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ACADEMIC LITERATURE REVIEW

Serious games in prevention and rehabilitation—a new panacea for elderly people?

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Abstract Digital games cannot only be used for fun and entertainment. The term "serious games" (SG) denotes digital games serving serious purposes like education, training, advertising, research and health. Recently, a new generation of games has emerged involving whole-body movements. Compared to traditional interventions, these games may help elderly people to improve their health by enhancing physical fitness and coordinative abilities by combining increased motivation, game experience like fun and game flow and training. Serious games, particularly adventure and shooter games, already play an important role in health education, prevention and rehabilitation, e.g. to enhance health-related physical activity, improve sensory–motor coordination, prevent asthma, change nutrition behaviour and alleviate diabetes and prevent smoking or HIV. In this paper, the impact of SG on prevention and rehabilitation is discussed. Three criteria are applied. Beyond effectivity and efficiency, the additional benefits of serious games can be described and explained by different models including social, psychological, physiological and sensory–motor factors. The quality of study serves as a third criterion. Despite first promising results, there are only few high-quality studies. Adequate content, game interfaces, sustainability and appropriate settings are critical factors for the success of SG. In this regard, (sport) science can help to develop and evaluate SG and test appropriate settings that ensure sustainable use of serious games.

Keywords Serious games · Rehabilitation · Prevention · Health

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Introduction

Digital games, i.e. games that are played on electronic devices working with microprocessors, are a widespread leisure activity which attracts not only children and youth but also younger and older adults [10, 17]. However, digital games seem to polarize science and society alike. On the one hand, digital games (i.e. video games, computer games and mobile games) are considered appropriate options to enhance cognitive, sensory–motor, emotional, personal and social competencies (see Fig. 1; e.g. [19, 73]). On the other hand, digital gaming is considered to cause addiction, inactivity, obesity, aggression and other social, psychological or physical hazards (e.g. [23, 43]).

Recently, an area of digital games emerged termed "serious games" (SG). The idea of "serious games" is to integrate playing games, simulation and learning or training for serious purposes like education, exercising, health, prevention, rehabilitation and advertisement (for a review, cf. [51]). Compared to "normal" digital games, SG have the potential to address the competencies illustrated in Fig. 1 in a more straightforward and systematic way, without neglecting the game experience of the players like fun, motivation, flow, immersion, presence, challenge, curiosity and other emotions (e.g. [45]).

Because elderly people (above 50 years) form a considerable portion of digital gamers, ranging from 14% (Germany; [10]) to 29% (USA; [17]), SG may be a reasonable, low-barrier, motivating and sustainable means to improve or at least delay the decrease of selected social, sensory–motor, cognitive and emotional functions of elderly people.

The issue of SG for elderly people as an attractive combination of gaming and serious application purposes on the one hand offers new fascinating options and on the other hand raises critical questions (e.g. [31]). The purpose of this

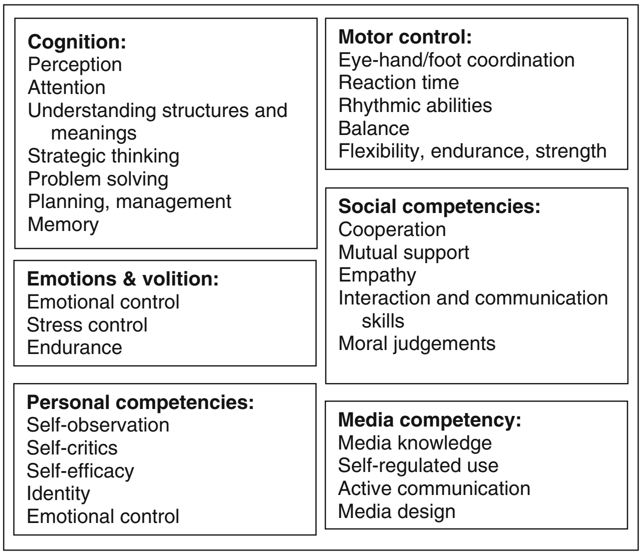

Fig. 1 Competencies that can be enhanced by playing digital games (adapted with modifications from Gebel, Gurt and Wagner [19], p. 262)

contribution is to address this ambivalence of SG and to discuss the specific chances and challenges for elderly people based on existing evidence. First, we deal with the possible additional benefits of SG for the elderly. From this discussion, criteria are derived to discuss the application areas of prevention and rehabilitation. Due to the scope of this journal, we focus on SG including physical activity neglecting the numerous SG aiming purely at cognitive or social functions.

