaluation of these GFH. A separate discussion that focuses on the aspects of adaptability and adaptivity in each project can be found in section 5.2 of the chapter on *Personalized and Adaptive Serious Games* in this volume.

A Brief History of Motion-based Games for Health. First historical examples of motion-based games for health (MGH) have been produced as early as the 1990s [89]. MGH have a close relation to exergames, which have an even longer history, reaching back to first exercise bicycle and dance mat games in the 1980s [126]. In a modern classification, exergames would likely be interpreted as a subclass of MGH with a loose medical focus on prevention. GFH experienced a first small surge with the introduction of first sensor and input devices for digital interactive systems for home use (i.e. the PC and gaming consoles with dance mats). A second surge was supported by recent improvements in sensor and interaction device technology due to low-cost and small scale sensors, sensor fusion, and increased processing power. This has enabled affordable consumer devices such as the EyeToy, the WiiMote, wearable fitness trackers, and the Kinect, which all augment the readily available technologies for motion-tracking, which in turn forms the basis of all motion-based games for health that aim to be truly interactive and make use of the three basics promises of MGH.

During the second surge over roughly the last ten years, games have been introduced to more and more application areas and target groups. While exergames had been created early on to focus on the young target audiences that were already accustomed to video games, and consumer releases for younger audiences are already commonplace and reach large international markets, different target groups have recently stood in the focus of a growing number of projects [120, 14, 83]. Positive indications have been found with GFH for a wide range of target groups, such as stroke patients, children with cerebral palsy, people with multiple sclerosis, or more general groups, like older adults (cf. to the introduction and the background sections of this chapter). This line of work can also be seen as a continuation of explorations of virtual reality (VR) applications in the respective application areas, such as hand function rehabilitation for people recovering from stroke [79]. As with other GFH, personalization through adaptability and adaptivity remains an important challenge, although promising advantages over traditional approaches, e.g. for instructing exercise executions, have already been demonstrated. In the case of exercise instructions, exercise executions at home were performed at a more adequate speed [148].

Project 1: WuppDi *WuppDi*, the first project at the TZI Digital Media Lab at the University of Bremen targeting motion-based games for health focused on supporting physiotherapy for people with Parkinson's disease (PD) [11]. PD is a non-reversible progressive neurodegenerative condition that affects many motor-related functions with symptoms such as balance problems, rigidity, and tremor. Physiotherapy is an important element of the long-term treatment of the disease. However, the frequent exercising sessions are often perceived as boring, and the slowly reduced abilities over time can lead to frustration, endangering a continued treatment. It is apparent how the three areas of potential of GFH, motivation, guidance, and feedback, appear valuable in the context of PD. Since the patients were largely older adults and had little experience with video games, it was assumed that games would have to be designed specifically for the use case. This decision was supported by informal trials of commercially available motion-based games with members of the target group. The games were found to be mostly overstraining and confusing.

An *iterative user-centered design approach* was employed from the beginning, including therapists and patients in exploratory discussion rounds and early prototype testing. Figure 14 shows the start screen of the game suite with the final selection of mini games, which were all designed around the scenario of fairy tales. That scenario had been determined to have positive associations and to be motivating for most patients. A number of earlier prototypes were abandoned, some since they were found to be too fast, or require motion patterns that were too complex, some due to less expected factors, such as the perceived violence of smashing bugs in one prototype. Overall, the final prototypes were perceived to be fun and motivating by both patients and therapists. However, it was also found that no single game fit the abilities and needs of all patients during evaluation sessions and it was concluded that the games, which featured traditional difficulty selection via different levels of difficulty, could be improved by realizing more *flexible* (adaptable) and potentially (automatically) *adaptive* implementations. Patients were also found to require *close guidance*, even after detailed video instructions had been added to the game suite, and all feedback in the games was tuned to focus on positive advancements. The focus on exclusively *positive feedback* was chosen since patients often lacked confidence and could be demotivated by negative feedback (e.g. "You Lose!"), although such feedback is a common element in regular video games.

Fig. 14. The game selection screen and screenshots of all five final prototypes in the WuppDi suite of games for the support of physiotherapy for PD patients.

The common and familiar theme of fairy tales was noted to reduce anxiety in some patients and attempts at hiding unnecessarily visible technical equipment (e.g. dangling connector cables) also appeared to reduce aversions towards interacting with the applications. Next to the need for personalization, shortcomings in tracking accuracy, accessibility, and playability for some patients were also identified as avenues for further improvements. Follow-up studies employing the WuppDi games informed the following projects by investigating the impact of various factors and manipulations on player performance and experience. The studies included topics such as adaptability with calibration and adaptivity via threshold heuristics [134], visual complexity [132], the role of rhythm and timing [95], rewards and achievements [142], and cooperative multiplayer effects [67].

Project 2: Spiel Dich Fit und Gesund On the basis of the lessons from the WuppDi project, and given the strong positive response expressed not only by PD patients, their relatives, and therapists, but also through notable public interest and requests by therapists for similar programs for other target groups, the project *Spiel Dich fit und gesund* (SDF), which translates roughly to "play to become fit and healthy", was set up to focus on exploring the use of MGH for older adults. Gerontologists and social care workers had suggested that games similar to those that they had seen as part of the WuppDi suite of games for people with PD could work well for general movement motivation with older adults. Thus, a suite of games was envisioned around the cornerstones of supporting motivation to improve upper body movement, flexibility, and balance, as well as exploring general movement motivation, cognitive training, and MGH with a strong musical, or rhythm and timing component. The possibility to personalize the games to individual users was also an integral part of the concept.

Older Adult Gamers. In opposition to the common assumption that computer or video games do not play a role in the day to day life of older adults, research has shown that many older adults do play games [78], although their preferences differ from those of younger target groups. Video games had even been considered for potential cognitive training benefits for older adults as early as 1983 [154]. Furthermore, recent research indicates that older adults have a strong interest in games that they credit with a reasonable potential of helping with improving their physical and mental well-being [109, 134]. This encompasses so-called "mind training" games, such as quizzes or mathematical puzzles, but increasingly also motion-based implementations, for example of known games, such as bowling [45]. Depending on the individual implementation and use case, such games or playful activities have been shown to have both cognitive [7] and physical [86] benefits. It can also be assumed that younger players will come to expect to continue to be able to play sedentary and motion-based games that work adequately for them as they age. Even today, video games as a market are often underestimated and in some markets, as many as 20% of the regular gamers are older than 50 years of age [28], with the average age being 35 years and the largest market segment by age being the gamers of age 35+ with 36% (US market data from 2012/2013) [46]. Such developments, together with the fact that the older adult population is notably impacted by modern sedentary lifestyle, provide good reason to suggest the exploration of MGH for the target group of older adults.

Perpetual User-Centered Iterative Design for MGH. Since related work and the prior project had underlined the importance of user-centered iterative design in the context of MGH, SDF was designed around that approach from the start. The project aimed for continuous iterative testing alongside the project development to start as soon as interactive prototypes were available. The continuous brief iterative testing was flanked by selective, more quantitative evaluations and comparative studies around specific questions that arose during the development.

Since SDF targeted the implementation of prototypes around three topic areas, namely *movement activation*, *cognitive training*, and *music, rhythm, and timing guided movement dual-tasks*, the first year of the project started with early brainstorming and conceptualization sessions together with experts from social support services for older adults and experts from a game development studio. These initial planning steps involved the creation of persona to facilitate a guided discussion and pre-evaluation of various design approaches and concepts, as well as discussions around topics such as the movement patterns that were to be implemented, the settings or scenarios in which the players should be placed, and potential game concepts which could serve to connect both of the prior aspects. Early on, group interviews with attendees of various older adult meeting centers, including the center staff, were conducted to gather more information regarding target group preferences regarding suggestions for game world scenarios, their musical taste, favored types of games, exercising, and preferences regarding potential visual styles for the game prototypes. The outcomes were largely in agreement with related work on similar sets of preferences [78, 109].

In these early explorations and throughout the iterative process of the SDF project it was regularly challenging to find groups with balanced numbers of male and female participants. While this largely represents the gender proportions present in older adult populations, differences in interests and motivation of the gender groups should still be considered if the target group definition does not explicitly exclude either them. In summary, and not separating by gender, the results hinted at "familiar scenarios", such as a garden or a shopping mall being frequently selected over more exotic ones. The importance of popular songs stood out regarding musical tastes, although later on, music that was not well-known also turned out to be accepted. Members of the target group mostly favored classic board or card games, and those that played computer or video games also most often reported to be playing digital versions of such classics or games of a very similar nature. Participants were split regarding exercising with some being regularly active and a larger portion not being active, although many said that they had been regularly active in the past. After showing members of the target group pictures of different levels of visual complexity to determine target design styles the responses were mixed.

Since the fidelity of the visual design has a large impact on the resource allocation in a game development project, the topic was selected for a detailed study that was performed to gain a more nuanced understanding of the preferences and needs of the target group with regard to visual complexity. Because it was not clear how the deterioration of vision ability with increasing age would combine with preferences of the members of the target group and the general setup of standing two to three meters away from a large screen for projecting game content, the comparative within-subjects design study referenced in figure 13 was setup to compare different levels of visual complexity on a continuum from completely abstract (only clear and simple shapes) to very detailed (almost photorealistic). In brief, regarding player experience, manipulating the presence or absence of a micro-story (compare the "abstract" version of the game to the other versions shown in figure 13) was shown to have an impact on the player experience, but strong differences in player experience or performance between three levels of visual complexity that all carried the micro-story of a fishing game were not detected [132]. For the SDF project these results led to the preference of a reduced complexity visual style as a cost-efficient approach. While the study on visual complexity was carried out with modified versions of non-SDF prototypes, the first SDF prototypes of movement activating games set in a garden scenario were tested early on with older adults in social meetup facilities, to allow for pre- and post-play discussions. Further early trials were conducted in public spaces, such as malls, which allowed for a broad exposure, testing the reactions of heterogeneous "walk-in subjects". Requests by a number of physiotherapists who showed great interest in the approach of MGH led to the more formal definition of the support of their application scenarios with the target group of older adults as a development target for SDF in order to determine the applicability in the context of physiotherapy, rehabilitation, and prevention.