Serious games for elderly people—what is the promise?

In the course of ageing virtually all functions of the human undergo substantial changes (e.g., [31, 72]). Physical activity (PA) and regular exercise (RE) are, among others, an important building block of successful ageing (e.g. [18, 29, 53, 63, 64]). Whereas many issues are still unclear, e.g. appropriate dose–response relationships or specific components and parameters of an individualised training programme, there are several desirable effects on the organism of elderly people which enhance activities of daily living, enhance health or reduce risk factors for numerous diseases (e.g. [68, 72]):

- Cardiovascular and cardiorespiratory system (e.g. endurance, cardiovascular fitness, prevention of cardiovascular diseases)
- Energy metabolism (e.g. weight control, prevention of obesity and diabetes mellitus)
- Strength and flexibility (e.g. posture, range of motion)
- Bone structure (e.g. prevention of osteoporosis)
- Immune system (e.g. prevention of cancer)
- Sensory–motor coordination (e.g. reaction, balance, fall prevention)
- Cognitive system (e.g. memory, perception, calculating, prevention of dementia)

Despite these positive effects of PA and RE, many elderly people do not engage sufficiently in sustained PA or RE, and respective health promotion programmes have not had the expected success [53, 60, 66]. In the literature, the impact of several barriers to sustained PA and RE for elderly people like programme safety, lack of access to required equipment and facilities, lack of PA/RE partners, fear of injury and lack of appropriate positive reinforcement has been confirmed (e.g. [31, 53, 64, 66]). Applying digital games to serious purposes like prevention and rehabilitation may help overcome at least some of these barriers.

Studies evaluating SG are based on detailed models of effects including variables that are well-known factors being associated with PA and RE (for a review, see [68]). There is a strong emphasis on psychological factors. Some models are extensions or derivatives of the models of planned behaviour and reasoned action (see Fig. 2) which have proved to be valid in many contexts like physical activity, health-related and exercise behaviour [21, 24, 28, 52, 61, 62]. The basic idea of the extended model of planned behaviour (EMPB) is to explain sustained behavioural changes mainly by psychological variables influencing intention directly as a primary condition for change and selected secondary variables mediating behavioural change. Furthermore, social factors like social support from family and friends and environmental factors like access to and satisfaction with facilities also play an important role in PA engagement (e.g. [64, 71]), and the structure of factors contributing to engagement in PA may change over time (e.g. [71]).

Despite their importance, particularly for the engagement of older people in digital gaming (e.g. [69, 70]), social and environmental factors have not yet been considered adequately in SG research. The model proposed by Mueller et al. [44] is a promising exception (see Fig. 3). The authors

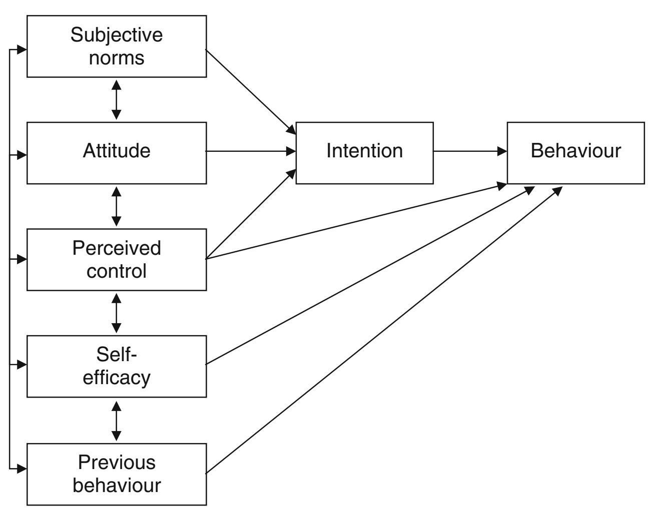

Fig. 2 Extended model of planned behaviour (adapted from Hagger, Chatzisarantis and Biddle [24])

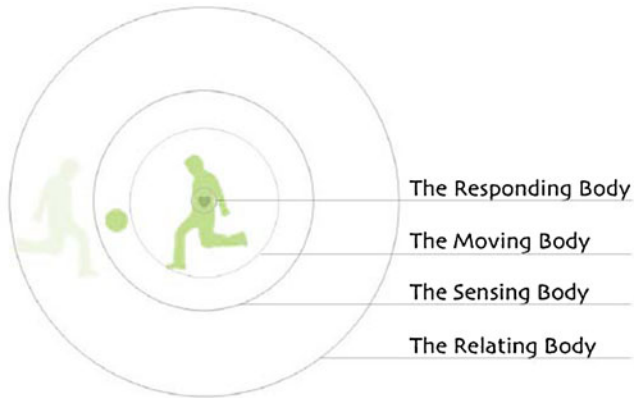

Fig. 3 Four-level model for the effects of exergames (from Mueller et al. [44])

distinguish four different levels ("lenses") of influences of SG with special emphasis on exergames: physiological reactions or the "responding body" (e.g. heart rate and ventilation), motor control including proprioception or the "moving body" (e.g. motor skills, behaviour and general motor abilities), experiences mediated by the senses or the "sensing body" (e.g. game experience) and social interactions or the "relating body" (e.g. communication with teammates or opponents). This four-lense model (4LM) is an important progress in theory because it allows the integration of the most relevant levels.

To sum it up, the following levels of effects can be distinguished:

- Physiological level

  Depending on the respective training purpose, positive effects on physiological functions of various systems like the cardiovascular, cardiorespiratory or immune system are expected. Bavelier et al. [8] even suppose that gaming may re-establish the neural plasticity the human brain has shown during early stages of development.
- Psychological level

  Serious games support a specific way of cognitive experience and learning. By solving attractive tasks, experiencing variable learning contexts, repeating the attempts to solve the problems, getting immediate feedback and background information processing can be enhanced. Transfer may be supported by more authentic and variable contexts or the appropriate symbolic representation of transfer-relevant information.

  Positive effects on intrinsic motivation, attitude, self-concept, emotions, perceived control and self-efficacy are also expected. Specific components of game experience like flow, challenge, tension, enjoyment, etc. are also highlighted (e.g. [45]).
- Sensory–motor level (behaviour)

  Depending on the quality of the (wo)man–game interface, the game tasks and the individual experiences, basic or specific sensory–motor skills and abilities can be performed, acquired and transferred (e.g. reaction and balance skills).
- Social interaction and communication

  Constructivist approaches emphasize the importance of social interaction and communication for learning. This component can be addressed by a specific genre of digital games: massive(ly) multi-player online games. Mobile devices like cell phones and personal digital assistants as well as specific social settings can also be used to support interaction and communication.

As a result, the additional benefit of serious games must not be reduced to the simple formula "serious purpose + motivation". Rather, serious games offer options for a new kind of prevention and rehabilitation with special emphasis on physiological, psychological, social and sensory–motor aspects: "Digital games may offer elderly users with new and exciting ways to be entertained, stimulating mental abilities, and supporting existing and emerging social networks, both within and across generations" ([31], p.19).

From the discussion of possible additional benefits of SG in general and for elderly people in particular and taking into consideration methodological issues like sample, intervention programme and data measures and collection (e.g. [13]), the following criteria for the evaluation of existing evidence are derived:

- Efficiency and effectivity of the intervention: Which effects are elicited—by which effort? Is there evidence for long-term effects (sustainability)? Particularly the first criterion is a "sine qua non". If SG are not effective and efficient in improving the respective physical, psychic, sensory–motor and/or social functions of elderly people, they cannot be considered reasonable means to enhance health or well-being.
- Additional benefits: Does the SG intervention show advantages compared to a traditional intervention (e.g. concerning barriers)? This feature is proposed by advocates of SG. Beyond effectivity and efficiency, a SG should offer additional advantages like fun, enjoyment and adherence.
- Study quality: Does the study fulfil the methodological requirements concerning sample, intervention programme and data? Does the study consider the relevant aspects of game effects including psychological, social, environmental and behavioural factors?