After initial user feedback and observations (both collected following loosely structured protocols) were integrated to improve the initial prototypes, regular bi-weekly testing sessions with roughly two to five participants per test run were started in cooperation with a large physiotherapy practice to accompany the further development and fine-tuning. Player feedback was collected with single-sheet questionnaire featuring smiley scales (regarding the game experience and the experience of performing the exercises) for brevity and clarity. Therapist feedback on their impression of interacting with the system, as well as their evaluation of the way that the respective patients interacted with the system, was also collected with a questionnaire accompanying each test session. The first major development cycle was rounded up by interviews and discussion rounds with therapists regarding their requests for settings and parameters to make the games adaptable to individual users, leading to the user-centric parameters *range of motion*, *speed*, *accuracy*, *endurance*, *cognitive complexity*, and *resilience* being targeted for settings interfaces with a threshold-based mapping onto game variables.

In addition to the continued iterative testing, the games were also employed in a first exploratory evaluation in a nursing home. While most patients were aware of the connection between their body movements and actions by a player character on screen after a thorough introduction, they still required close guidance or direct physical support and in many cases tracking was complicated by obstructive devices, such as wheelchairs or walking aids, or by limitations in the tracking of less pronounced movements. These findings are in line with the limitations encountered by other researchers when attempting to employ MGH with frail older adults [54]. Due to the challenges encountered in this exploratory trial, the target group for SDF was limited to not include frail older adults.

Fig. 15. A screenshot of the game Sterntaler which was employed for the study of adaptability and adaptivity in MGH for PD patients [134].

The approach to adaptability and adaptivity in SDF was informed by a further study based on the WuppDi (cf. section 4.2) project where three PD patients were observed during multiple consecutive sessions of play over the course of three weeks. The study setup featured a calibration- and settings-based original set of three parameters (*range of motion*, *accuracy*, and *speed*) that was adjusted between sessions following a threshold-based rubberbanding heuristic with predefined upper limits that were based on individual calibration. This approach was found to work well in increasing the range of motion whilst maintaining good player experience measures. Clarifications were found to be helpful with regard to the impact on scoring and therapists remarked that the set of parameters was rather limited, leading to the extended parameter set employed in SDF. In further adjustments of the principle for prolonged use in SDF the single pre-calibrated development targets were replaced with a milestone system that enabled therapists to set development milestones with target values for all parameter settings for either individual players or groups of players. The heuristic employed in SDF then facilitated automatic adaptation as long as the performance was found to remain in pre-configured acceptable boundaries around the current interpolated performance target at any given point in time.

With first prototypes of a settings and configuration interface for therapists at hand, usability focused testing helped with resolving general design challenges. A small study with therapists confirmed the adequate breadth, understandability, and flexibility of the chosen user-centered parameter set. Since movement capability configurations were deemed important by the therapists, a special grid-based settings interface was implemented that allowed therapists to configure intensities of activation (ranging from full activation to complete deactivation) of zones for the placement of interactive targets in the game (see figure 16).

Fig. 16. Screenshots from the configuration interface for therapists designed in the context of the SDF project. Left: Settings are performed per player / per group on separate controls for speed, accuracy, etc. Right: A custom grid-based component that allows for configuring range of motion via active or inactive motion-target zones.

Next to the subsequent introduction of more game prototypes from the second and third development target areas, which were tested in social meetup facilities for older adults and in public spaces, further dedicated studies investigated the *impact of modality and delay of audio instructions*, especially in the games focused on rhythm and timing, the *optimal activation time for motion-based interactions with hover activated buttons* for the target group, and the *preference and impact on player experience and performance of different modalities for instructing dance movements* in a rhythm and timing game. The latter included a comparison of instructions between dance moves shown by (a) an instructor character that was similar in visual style to the player character (the player character is not shown in the figure), (b) instructions shown by icons approaching an "action zone" akin to popular dance games in the tradition of Dance Dance Revolution, and (c) a mixture of both approaches (see figure 17).

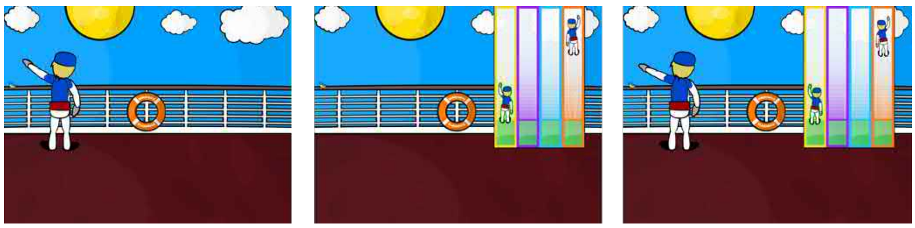

Fig. 17. Screenshots of the dancing game from the rhythm and timing development target in SDF showing the different experiment conditions (left to right: a, b, c) for motion instructions.

While quantitative results on game experience and performance showed no consistent differences, observations and player comments indicated that the participants were able to play with all three modalities. However, the overlay version (b) required more introduction and training than the instructor character version (a) and while the overlay version was eventually used by some participants to foresee the coming actions, many participants had troubles with understanding the instructions indicated by the icons, thinking, for example, that poses should be held indefinitely. The version with both displays (c) was confusing to some participants, which led to SDF adopting the instructor character for the continuing development.

Additional parallel studies that were carried out alongside the principal development of SDF investigated the impact of different *interaction modalities for range of motion* and other movement related capability adjustments (leading to the selection of the grid-based method over a more classic windows-icons-mouse-pointer components based interface or motion-based input), *reactions to being informed or not informed about automated difficulty adjustments* (leading to the decision to spare attempts at avoiding any mention or visibility of the adjustments), and the *impact of different modalities for presenting movement instructions* comparing a virtual character to video based and real human instructor based instructions [140], with the latter study underpinning the adoption of a virtual instructor for SDF, since the resulting performance was found to be significantly improved over the performance achieved with a video instructor, while there were no clear and consistent differences on the experiential measures aside from a greater ease of understanding and preference of the human instructor.

The last major development and evaluation cycle included further implementations of the interaction work-flow surrounding the core games (game menus, pausing the game, etc.), validating the acceptance of intermittent non motion-based quizzes that were implemented to ensure breaks between sessions of more physically intense gameplay in order to avoid overstraining, as well as prototype finalizations and polishing (including, for example, visual notifications and guides if players left the trackable space in front of the sensor device). In a final study, the suite of movement activating games was employed in situated use over a period of five weeks in individual therapy sessions in a large physiotherapy practice. The study compared the usage and impact on performance, experience, and on upper body flexibility and balance indicators, of (a) the suite of games with purely manual settings with (b) the suite with semi-automatic difficulty adjustments, and (c) classic therapy interventions without the games [136]. Findings indicated that using the games benefitted the perception of *autonomy* and *presence* expressed as need satisfaction components, while the classic therapy sessions showed higher *tension-pressure* and *effort-importance* with all measures being positively related to intrinsic motivation. While no significant differences were found on these measures regarding the two versions of the game suite, automatic adjustments were preferred by the therapists, and the game groups showed significantly increased functional reach compared to classic treatment [136]. For SDF these findings were interpreted to support the integration of semi-automatic adaptivity, since it was not found to have notable negative impacts on the player experience while therapists indicated a preference for automated support in adjusting the games to the individual patients (following the semi-automatic miltestone-based pattern with threshold-limited linearly interpolated game parameter settings that is mentioned above and detailed in the chapter on *Personalized and Adaptive Serious Games* in this volume).

Fig. 18. Screenshots of two games that were part of the final SDF suite, a photo of a player interacting with a third game from the suite, and a screenshot of the range of motion configuration component of the therapist configuration interface.

Project 3: Adaptify SDF had demonstrated, along with simultaneously developing related work, further aspects of the applicability of MGH in the context of physiotherapy, rehabilitation, and prevention. The games were largely tailored to motivate movements of broad characteristic classes, such as picking apples from a tree (broad movements at medium or high, self-controlled speed), catching locusts (slow movements that require more accuracy) or striking balancing poses with stretched out arms (very slow, highly controlled, endurance poses). Many physiotherapy treatment programs can incorporate such elements, but many exercises that therapists regularly work with were not explicitly present in those games. The SDF games were also limited to a suite of mini games that were very accessible but did not aim to provide a lot of alternation over time and all games relied on a direct player-body to player-character mapping as the core mechanism. While semi-automatic adaptivity was present, it required the initial configuration of milestones and no direct relation to the content, duration, or progression of traditional physiotherapy treatment programs was given. Lastly, the optical tracking from the front limited the number of exercises that could be reliably and accurately detected. The subsequent project *Adaptify* [2] is currently en-route targeting these potential points for improvements, along the design and implementation of a new series of prototypes for motion-based games for health. Three MGH are being created, focusing on (1) the modular extensibility to multiple exercises, (2) the implementation of more complex game mechanics and elements of storytelling, as well as (3) generative content for improved alternation in game play experiences. Adaptify targets adaptivity both with regard to the personalization of therapeutic exercise programs, expressed in series of exercising sessions (which are composed of sets of established therapeutic exercises) over time, as well as in user capability and needs modeling, which can facilitate the automatic generation of customized exercises, guidance, and feedback.

Figure 19 shows the complexity of a project such as Adaptify that takes a modular approach to the iterative user-centered design of MGH and the surrounding ecosystem that is designed to support multiple MGH and future expansions with additional exercises. The project also focuses on adaptability and adaptivity that encompasses overarching therapy goals and includes the design and inclusion of a sensor mat (see figure 23) to augment the vision-based full-body tracking, in order to support a broader selection of exercises including many exercises that are performed whilst kneeling or lying down and which are central to the main use case of chronic lower back afflictions. The project focus on supporting physiotherapy was determined based on experiences and findings in the prior projects, and also since physiotherapy presents a considerable section of the health market, where increases in demand put notable pressure on individual therapists, practices, and the system as a whole.