Serious games for prevention—exergames and games for health

According to the WHO [77], health is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (p.1). This definition includes behavioural, physical, mental and social aspects of health and well-being. Besides control of nutrition and drug consumption, performing an active lifestyle including adequate, continuous, and enduring participation in physical activity, exercise or sport is an important issue (e.g. [4]). In this section, we differentiate endurance training, resistance training, training of sensory–motor functions and further effects relevant to prevention.

Endurance training

One goal of PA and RE is to raise the additional energy expenditure above a minimum of 600–800 kcal per week, with an optimum of about 3,000 kcal per week [57]. According to the proposed theory of planned behaviour and its extensions or modifications, SG may offer a good option for PA because of their positive effects on attitude, emotions, motivation, intention and self-efficacy.

The new generation of digital games, especially video games, works on interfaces that demand whole-body movements to control the game, like Konami Dance Dance Revolution, Sony EyeToy Kinetics, XaviX Sports, Nintendo Wii Sports and Wii Fit and Microsoft Xbox Kinect. Specific sensors like cameras, motion sensors and force sensors measure the movements of the players and integrate this information into the control of the respective game.

Numerous studies have been published showing great differences concerning the applied research methods (see [5, 36, 39, 74] for recent reviews). Concerning the rise of energy expenditure (EE), Fig. 4 shows the results of the available studies [3, 7, 11, 22, 37, 54, 59, 65, 75]. The impact of playing games on energy expenditure highly depends on the gaming device, game type and intensity of gaming. Energy expenditure in "virtual" sport games is always below the respective "real" sports activity (e.g. [3, 22]). At best, an EE of above 400 kcal/h can be achieved. This means that in order to meet the minimum requirements for health-enhancing PA, one has to play at least 2 h/week; for the optimum, at least 7.5 h are required. From long-term SG studies, we know that the participants have difficulties to meet this challenging criterion (e.g. [42]). Unfortunately, all the above-mentioned studies have analysed children, youth or young adults, and study quality is often low (e.g. lack of experimental control in gaming). Therefore, it is not clear whether the reported EE increases hold for elderly people.

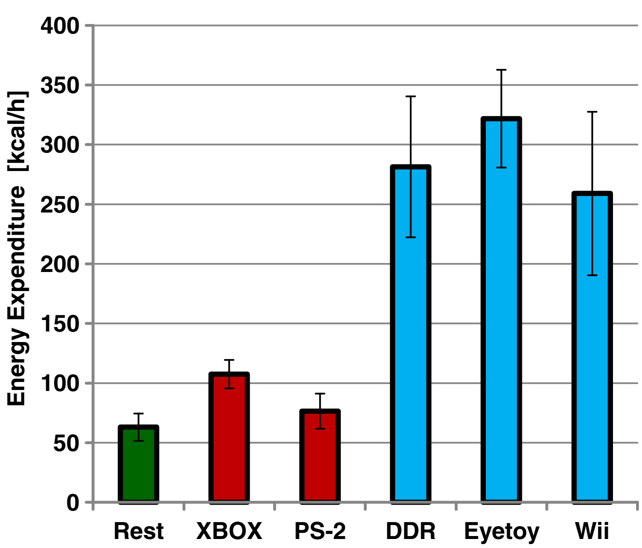

Fig. 4 Results of game studies trying to raise energy expenditure (from Wiemeyer [74]). *PS-2* Playstation 2; *DDR* Dance Dance Revolution, Wii-Golf/Base/Bowl—Wii Golf, baseball, bowling