Games for Health in Physiotherapy. Taking Germany as an example, although the number of practicing physiotherapists in in the country has more than doubled since 2000 (data from 2000 to 2011), many therapy practices are operating at capacity limits. Expenses of public health insurances on physiotherapeutic

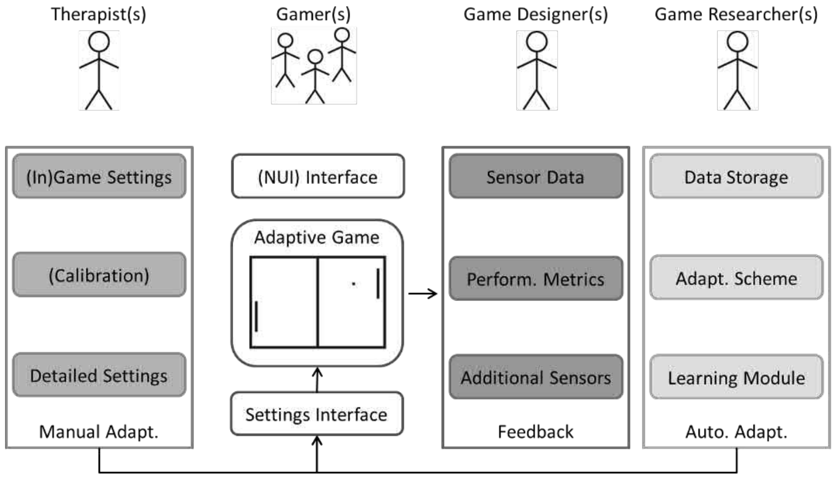

Fig. 19. Modular components of the general engineering model for the project Adaptify.

services have almost doubled from about 0.9 billion Euros in 1993 to 1.8 billion Euros in 1999 [60]. The gross expenses have since increased to 2.9 billion Euros in 2005 [3] and reached 4.4 billion Euros in 2015 [4]. Opportunities for saving costs are in great demand and therapy guidelines already implement a larger proportion of self-directed and at home exercising. Dynamic and "hands-off" exercises in which the patient is not actively guided by a therapist are growing in importance and the clinical indications of such approaches are positive [144]. In the context of reduced supervision, achieving a high and constant quality of treatments is a major challenge. Next to the challenge that therapists, in many ways, mirror aspects of the school that they were educated in, and that inter-therapist agreement e.g. in quality of motion ratings is often not strong [114], the self-dependent adherence of patients to exercise protocols is an important factor for therapeutic success [144]. In this context, unchecked increases in the number of prescribed exercises can lead to reduced compliance [66]. Individual behavioral and socioeconomic factors are known to present further challenges and even a life threatening diagnosis does not necessarily increase compliance (e.g. in cardiac rehabilitation [77]). Further factors that have been found to correlate with non-compliance are self-reported and factual barriers, lack of positive feedback, and a sense of helplessness [131].

Improvements in compliance in the context of physiotherapy, prevention, and rehabilitation (PRP), on the opposite, can be a achieved through strategies such as (a) the frequent encouragement of patients, (b) stimulus control, such as wearing training clothing, (c) cognitive strategies such as directing attention towards the thoughts of a patient before, during, and after exercising, (d) time oriented and flexible personalized goals from session to session and for the month, (e) codes of conduct between patients and therapists regarding long-term goals, (f) including family members, (g) increased interactions with therapists and consistent binding of therapists to patients, (h) goal oriented clubs, (i) increased feedback regarding progress, (j) self-directed goals [77]. Furthermore it has been shown that written exercise instructions with illustrations led to increased compliance rates compared to purely verbal instruction for back pain exercises [127]. In this light, and considering the potential of MGH to provide, e.g., positive feedback, clear and self-directed goals, encouraging guidance, and immediate feedback, as well as a reliable and objective overview of the individual progress, strongly suggest further explorations of MGH in the context of PRP, especially for usage scenarios where patients would otherwise perform exercises without immediate professional oversight by a therapist.

In summary, MGH for the support of PRP have seen increasing attention in research and development over the past years and GFH have also been explored for many other application scenarios ranging from specific maladies to general fitness. First validated MGH are beginning to enter the market and the basic promises of GFH are beginning to show real outcomes with broad audiences. What is mostly missing are approaches to more overarching treatments, such as protocols for data exchange not only concerning the health status of individual patients, but also the MGH history and achievements. While aggregating information from multiple GFH is extremely promising, and first GFH are beginning to make use of game delivery and platforms that feature mechanisms for performance data aggregation and exchange [47], there are a number of challenges that remain with the developing ambitious GFH. We will discuss a selection of prominent challenges in the following section.

5 Challenges with Designing and Researching GFH

While helpful design techniques and research approaches are available for GFH, as illustrated above, a number of central challenges with researching, creating, and evaluating GFH still remain. The following sections build on prior work [133] and summarize challenges, adding additional aspects to those areas that have already been mentioned in the prior sections, and discussing a number of additional aspects that have only been touched implicitly in the remainder of this chapter (namely truly user-centered design, sensing and tracking, practical integration, safety and clinical validation, ethics, data privacy, and regulations).

5.1 Interdisciplinarity and Multiple Party Interests

As noted before, the field of GFH is highly interdisciplinary, with contributions from many fields of work with numerous respective sub-fields, including *research* with the fields of human-computer interaction, game user research, game studies, psychology, medicine, health sciences, and more; *engineering*, with subfields such as graphics engines, networking, multi-sensor devices, etc.; *design*, with game design, game asset design, user interface (UI) and UX design, sound design, etc.; and *health*, with therapy, nursing, pharmacology, etc. and many others, which may or may not be actively involved. In addition, besides the patients or players, multiple parties may interact with GFH or the surrounding projects and become stakeholders with their own interests and impact, such as (a) health professionals, care-givers or medical staff, who use the applications in their line of work, (b) guardians or relatives of patients who are interested in the well-being, safety, and progress, (c) the researchers, designers, health professionals, and engineers involved with creating the GFH, and (d) even co-players or bystanders who are not directly involved with using the GFH for any serious purpose. Next to careful user-centered iterative research and design as noted above, acknowledging the interdisciplinarity of GFH, and proactively analyzing projects with regards to potential interest groups can be helpful. Assuming different lenses of reflection, such as investigator-specific, project-specific, and external factors [87] related aspects of interdisciplinarity can help to avoid neglecting important angles.

5.2 Truly User-Centered Iterative Design

Approaching the conceptualization and design of GFH around multiple party interests serves to illustrate a common misconception with *user-centered design*: Encompassing a single user group often is not sufficient. This is aggravated by the fact that test or evaluation candidates have to be swapped out frequently if shortcomings are to be detected reliably, since users frequently adapt to existing problems more swiftly than those problems can be detected and fixed across iterative design and evaluation cycles. Thus, if evaluation participants are frequently changing, it would perhaps be more adequate to speak of *user-group centered design*. This, of course, implies the insight that GFH, at the beginning of an interaction with a new player, are always optimized for a certain sample group mean, indicating that there is still room (and often the need) to optimize the game further for individual users. Thus, while user-centered design and participatory methods are important, they often leave room for further improvements. As the next section will discuss in more detail, manual adaptability and automatic adaptivity play an important role in further optimizing GFH for individual players. Yet again, testing adaptable and adaptive systems in an iterative manner is complicated, since multiple game sessions are usually necessary in order to gain any reliable evidence regarding the quality of the adaptation approaches. Approaches range from simulating users with automated actors or recordings, over collecting group-based information to provide a reasonable initial setup, to the continuous development of the adaptability and adaptivity of a game as a service after an initial release.

5.3 Heterogeneity and a Broad Range of Serious Goals: The Need for Adaptability and Adaptivity

In addition to multiple party interests, the central challenge of adaptability and adaptivity results from the highly variable individual abilities and needs of patients even within specific target groups and within the individuals themselves, due to complex change over time. While GFH have great potential in terms of health applications, education, or behavioral change, an efficient personalization [62] and customization to groups and individuals is clearly a requirement. Despite notable setbacks and disappointments since the early beginnings of adaptive software [75], the area has made great progress, and many commercial and mass-market applications nowadays have adaptive features. It is therefore not surprising that adaptive elements are increasingly being explored for usage within games, be it for personalization regarding a single player, or for balancing between multiple players [57, 107]. Adaptive techniques in the context of games have been shown to have the potential to improve game experiences [9] and are being discussed intensively especially in the context of motion-based games for health [6, 119], due to the complexity of body-based input [70, 73, 136, 134] and the related physiological health targets. While *implicit* game performance data and physiological data play a self-evident role in measurements to perform adaptation in GFH, psychological data and *explicit* user feedback can complement that information both as feedback data for "on-line" adaptive mechanisms [98] and for determining presets [96]. Methods that are based on user-centered feedback measurements also offer great potential for efficient generalizations and transfer from one GFH application to another, since the outcome measures are not relating to aspects of the game, but to aspects of the player [69].

The Role of Machine Learning and Data Analysis in Games for Health. In many cases, due to the multivariate and nonlinear nature of measures and settings in GFH, heuristics that are fully defined during development become hard to employ efficiently and may not be the optimal choice. Methods from artificial intelligence, machine learning, and statistical data analysis, both with a frequentist and Bayesian background, are not only employed in the larger context of GFH development for research and evaluations, as well as for learning about application scenarios etc.; they can also be employed for dynamic difficulty adjustments [76] and other kinds of adaptivity in GFH [62]. Examples range from the heuristic analysis of facial expressions in order to determine the emotional status of the players [63], over the usage of Bayesian methods for overcoming cold-start problems [157], the usage of support vector machines for classifying emotional states based on physiological player data (see discussion in the chapter in *Affective Computing* in this volume) such as galvanic skin response and body temperature [30], reinforcement learning for determining challenge sensitive actions [8], and genetic algorithms for difficulty adjustments in platform games [153], to neural networks for games for the support of rehabilitation [15], and implementations featuring components of recommender systems [105]. Furthermore, the construction of dynamic user models [92] for supporting the continued optimization of adaptive components can be helpful during development and after deployment [106], especially when complex multivariate fluctuations of player preconditions are closely tied to the potential serious outcomes, as for example in the application area of depression prevention [80]. Furthermore, games with online functions and account management, and games with large player numbers can allow for a continuous adaptation to individual players whilst also adapting the parameters of the underlying models themselves [99].

5.4 Sensing and Tracking

GFH frequently rely on special sensing and tracking devices, be it for direct player input and control, for performance, action execution quality, or player health status estimation, or to provide data for performance measures for adaptivity. Next to costs and maintenance, accuracy, and reliability can often be challenging to achieve and maintain, although the increasing ability of affordable and durable consumer (multi)sensor devices such as optical body trackers or wearables with motion-tracking capabilities are easing some of these challenges. For example, the Kinect depth-camera based skeleton tracking has been shown to provide comparable performance to professional optical tracking systems [50, 31], with some limitations due to the fixed tracking angle, yet some advantages in terms of ease of use and calibration drift.

In some areas, the integration with professional medical devices, services, and medical data management have to be considered early in the process, since they can otherwise grow very expensive to implement. As examples like SnowWorld [72], where a virtual reality display was required to be submerged under water during burn treatment, show, additional and highly unusual requirements regarding hardware can occur with GFH. Early explorations investigating the context for later situated use [136] of the GFH in a targeted domain can help with foreseeing the requirements and early tests of sensing and tracking hardware often lead to additional analysis methods, or modes, or to switching to alternative hardware.

One aspect that is frequently overlooked is the strong likelihood that sensing and tracking not only present challenges in accuracy, reliability, and calibration drift, any given combination of sensors will also not capture all information that is relevant to determining the full objective state of a complex game-player ecosystem. This strongly implies the perspective of augmenting the toolset for professionals instead of replacing professionals in GFH, as not to lose the flexibility and ability of embodied judgement provided by human professionals.

Lastly, when discussing sensing and tracking, it should be mentioned that actuation also plays an important role in GFH. Especially with motion-based games, exploring additional actuation channels in addition to the traditional non-tactile audio-visual feedback provided by computing and gaming systems can be beneficial. While the SDF project mentioned above, for example, gained notable benefits in tracking reliability due to employing the advanced depth-image based tracking of the Kinect device compared to the difference image and color-blob tracking employed in most prototypes from the WuppDi project, the latter required players to hold sticks with bright-colored markers in their hands and this tactile aspect of the interaction was missed by some testing participants who got to experience both systems.

5.5 Practical Integration

The aforementioned potential special requirements with regard to the environmental compatibility of hardware represent one important consideration regarding practical integration. GFH only make for a worthwhile pursuit if they can eventually be used in the targeted application scenarios. In many cases this means practices or clinics, where next to special requirements (e.g. with regard to hygiene or electromagnetic shielding), the efficient integration into existing procedures is usually key. Experience from projects about MGH for the support of physiotherapy, rehabilitation, and prevention at the University of Bremen with deployments at multiple therapy practices have produced the expert guideline that roughly two minutes per patient are the maximum time for adjustments and calibrations in settings interfaces such as those pictured in figure 20 that therapists will tolerate on a regular basis, since the usual treatment blocks last for only 20 minutes in total. Furthermore, manual configuration should always be optional, although clinic and practice leaders found it important to be able not only to make customized treatment plans for groups or personalized treatment plans for individuals, but also to be able to customize the whole GFH system to encompass some of their respective branding as well as their own treatment approaches or patterns.

In home or unsupervised usage scenarios, the setup has to be manageable for novice users and spatial requirements can quickly become limiting, especially with full-body based input. Lastly, acceptance is an important factor, and due to the multiple interest groups unusually difficult to achieve equally well in all relevant groups for GFH. With health professionals, for example, it has proven important to clearly develop and position GFH as augmentations and not as potential replacements for the very health professionals who would oversee their use with patients.

5.6 Safety and Clinical Validation

Both with supervised and unsupervised usage in healthcare environments and at home, safety plays an important role and can be challenging to guarantee to the required extent. MGH carry a risk of overexertion and the ties to health applications mean that special health implications may be present with many players. Even under supervision, patients have been observed to perform beyond their usual limits, which can be beneficial and is part of the motivation to employ games in health applications, but also carries the danger of both physically and mentally overstraining players. Clear information and instructions regarding proper usage (figure 21, for example, shows frequent embedded video demonstrations of how a movement exercise should be performed in *sPortal*, an experimental modification of the game Portal 2 that was employed for a study about motion-based game inputs for existing high quality commercial games [152]) and potential dangers are important issues to be considered in the creation of MGH. Furthermore, the implementation of heuristics for detecting dangerous states and forced breaks or usage limits can be required. It has to be taken into consideration that unnecessary interruptions due to false-positives can have very negative impacts on the player experience in such cases. Next to careful testing and cautious recommendation for usage scenarios that should only include tested contexts, the numerous laws and regulations that might apply to

Fig. 20. Studies with physiotherapists in the context of the projects Spiel Dich Fit and Adaptiy have indicated that the time required to successfully interact with therapist configuration interfaces for motion-based games for health for individual players should be kept smaller than two minutes per patient. Accordingly, more efficient interaction modalities for mobile devices (right) are being explored as an alterternative or augmentation to classical windows, mouse, icons, and pointer (WIMP; components highlighted with color markings) interfaces on stationary or laptop devices (full classic WIMP interface on the left).

the interdisciplinary application should be researched early in order to facilitate implementations that respect these requirements.

For GFH respecting existing regulations will often mean that clinical trials must eventually be pursued. While some clinical investigations of GFH have been published [7, 10, 117, 22] and a larger number is currently underway, the number is still very limited compared to the number of GFH that have been developed and discussed publicly or published. The often prohibitive costs of clinical trials are one reason, as is the duration that clinical trials require not only for the execution, but also in planning with complex ethics approvals and pre-studies for endpoint investigation to facilitate effect size estimations. These aspects quickly sum up to multiple years of planning and preparation. In the light of the usual speed of operations in the game development world, this aspect represents a further point for frictions in the interdisciplinary field of GFH.

5.7 Evaluation Methods and Long Term Use

Not only are clinical or any reliable studies of GFH challenging to setup, due to the hard-to-control environments that situated use of GFH usually entails, due to the complications around acquiring participants for health-related studies, and due to the complexity of human-subject research with heterogeneous subjects, but validated research tools are also often not readily available, since

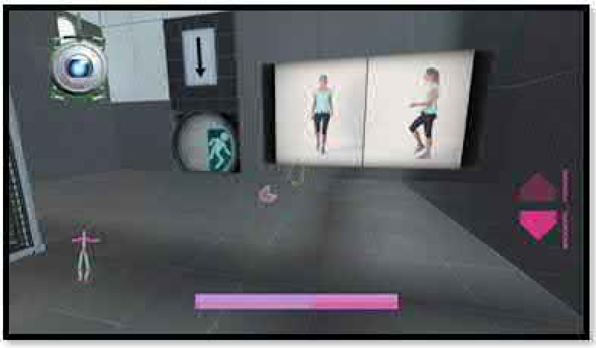

Fig. 21. A screenshot from the project sPortal where detailed instructions are delivered via integrated video during gameplay in order to achieve correct executions of movement patterns without breaking immersion [152].

tools are originally made either for the investigation of health aspects, or for the investigation of game user experience, yet not for a combination. This means that tools are frequently challenged to include potentially conflicting sub-scales and tradeoffs (e.g. regarding the importance of efficiency and effectiveness). Furthermore, research methods may feel intrusive to the players, interfering with positive game experiences and also with health-related outcomes. While some validated game user research questionnaires have been successfully used in recent GFH studies (such as the player experience of needs satisfaction (PENS) questionnaire [122]), personality or player types also play an important role [112], and health related endpoints (typically dependent variables in studies) are usually most important in clinical terms. These require domain knowledge for the application use case. The combination of multiple research instruments further complicates setups and analyses, and can quickly lead to survey fatigue and overstrained study participants. It is therefore not surprising that clinical studies or other controlled medium- to long term preclinical studies of GFH are still rare. In this light, the careful piloting of studies, expert advice in selecting measurements and target endpoints, as well as a limitation in the implemented features of a GFH and in the number of study conditions can be strategies to approach the aforementioned challenges.

5.8 Ethics, Data Privacy, and Regulations

As noted above with regard to safety, laws and regulations play a much more critical role in many GFH when compared to games that are produced primarily for entertainment. With patient data, data privacy becomes much more sensitive than regular game performance data and even seemingly non-medical information (such as a purely game mechanics oriented game performance measures) can carry medical implications. This poses challenges when aiming to capitalize on the promises of guidance and feedback in GFH (as discussed above), and also concerning learning for adaptivity across individual users and use cases, since such aspects typically entail the transfer of player-patient data via the Internet and the storage of said data on remote servers.

With regards to promises of benefits, claims regarding medical or therapeutic effectiveness and potency require the cautious use of specific legal terms and phrasing, and beyond adhering to regulations as required by law, it should be a general concern to produce ethical GFH, which may in many cases mean limitations beyond what is required by law. For example, while games for positive health behavior change can make use of persuasive techniques, the users should not be coerced into act in ways they would normally not approve of [65] and creators of GFH should keep in mind that the data gathered from players interacting with these games often has the potential to be a unique identifier for a given user, akin to a fingerprint, since it stems from physiological origins.

6 Current Trends and Open Research Questions

In summary it can be said that, while a large number of research and development projects on GFH have been completed or are currently underway, the challenges around researching, designing, implementing, and using GFH in practice are still considerable and there is a lot of room for research and technical innovation in the field. At the same time, it should also be highlighted again that GFH do not necessarily have to compete with the highest quality commercial games for entertainment, since they often rather compete with the existing alternative applications regarding the serious health target [149]. However, the pursuit of a higher production quality, of moving beyond mere (collections of) mini games (see figure 22 for an example collection of small motion-based GFH from the project Spiel Dich Fit that feature micro stories due to being set in different vivid scenarios) into the domain of storytelling and more complex overarching game mechanics for improved motivation and longer adherence is one of the trends that is currently occurring, after first GFH and MGH products have started to take hold in the broader (health) consumer market.

Figure 23 shows the exemplary approach of the project *sPortal* [152], which investigated a control layer abstraction to turn existing first-person games into motion-based games [151]. In some cases, studies have shown greater benefits in well-produced games without explicit serious focus than the benefits achieved with explicit serious games (e.g. neurocognitive benefits from playing *Portal 2* compared to *Luminosity*, a game designed specifically for cognitive training [128]). With most GFH, however, the specifics of the targeted health aspects likely make the usage of existing high quality games without large modifications unreasonable, even if considerations about copyrights are put aside. As indicated in the section on sensing and tracking, hardware devices, especially with (multiple) sensing abilities are major drivers of GFH development. This trend will likely continue with new GFH being developed for existing medical or therapeutics devices (such as the gait rehabilitation harness shown in figure 23), other devices becoming affordable enough for larger health market applications (as for

Fig. 22. Screenshots from prototypes of a collection of small movement and cognition stimulating GFH around familiar scenarios, such as a cruise ship (with a dancing game), a shopping mall (with a calculation game shown in the top right and an item matching game in the bottom right), or a garden (with an apple picking game) that were produced for the project Spiel Dich fit.

example with pressure sensitive mats, as developed in the project Adaptify for MGH that feature exercises where ground contact points matter; cf. figure 23 on the right; other examples of similar mats from related research efforts are also available [145]), and new devices being developed or brought into medical or therapeutic use specifically for coupling with GFH.

From the point of view of medical and health research, next to questions relating to the given health target, general effects from health and medical research are increasingly investigated with regard to their applicability with GFH, such as the prevalence and impact of placebo effects [43]. Sensor fusion, mixed sources of evidence, and the continuous integration into user and user-group models contain numerous open ends for future research that can serve both game control, difficulty- and health-target-related challenge adjustments, as well as potential health analysis. From a health psychological point of view, the aspect of competitive and cooperative multiplayer in the context of different GFH application areas requires further study, since the aspect of relatedness bears great promise with regard to increasing motivation, whilst people show specific and culturally influenced interplay in the context of health. On a similar note, the impact of different approaches to balancing and finding tradeoffs between playfulness and seriousness in terms of framing, presentation, and interaction with patients as well as with health professionals, has yet to be explored systematically. Intercultural research and research between different socio-economic groups is also still rare. Many existing research methods still require validation for use with GFH, and new validated questionnaires combining aspects of player experience, perceived health outcome, and treatment experience could benefit a wide range

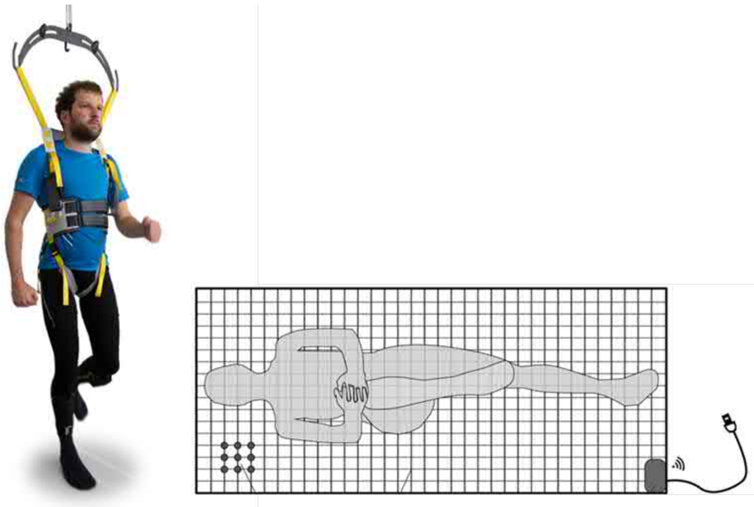

Fig. 23. Left: The project sPortal explored a motion-rehabilitation harness suspension together with motion tracking for walking in virtual worlds that could be employed in GFH. Right: Early concept draft from the context of the project Adaptify of an affordable sensor mat to support motion tracking of complex exercises that could not be tracked fully adequately with optical motion sensing alone.

of individual research projects and greatly improve the comparability of results across research projects.

Overall, it is clear that a host of additional specific questions awaits those who attempt any use case specific project in games for health, and that evidence in support of methods and approaches should be collected systematically [33].

7 Conclusion and Outlook

In this chapter, the basic promises of games for health, namely motivation, guidance, and analysis, are discussed together with background information on related fields. To outline the complexity of games for health, the major contributing factors of interdisciplinarity of the field and heterogeneity of the users are introduced. A number of challenges with corresponding approaches to tackling these challenges are then presented. Based on a discussion of general design principles, research and design of GFH is illustrated along the lines of several motion-based games for the support of physiotherapy, rehabilitation, and prevention. These projects, together with the overview of seminal works show that, despite the considerable challenges, GFH are a worthy area of investigation with great potential to improve health applications in many areas and to benefit from the considerable size of the health market. Recent trends are discussed together with suggested topics for much needed further research. Progress in technical developments and research will likely facilitate the much more ubiquitous deployment of games for health over the next years, if advancements in personalization can be implemented together with reasonable integration into existing health application procedures, and if the regulatory frameworks evolve to facilitate GFH to enter health applications with as little friction as necessary. In tight coupling with non-game applications and with data exchange between multiple platforms, GFH stand to play an important role in the movement towards a more quantified and personalized overall approach to health. Due to the possibility of aggregating much more detailed and comprehensive information about the development of individual abilities, needs, and maladies over time, this looming shift has the potential to empower individuals and to – in turn – inform the rapid improvement of GFH and related health applications in the near future.

8 Further Reading

- Beale I.L.: *Video Games for Health: Principles and Strategies for Design and Evaluation.* Nova Science Publishers (2011).
  The book focuses on the transfer of lessons from learning theory and technology to support procedures for the evaluation of the efficacy of (mostly educational) health games and their design components.
- Göbel S., Wiemeyer J. *Games for Training, Education, Health and Sports*: 4th International Conference on Serious Games, GameDays 2014, Darmstadt, Germany, April 1–5, 2014. Proceedings. Springer (2014).
  This is a proceedings volume which covers a wide range of fields with roughly half of the chapters focussing on topics that are directly related to games for health, while the other half focuses mostly on educational games.
- Ma M., Jain L.C., Anderson P.: *Virtual, Augmented Reality and Serious Games for Healthcare 1.* Springer Science & Business (2014).
  This book covers applications and games for health largely from the angle of the virtual reality and virtual rehabilitation communities. Many practical developments from a broad range of medical application areas are discussed.
- Primack B.A., Carroll M.V., McNamara M., et al: *Role of Video Games in Improving Health-Related Outcomes: A Systematic Review.* American Journal of Preventive Medicine 42:630–638 (2012).
  This review paper provides a concise overview of recent work in the area of games for health together with a discussion of signs for aggregating evidence of their role in improving health-related outcomes.
- Bauman, E.B.: *Game-Based Teaching and Simulation in Nursing and Health Care.* Springer Publishing Company, New York (2012).
  This book provides theory and practical guidelines for the application of game-based teaching / learning and simulations in healthcare.

Online Resources.
http://www.ebgd.be/
http://gamesforhealth.org/

http://www.cdgr.ucsb.edu/db/
http://gameswithpurpose.org/
http://www.seriousgamesdirectory.com/proj/health-care-medical/
http://www.fitness-gaming.com

Acknowledgments. I would like to thank Stefan Göbel and Jenny Cramer for supporting the writing of this chapter. The non-external projects mentioned in this text were in part supported and in part spearheaded by the research staff and students at the *Digital Media Lab* at the *University of Bremen* as well as members of the *Interaction Lab* at the *University of Saskatchewan*. Marc Herrlich, Markus Krause, and Rainer Malaka are invaluable collaborators in this line of work. The projects were also supported by the consortium partners of the projects *Spiel Dich Fit* and *Adaptify*, as well as by the German Parkinson's association (*Deutsche Parkinson Vereinigung*) Bremen. Funding was provided by the *Klaus Tschira Stiftung*, the *GRAND NCE*, as well as by the *Federal Ministry of Education and Research, Germany* (BMBF).

References

1. http://reflexionhealth.com/
2. https://adaptify.de/
3. Der Heilmittelmarkt in Deutschland - Januar bis Dezember 2005. Der Heilmittelmarkt in Deutschland (Apr 2006), http://www.gkv-heilmittel.de/media/dokumente/his_statistiken/2005_04/HIS-Bericht-Bund_200504.pdf
4. Heilmittel-Schnellinformation - Januar bis Dezember 2015. Der Heilmittelmarkt in Deutschland (Apr 2016), http://www.gkv-heilmittel.de/media/dokumente/his_statistiken/2005_04/HIS-Bericht-Bund_200504.pdf
5. Adams, E.: Fundamentals of Game Design. New Riders (2010)
6. Alankus, G., Proffitt, R., Kelleher, C., Engsberg, J.: Stroke therapy through motion-based games?: A case study. Therapy p. 219–226 (2010)
7. Anderson-Hanley, C., Arciero, P.J., Brickman, A.M., Nimon, J.P., Okuma, N., Westen, S.C., Merz, M.E., Pence, B.D., Woods, J.A., Kramer, A.F., et al.: Exergaming and older adult cognition. American Journal of Preventive Medicine 42(2), 109–119 (Feb 2012)
8. Andrade, G., Ramalho, G., Santana, H., Corruble, V.: Extending reinforcement learning to provide dynamic game balancing. In: Proceedings of the Workshop on Reasoning, Representation, and Learning in Computer Games, 19th International Joint Conference on Artificial Intelligence (IJCAI). p. 7–12 (2005)
9. Andrade, G., Ramalho, G., Gomes, A.S., Corruble, V.: Dynamic game balancing: An evaluation of user satisfaction. In: AIIDE'06. p. 3–8 (2006)
10. Anguera, J.A., Boccanfuso, J., Rintoul, J.L., Al-Hashimi, O., Faraji, F., Janowich, J., Kong, E., Larraburo, Y., Rolle, C., Johnston, E., et al.: Video game training enhances cognitive control in older adults. Nature 501(7465), 97–101 (Sep 2013)
11. Assad, O., Hermann, R., Lilla, D., Mellies, B., Meyer, R., Shevach, L., Siegel, S., Springer, M., Tiemkeo, S., Voges, J., et al.: Motion-based games for parkinson's disease patients. In: Proceedings of the International Conference on Entertainment Computing ICEC 2011. p. 47–58 (2011)

12. Bandura, A.: Self-efficacy mechanism in human agency. American psychologist 37(2), 122–147 (1982)
13. Bandura, A.: Guide for constructing self-efficacy scales. Self-efficacy beliefs of adolescents 5, 307–337 (2006)
14. Baranowski, T., Buday, R., Thompson, D.I., Baranowski, J.: Playing for real: Video games and stories for health-related behavior change. American journal of preventive medicine 34(1), 74–82 (Jan 2008)
15. Barzilay, O., Wolf, A.: Adaptive rehabilitation games. Journal of electromyography and kinesiology: official journal of the International Society of Electrophysiological Kinesiology 23(1), 182–189 (Feb 2013), pMID: 23141481
16. Beale, I.L.: Video Games for Health: Principles and Strategies for Design and Evaluation. Nova Science Publishers (2011)
17. Benyon, D.: Adaptive systems: a solution to usability problems. User Modeling and User-Adapted Interaction 3(1), 65–87 (1993)
18. Berkowitz, L., McCarthy, C.: Innovation with Information Technologies in Healthcare. Springer Science & Business Media (Nov 2012)
19. Birk, M., Mandryk, R.L.: Control your game-self: effects of controller type on enjoyment, motivation, and personality in game. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. p. 685–694. CHI '13, ACM (2013)
20. Birk, M.V., Mandryk, R.L., Miller, M.K., Gerling, K.M.: How self-esteem shapes our interactions with play technologies. In: Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play. p. 35–45. CHI PLAY '15, ACM (2015)
21. Black, A.D., Car, J., Pagliari, C., Anandan, C., Cresswell, K., Bokun, T., McKinstry, B., Procter, R., Majeed, A., Sheikh, A.: The impact of ehealth on the quality and safety of health care: A systematic overview. PLoS Med 8(1), e1000387 (Jan 2011)
22. Bredl, K., Bösche, W.: Serious Games and Virtual Worlds in Education, Professional Development, and Healthcare. IGI Global (Mar 2013)
23. Brooke, J.: SUS: a "quick and dirty" usability scale, p. 189–194. Taylor & Francis (1996)
24. Brooks, A.L., Brahnam, S., Jain, L.C.: Technologies of Inclusive Well-Being: Serious Games, Alternative Realities, and Play Therapy. Springer (Jan 2014)
25. Brox, E., Fernandez-Luque, L., Tollefsen, T.: Healthy gaming video game design to promote health. Applied Clinical Informatics 2(2), 128–142 (Apr 2011)
26. Brox, E., Hernandez, J.E.G.: Exergames for elderly: Social exergames to persuade seniors to increase physical activity. In: Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2011 5th International Conference on. p. 546–549 (2011)
27. Bruin, E., Schoene, D., Pichierri, G., Smith, S.: Use of virtual reality technique for the training of motor control in the elderly. Zeitschrift für Gerontologie und Geriatrie 43(4), 229–234 (Jul 2010)
28. Bundesverband Interaktive Unterhaltungssoftware e.V.: (2013), `http://goo.gl/ge2ht2`
29. Burke, J.W., McNeill, M.D.J., Charles, D.K., Morrow, P.J., Crosbie, J.H., McDonough, S.M.: The Visual Computer (12), 1085–1099 (Aug 2009)
30. Chanel, G., Rebetez, C., Betrancourt, M., Pun, T.: Boredom, engagement and anxiety as indicators for adaptation to difficulty in games. In: Proceedings of the 12th international conference on Entertainment and media in the ubiquitous era. p. 13–17. MindTrek '08, ACM (2008)

31. Chang, C.Y., Lange, B., Zhang, M., Koenig, S., Requejo, P., Somboon, N., Sawchuk, A.A., Rizzo, A.A.: Towards pervasive physical rehabilitation using Microsoft Kinect. In: Pervasive Computing Technologies for Healthcare (PervasiveHealth), 2012 6th International Conference on. p. 159–162. IEEE (2012)
32. Chen, J.: Flow in games (and everything else). Commun. ACM 50(4), 31–34 (Apr 2007)
33. Cheng, J., Putnam, C., Rusch, D.C.: Towards efficacy-centered game design patterns for brain injury rehabilitation: A data-driven approach. In: Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility. p. 291–299. ASSETS '15, ACM (2015)
34. Ciaramitaro, B.L.: Mobile Technology Consumption: Opportunities and Challenges: Opportunities and Challenges. IGI Global (Oct 2011)
35. Crawford, C.: The Art of Computer Game Design. Osborne/McGraw-Hill (Jan 1984)
36. Csikszentmihalyi, M.: Flow: The Psychology of Optimal Experience. Harper & Row (1990)
37. Csikszentmihalyi, M., Abuhamdeh, S., Nakamura, J.: Flow, p. 227–238. Springer Netherlands (2014)
38. Curtis, J., Ruijs, L., Vries, M.d., Winters, R., Martens, J.B.: Rehabilitation of handwriting skills in stroke patients using interactive games: a pilot study. In: Proceedings of the 27th international conference extended abstracts on Human factors in computing systems. p. 3931–3936. ACM (2009)
39. De Schutter, B., Vanden Abeele, V.: Designing meaningful play within the psychosocial context of older adults. In: Proceedings of the 3rd International Conference on Fun and Games. p. 84–93 (2010)
40. Deci, E.L.: Effects of externally mediated rewards on intrinsic motivation. Journal of Personality and Social Psychology 18(1), 105–115 (1971)
41. Deci, E.L., Ryan, R.M.: The "what" and "why" of goal pursuits: Human needs and the self-determination of behavior. Psychological inquiry 11(4), 227–268 (2000)
42. Denis, G., Jouvelot, P.: Motivation-driven educational game design: Applying best practices to music education. In: Proceedings of the 2005 ACM SIGCHI International Conference on Advances in Computer Entertainment Technology. p. 462–465. ACE '05, ACM (2005)
43. Denisova, A., Cairns, P.: The placebo effect in digital games: Phantom perception of adaptive artificial intelligence. In: Proceedings of the 2015 Annual Symposium on Computer-Human Interaction in Play. p. 23–33. ACM (2015)
44. Deterding, S., Dixon, D., Khaled, R., Nacke, L.: From game design elements to gamefulness: Defining "gamification". In: Proceedings of the 15th International Academic MindTrek Con-ference: Envisioning Future Media Environments. p. 9–15. MindTrek '11, ACM (2011)
45. Deutsch, J.E., Borbely, M., Filler, J., Huhn, K., Guarrera-Bowlby, P.: Use of a low-cost, commercially available gaming console (wii) for rehabilitation of an adolescent with cerebral palsy. Physical Therapy 88(10), 1196–1207 (2008)
46. Entertainment Software Association (ESA): Essential Facts About the Computer and Video Game Industry 2013 (2013), `https://igea.wpengine.com/wp-content/uploads/2013/06/ESA_EF_2013.pdf`
47. Federico Semeraro, A.F.: Relive: A serious game to learn how to save lives. Resuscitation 85(7), e109–e110 (2014)
48. Fogg, B.: A behavior model for persuasive design. In: Proceedings of the 4th International Conference on Persuasive Technology. p. 40:1–40:7. Persuasive '09, ACM (2009)

49. Fullerton, T., Swain, C., Hoffman, S.: Game design workshop: designing, prototyping, and playtesting games. Focal Press (2004)
50. Galna, B., Barry, G., Jackson, D., Mhiripiri, D., Olivier, P., Rochester, L.: Accuracy of the microsoft kinect sensor for measuring movement in people with parkinson's disease. Gait & Posture 39(4), 1062–8 (2014)
51. Gao, Y., Mandryk, R.L.: The acute cognitive benefits of casual exergame play p. 1863–1872 (2012)
52. Gekker, A.: Health Games, Lecture Notes in Computer Science, vol. 7528, p. 13–30. Springer Berlin / Heidelberg (2012)
53. Gerling, K.M., Livingston, I.J., Nacke, L.E., Mandryk, R.L.: Full-body motion-based game interaction for older adults. In: CHI'12: Proceedings of the 30th international conference on Human factors in computing systems. p. 1873–1882 (2012)
54. Gerling, K.: Motion-Based Video Games for Older Adults in Long-Term Care. Ph.D. thesis, University of Saskatchewan (May 2014)
55. Gerling, K., Schulte, F., Masuch, M.: Designing and evaluating digital games for frail elderly persons. In: International Conference on Advances in Computer Entertainment Technology (ACE 2011). p. 62:1–62:8. ACM (2011)
56. Gerling, K.M., Mandryk, R.L., Miller, M., Kalyn, M.R., Birk, M., Smeddinck, J.D.: Designing wheelchair-based movement games. ACM Trans. Access. Comput. 6(2), 6:1–6:23 (Mar 2015)
57. Gerling, K.M., Miller, M., Mandryk, R.L., Birk, M., Smeddinck, J.: 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. p. 2201–2210 (2014)
58. Gerling, K.M., Schulte, F.P., Smeddinck, J., Masuch, M.: Game design for elderly: Effects of age-related changes on structural elements of digital games. In: Proceedings of the 11th International Conference on Entertainment Computing. p. 235–242. Springer Berlin / Heidelberg (2012)
59. Gerling, K.M., Smeddinck, J.: Involving users and experts in motion-based game design for older adults. In: Proceedings of the CHI Game User Research Workshop (2013)
60. Gesundheitsberichterstattung des Bundes: (2006), `http://www.gbe-bund.de/gbe10/abrechnung.prc_abr_test_logon?p_uid=gasts\&p_aid=\&p_knoten=FID\&p_sprache=D\&p_suchstring=10791::Physiotherapie`
61. Giannotti, D., Patrizi, G., Di Rocco, G., Vestri, A.R., Semproni, C.P., Fiengo, L., Pontone, S., Palazzini, G., Redler, A.: Play to become a surgeon: Impact of nintendo wii training on laparoscopic skills. PLoS ONE 8(2), e57372 (Feb 2013)
62. Göbel, S., Hardy, S., Wendel, V., Mehm, F., Steinmetz, R.: Serious games for health: personalized exergames. In: Proceedings of the international conference on Multimedia. p. 1663–1666. MM '10, ACM (2010), aCM ID: 1874316
63. Grafsgaard, J.F., Wiggins, J.B., Boyer, K.E., Wiebe, E.N., Lester, J.C.: Automatically recognizing facial expression: Predicting engagement and frustration. In: Proceedings of the 6th International Conference on Educational Data Mining. p. 43–50 (2013)
64. Hartson, R., Pyla, P.: The UX Book: Process and Guidelines for Ensuring a Quality User Experience. Morgan Kaufmann, 1 edn. (Mar 2012)
65. Hekler, E.B., Klasnja, P., Froehlich, J.E., Buman, M.P.: Mind the theoretical gap: interpreting, using, and developing behavioral theory in hci research. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. p. 3307–3316. ACM (2013)

66. Henry, K.D., Rosemond, C., Eckert, L.B.: Effect of number of home exercises on compliance and performance in adults over 65 years of age 79(3), 270–277 (Jan 1999), pMID: 10078770
67. Hermann, R., Herrlich, M., Wenig, D., Smeddinck, J., Malaka, R.: Strong and loose cooperation in exergames for older adults with parkinson s disease. In: Mensch & Computer Workshopband. p. 249–254. Oldenbourg Verlag (2013)
68. Hernandez, H.A., Graham, T.C., Fehlings, D., Switzer, L., Ye, Z., Bellay, Q., Hamza, M.A., Savery, C., Stach, T.: Design of an exergaming station for children with cerebral palsy. In: Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems. p. 2619–2628 (2012)
69. Hocine, N., Gouaich, A., Di Loreto, I., Joab, M.: Motivation based difficulty adaptation for therapeutic games. In: 2011 IEEE 1st International Conference on Serious Games and Applications for Health (SeGAH). p. 1–8 (2011)
70. Hocine, N., Gouaich, A., Cerri, S.A.: Dynamic Difficulty Adaptation in Serious Games for Motor Rehabilitation, p. 115–128. Lecture Notes in Computer Science, Springer International Publishing (Jan 2014)
71. Hoffman, H.G., Garcia-Palacios, A., Patterson, D.R., Jensen, M., Furness, T., Ammons, W.F.: The effectiveness of virtual reality for dental pain control: A case study. CyberPsychology & Behavior 4(4), 527–535 (Aug 2001)
72. Hoffman, H.G., Patterson, D.R., Seibel, E., Soltani, M., Jewett-Leahy, L., Sharar, S.R.: Virtual reality pain control during burn wound debridement in the hydrotank:. The Clinical Journal of Pain 24(4), 299–304 (May 2008)
73. Hoffmann, K., Wiemeyer, J., Hardy, S., Göbel, S.: Personalized Adaptive Control of Training Load in Exergames from a Sport-Scientific Perspective, p. 129–140. Lecture Notes in Computer Science, Springer International Publishing (Jan 2014)
74. Holt, R., Weightman, A., Gallagher, J., Preston, N., Levesley, M., Mon-Williams, M., Bhakta, B.: A system in the wild: Deploying a two player arm rehabilitation system for children with cerebral palsy in a school environment. J. Usability Studies 8(4), 111–126 (Aug 2013)
75. Horvitz, E., Breese, J., Heckerman, D., Hovel, D., Rommelse, K.: 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. p. 256–265 (1998)
76. Hunicke, R.: The case for dynamic difficulty adjustment in games. In: Proceedings of the 2005 ACM SIGCHI International Conference on Advances in computer entertainment technology. p. 429–433 (2005)
77. Ice, R.: Long-term compliance. Physical Therapy 65(12), 1832–1839 (Jan 1985), pMID: 3906687
78. Ijsselsteijn, W., Nap, H., de Kort, Y., Poels, K.: Digital game design for elderly users. In: Proceedings of the 2007 conference on Future Play. p. 17–22 (2007)
79. Jack, D., Boian, R., Merians, A.S., Tremaine, M., Burdea, G.C., Adamovich, S.V., Recce, M., Poizner, H.: Virtual reality-enhanced stroke rehabilitation. Neural Systems and Rehabilitation Engineering, IEEE Transactions on 9(3), 308–318 (2001)
80. Janssen, C.P., Van Rijn, H., Van Liempd, G., Van der Pompe, G.: User modeling for training recommendation in a depression prevention game. In: Proceedings of the first NSVKI student conference. p. 29–35 (2007)
81. Jarske, H., Kolehmainen, H.: Valedo(r)motion-terapialaitteiston hyväksyminen ja käyttökelpoisuus tullinkulman työterveydessä (2013)

82. Kamel Boulos, M.N., Gammon, S., Dixon, M.C., MacRury, S.M., Fergusson, M.J., Miranda Rodrigues, F., Mourinho Baptista, T., Yang, S.P.: Digital games for type 1 and type 2 diabetes: Underpinning theory with three illustrative examples. JMIR Serious Games 3(1), e3 (Mar 2015)
83. Kato, P.M.: Video games in health care: Closing the gap. Review of General Psychology p. 113–121 (2010)
84. Kato, P.M., Cole, S.W., Bradlyn, A.S., Pollock, B.H.: A video game improves behavioral outcomes in adolescents and young adults with cancer: A randomized trial. Pediatrics 122(2), 305–317 (Jan 2008), pMID: 18676516
85. Kayama, H., Okamoto, K., Nishiguchi, S., Nagai, K., Yamada, M., Aoyama, T.: Games for Health Journal 1(5), 348–352 (Oct 2012)
86. Kempermann, G., Fabel, K., Ehninger, D., Babu, H., Leal-Galicia, P., Garthe, A., Wolf, S.A.: Why and how physical activity promotes experience-induced brain plasticity. Frontiers in Neuroscience 4, 189 (Dec 2010), pMID: 21151782PMCID: PMC3000002
87. Kessel, F., Rosenfield, P., Anderson, N.: Interdisciplinary Research. Oxford University Press (Apr 2008)
88. Kratzke, C., Cox, C.: Smartphone technology and apps: Rapidly changing health promotion. International Electronic Journal of Health Education 15, 72 (Jan 2012)
89. Krichevets, A.N., Sirotkina, E.B., Yevsevicheva, I.V., Zeldin, L.M.: Computer games as a means of movement rehabilitation. Disability & Rehabilitation 17(2), 100–105 (1995)
90. Kuhn, J.T., Holling, H., Raddatz, J., Dobel, C.: Meister CODY: Ein computergestützter Test und Training für Kinder mit Dyskalkulie (2015)
91. Kuhn, J.T., Raddatz, J., Holling, H., Dobel, C.: Dyskalkulie vs. re-chenschwäche: Basisnumerische verarbeitung in der grundschule. Lernen und Lernstörungen 2(4), 229–247 (Jan 2013)
92. Langley, P., Hirsh, H.: User modeling in adaptive interfaces. Courses and Lectures - International Centre for Mechanical Sciences p. 357–370 (1999)
93. Laugwitz, B., Held, T., Schrepp, M.: Construction and evaluation of a user experience questionnaire. Springer (2008)
94. Leijdekkers, P., Gay, V.: User Adoption of Mobile Apps for Chronic Disease Management: A Case Study Based on myFitnessCompanion(r), p. 42–49. Lecture Notes in Computer Science, Springer Berlin Heidelberg (2012)
95. Lilla, D., Herrlich, M., Malaka, R., Krannich, D.: The Influence of Music on Player Performance in Exergames for Parkinson's Patients, p. 433–436. Springer (2012)
96. 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. p. 47–53 (2006)
97. Lister, C., West, J.H., Cannon, B., Sax, T., Brodegard, D.: Just a fad? gamification in health and fitness apps. JMIR Serious Games 2(2) (Aug 2014)
98. Liu, C., Agrawal, P., Sarkar, N., Chen, S.: Dynamic difficulty adjustment in computer games through real–time anxiety–based affective feedback. International Journal of Human–Computer Interaction 25(6), 506–529 (Aug 2009)
99. Lomas, D., Patel, K., Forlizzi, J.L., Koedinger, K.R.: Optimizing challenge in an educational game using large-scale design experiments. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. p. 89–98. CHI '13, ACM (2013)

100. Luxton, D.D., McCann, R.A., Bush, N.E., Mishkind, M.C., Reger, G.M.: mhealth for mental health: Integrating smartphone technology in behavioral healthcare. Professional Psychology: Research and Practice 42(6), 505–512 (2011)
101. Maier, M., Ballester, B.R., Duarte, E., Duff, A., Verschure, P.F.M.J.: Social Integration of Stroke Patients through the Multiplayer Rehabilitation Gaming System, p. 100–114. Lecture Notes in Computer Science, Springer International Publishing (Jan 2014)
102. Malaka, R.: How Computer Games Can Improve Your Health and Fitness, p. 1–7 (2014)
103. Malaka, R., Herrlich, M., Smeddinck, J.: Anticipation in Motion-based Games for Health. Lecture Notes in Computer Science, Springer Berlin Heidelberg (2016 (accepted))
104. McAuley, E., Duncan, T., Tammen, V.V.: Psychometric properties of the intrinsic motivation inventory in a competitive sport setting: a confirmatory factor analysis. Research quarterly for exercise and sport 60(1), 48–58 (Mar 1989), pMID: 2489825
105. Medler, B.: Using recommendation systems to adapt game-play. International Journal of Gaming and Computer-Mediated Simulations 1(3), 68–80 (2009)
106. Missura, O., Gärtner, T.: Player Modeling for Intelligent Difficulty Adjustment, vol. 5808, p. 197–211. Springer Berlin Heidelberg (2009)
107. Mueller, F., Vetere, F., Gibbs, M., Edge, D., Agamanolis, S., Sheridan, J., Heer, J.: Balancing exertion experiences. In: Proceedings of the 2012 ACM annual conference on Human Factors in Computing Systems. p. 1853–1862 (2012)
108. Mueller, F., Gibbs, M.R., Vetere, F., Edge, D.: Supporting the creative game design process with exertion cards. p. 2211–2220. ACM Press (2014)
109. Nap, H., Kort, Y.d., IJsselsteijn, W.: Senior gamers: Preferences, motivations and needs. Gerontechnology 8, 247–262 (Nov 2009)
110. Natbony, L.R., Zimmer, A., Ivanco, L.S., Studenski, S.A., Jain, S.: Perceptions of a videogame-based dance exercise program among individuals with parkinson's disease. Games for Health Journal 2(4), 235–239 (Aug 2013)
111. Oinas-Kukkonen, H., Harjumaa, M.: Persuasive systems design: Key issues, process model, and system features. Communications of the Association for Information Systems 24(1), 28 (2009)
112. Orji, R., Mandryk, R.L., Vassileva, J., Gerling, K.M.: Tailoring persuasive health games to gamer type. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems. p. 2467–2476. CHI '13, ACM (2013)
113. Pichierri, G., Wolf, P., Murer, K., Bruin, E.D.d.: Cognitive and cognitive-motor interventions affecting physical functioning: A systematic review. BMC Geriatrics 11(1), 29 (Jun 2011)
114. Pomeroy, V.M., Pramanik, A., Sykes, L., Richards, J., Hill, E.: Agreement between physiotherapists on quality of movement rated via videotape. Clinical Rehabilitation 17(3), 264–272 (Jan 2003)
115. Portland Pharmaceuticals, G.f.H.P.: Games for health project
116. Prange, G.B., Jannink, M.J.A., Groothuis-Oudshoorn, C.G.M., Hermens, H.J., IJzerman, M.J.: Systematic review of the effect of robot-aided therapy on recovery of the hemiparetic arm after stroke. The Journal of Rehabilitation Research and Development 43(2), 171 (2006)
117. Primack, B.A., Carroll, M.V., McNamara, M., Klem, M.L., King, B., Rich, M., Chan, C.W., Nayak, S.: Role of video games in improving health-related outcomes: A systematic review. American Journal of Preventive Medicine 42(6), 630–638 (Jun 2012)

118. Privacy Rights Clearinghouse: Fact sheet 39: Mobile health and fitness apps: What are the privacy risks? (2014), https://www.privacyrights.org/mobile-health-and-fitness-apps-what-are-privacy-risks
119. Rego, P., Moreira, P., Reis, L.: Serious games for rehabilitation: A survey and a classification towards a taxonomy. In: 2010 5th Iberian Conference on Information Systems and Technologies (CISTI). p. 1–6 (Jun 2010)
120. Ricciardi, F., De Paolis, L.T., Ricciardi, F., De Paolis, L.T.: A comprehensive review of serious games in health professions, a comprehensive review of serious games in health profes-sions 2014, 2014, e787968 (Aug 2014)
121. Rigby, S.: Glued to Games: How Video Games Draw Us In and Hold Us Spellbound. Praeger (Feb 2011)
122. Rigby, S., Ryan, R.: The Player Experience of Need Satisfac-tion(PENS): an applied model and methodology for understanding key components of the player experience (2007)
123. Ryan, R.M., Rigby, C.S., Przybylski, A.: The motivational pull of video games: A self-determination theory approach. Motivation and Emotion 30(4), 344–360 (Nov 2006)
124. Sanchez, R.G., Thin, A.G., Hauge, J.B., Fiucci, G., Nabeth, T., Rudnianski, M., Luccini, A.M., Star, K.: Value Propositions for Serious Games in Health and Well-Being, p. 150–157. Lecture Notes in Computer Science, Springer Berlin Heidelberg (Jan 2012)
125. Sawyer, B., Smith, P.: Serious games taxonomy (2008)
126. Schneider, G.: Exergames. Ph.D. thesis, uniwien (2008)
127. Schneiders, A.G., Zusman, M., Singer, K.P.: Exercise therapy compliance in acute low back pain patients 3(3), 147–152 (1998)
128. Shute, V.J., Ventura, M., Ke, F.: The power of play: The effects of portal 2 and lumosity on cognitive and noncognitive skills. Computers & Education 80, 58–67 (Jan 2015)
129. Sinclair, J., Hingston, P., Masek, M.: Considerations for the design of exergames. In: Proceedings of the 5th international conference on Computer graphics and interactive techniques in Australia and Southeast Asia. p. 289–295. GRAPHITE '07, ACM (2007), aCM ID: 1321313
130. Sinclair, J., Hingston, P., Masek, M.: Exergame development using the dual flow model. In: Proceedings of the Sixth Australasian Conference on Interactive Entertainment. p. 11:1–11:7. IE '09, ACM (2009)
131. Sluijs, E.M., Kok, G.J., Zee, J.v.d.: Correlates of exercise compliance in. Physical Therapy 73(11), 771–782 (Jan 1993), pMID: 8234458
132. Smeddinck, J., Gerling, K.M., Tiemkeo, S.: Visual complexity, player experience, performance and physical exertion in motion-based games for older adults. In: Proceedings of the 15th International ACM SIGACCESS Conference on Computers and Accessibility. p. 25:1–25:8. ASSETS '13, ACM (2013)
133. Smeddinck, J., Herrlich, M., Krause, M., Gerling, K., Malaka, R.: Did they really like the game? – challenges in evaluating exergames with older adults. In: Proceedings of the CHI Game User Research Workshop (2012)
134. Smeddinck, J., Siegel, S., Herrlich, M.: Adaptive difficulty in exergames for parkinson's disease patients. In: Proceedings of the 2013 Graphics Interface Conference. p. 141–148. GI '13, Canadian Information Processing Society (2013)
135. Smeddinck, J.D., Gerling, K.M., Malaka, R.: Anpassbare computerspiele für senioren. Informatik-Spektrum 37(6), 575–579 (Dec 2014)

136. Smeddinck, J.D., Herrlich, M., Malaka, R.: Exergames for physiotherapy and rehabilitation: A medium-term situated study of motivational aspects and impact on functional reach. In: Proceedings of CHI 2015. p. 4143–4146. ACM (2015)
137. Smeddinck, J.D., Herrlich, M., Roll, M., Malaka, R.: Motivational effects of a gamified training analysis interface. Mensch & Computer 2014-Workshopband p. 397–404 (2014)
138. Smeddinck, J.D., Hey, J., Runge, N., Herrlich, M., Jacobsen, C., Wolters, J., Malaka, R.: Movitouch: Mobile movement capability configurations. In: Proceedings of the 17th International ACM SIGACCESS Conference on Computers & Accessibility. p. 389–390. ASSETS '15, ACM (2015)
139. Smeddinck, J.D., Mandryk, R., Birk, M., Gerling, K., Barsilowski, D., Malaka, R.: How to present game difficulty choices? exploring the impact on player experience. In: Proceedings of the 34th Annual ACM Conference on Human Factors in Computing Systems. CHI '16, ACM (2016 (inpress))
140. Smeddinck, J.D., Voges, J., Herrlich, M., Malaka, R.: Comparing modalities for kinesiatric exercise instruction. In: CHI '14 Extended Abstracts on Human Factors in Computing Systems. p. 2377–2382. CHI EA '14, ACM (2014)
141. Song, H., Peng, W., Lee, K.M.: Promoting exercise self-efficacy with an exergame 16(2), 148–162 (Jan 2011), pMID: 21213171
142. Springer, M., Herrlich, M., Krannich, D., Malaka, R.: Achievements in Exergames for Parkinson s Patients. Oldenbourg Verlag (2012)
143. Staiano, A.E., Calvert, S.L.: The promise of exergames as tools to measure physical health. Entertainment Computing 2(1), 17–21 (2011)
144. Stenström, C., Arge, B., Sundbom, A.: Home exercise and compliance in inflammatory rheumatic diseases–a prospective clinical trial. The Journal of rheumatology 24(3), 470–476 (Mar 1997), pMID: 9058651
145. Sundholm, M., Cheng, J., Zhou, B., Sethi, A., Lukowicz, P.: Smart-mat: Recognizing and counting gym exercises with low-cost resistive pressure sensing matrix. In: Proceedings of the 2014 ACM International Joint Conference on Pervasive and Ubiquitous Computing. p. 373–382. UbiComp '14, ACM (2014)
146. Theng, Y.L., Chua, P.H., Pham, T.P.: Wii as entertainment and socialisation aids for mental and social health of the elderly. In: Proceedings of the 2012 ACM annual conference extended abstracts on Human Factors in Computing Systems Extended Abstracts. p. 691–702. ACM (2012)
147. Thompson, D.: Designing serious video games for health behavior change: current status and future directions. Journal of Diabetes Science and Technology 6(4), 807–811 (Jul 2012), pMID: 22920806PMCID: PMC3440151
148. Uzor, S., Baillie, L.: Exploring & designing tools to enhance falls rehabilitation in the home. In: Proceedings of the SIGCHI Conference on Human Factors in Com-puting Systems. p. 1233–1242. CHI '13, ACM (2013)
149. Uzor, S., Baillie, L.: Investigating the long-term use of exergames in the home with elderly fallers. p. 2813–2822. ACM Press (2014)
150. VirtualRehab: VirtualRehab - Virtual rehabilitation through gaming (Sep 2014)
151. Walther-Franks, B., Wenig, D., Smeddinck, J., Malaka, R.: Exercise My Game: Turning Off-The-Shelf Games into Exergames, p. 126–131. Lecture Notes in Computer Science, Springer Berlin Heidelberg (Jan 2013)
152. Walther-Franks, B., Wenig, D., Smeddinck, J., Malaka, R.: Sportal: A first-person videogame turned exergame. In: Boll, S., Maaš, S., Malaka, R. (eds.) Mensch & Computer 2013 - Workshopband. p. 539–542. Oldenbourg Verlag (2013)

153. Watcharasatharpornpong, N., Kotrajaras, V.: Automatic level difficulty adjustment in platform games using genetic algorithm based methodology. Department of Computer Engineering, Faculty of Engineering, Chulalongkorn University.[Online][Cited: October 14, 2010.] (2010)
154. Weisman, S.: Computer games for the frail elderly. The Gerontologist 23(4), 361–363 (1983)
155. Wiemeyer, J., Kliem, A.: Serious games in prevention and rehabilitation-a new panacea for elderly people? European Review of Aging and Physical Activity 9(1), 41–50 (Dec 2011)
156. Yavuzer, G., Senel, A., Atay, M.B., Stam, H.J.: Playstation eyetoy games" improve upper extremity-related motor functioning in subacute stroke: a randomized controlled clinical trial. European Journal of Physical and Rehabilitation Medicine 44(3), 237–244 (Sep 2008), pMID: 18469735
157. Zigoris, P., Zhang, Y.: Bayesian adaptive user profiling with explicit & implicit feedback. In: Proceedings of the 15th ACM international conference on Information and knowledge management. p. 397–404. CIKM '06, ACM (2006)