Wollersheim et al. [78] investigated the physical and psychosocial effects of exergaming with the Wii Sports in community-dwelling older women (N=11; mean age, 73.5± 9.0 years). The treatment consisted of a 6-week training period with two sessions a week (average duration of one session, 51 min; range, 9–130 min). The participants played individually or in groups of up to four in a planned activity group offered by a community health service. Quantitative accelerometer data showed that the exergaming did not have substantial physical effects. The qualitative data reveal that the participants on the one hand had difficulties in getting familiar with the game technology, were embarrassed and needed continuous extrinsic positive feedback by the experimenters and on the other hand experienced fun, challenge, motivation, as well as social and psychological well-being. It is noteworthy that two participants left the programme because of "embarrassment about using the Wii" ([78], p.88). Another woman dropped out on advice of her physician. The quality of this study is low because of a missing control group and lack of treatment control. The results clearly show that the SG was a motivating experience with additional benefit only for a part of the sample. According to the EMPB, perceived control and self-efficacy was supported by playing the game, enhancing the intention to continue playing in some women. According to the 4LM, SG effects were mainly confirmed on the psychological and social level, i.e. the "sensing body" and the "relating body". One important conclusion can be drawn from the results: Older SG players prefer individualised gaming, i.e. gaming corresponding to their individual needs, experiences and physical conditions, within social gaming contexts.

Resistance and strength training

Some studies addressing strength training have included older subjects. King [33] showed in a clinical laboratory study with 146 patients (age range, 16–78 years) that embedding gaming contexts into strength exercises increased the number of repetitions of strength exercises (training volume) significantly. However, the study quality is low because of the confounding of game and task requirements.

The authors did not assess psychological, physiological and social parameters.

Sohnsmeyer, Gilbrich and Weisser [56] performed a randomized control trial study with 40 subjects above 70 years. The subjects of the game group (age, 76.95±4.84 years) played an activity-promoting video game (Wii Bowling) for 6 weeks (two 20-min sessions per week). The control group (age, 77.75±8.69 years) did not exercise. After training, strength of the left and right quadriceps increased significantly compared to the control group. The authors on the one hand report high acceptance by the participants but on the other hand emphasize that exergames are very demanding and include some risk of injury. One issue of this study is the lack of treatment control.

Both studies examining the effects of strength training cannot be related to the EMPB or 4LM because the respective variables have either not been assessed or not been reported in detail. However, both studies confirm psychological effects on motivation.

Sensory–motor training

The reviews by Lager and Bremberg [36] and Ijsselsteijn et al. [31] reveal positive effects of SG on the reaction time of older people. The age of the participants ranges from 57 to 90 years.

Kliem and Wiemeyer [34] compared a game-based balance training programme with a traditional programme using a convenient sample of 22 members in a health-care centre (age: range=18–67 years; M=47.36 years, SD=13.14). After a period of 3 weeks (three 10- to 12-min sessions per week), both groups improved significantly in four of five balance tests. On the one hand, subjects improved their performance in tests that were part of their training programme; on the other hand, subjects were able to transfer training effects to new balance tasks. Self-efficacy and enjoyment of PA did not change. Overall, the traditional training programme was more effective than the game-based programme. In contrast to Brumels et al. [12] who examined younger subjects, no motivational benefit was found for older adults. In the original publication, a no-treatment control group is missing; therefore, the learning effects cannot unequivocally be attributed to the intervention. According to the EMPB, the results indicate that because of the lack of differential effects on self-efficacy and enjoyment, the proposed SG intervention will not lead to enhanced intention and behaviour changes in older people. Due to the individual training procedure, social effects were not examined. Concerning the 4LM, only two levels have been analysed: the psychological and the behavioural level.

Williams et al. [76] performed a pilot and feasibility study with subjects above 70 years who had suffered from falls. The intervention group (N=15) underwent a structured individual 12-week training with two training sessions a week using the Wii fit console, while the control group (N=6) performed a conventional 12-week exercise and training programme. While the intervention group showed a transient improvement of balance (week 4) and a terminal improvement of Wii-fit age (week 12), the control group did not improve balance skill. Furthermore, two subjects dropped out in each group. There were no differences concerning the attendance of the programme. Members of the intervention group reported enjoyment (100%), adequate length and frequency of exercise (69%), low barrier for participation (77%) and the strong desire to continue Wii training (92%). Unfortunately, the members of the control group were not interviewed. Based on the EMPB, positive attitude and perceived control increased the intention to continue training. Concerning the 4LM, only the behavioural and psychological levels have been investigated.

Harley et al. [27] conducted a qualitative 1-year study with 30 players (age, 60 to 94 years) using the Wii console for bowling competitions. Participant observations of ten gaming sessions and interviews revealed that the older people easily adopted the new technology, had a lot of fun and gradually established and broadened social connections with their peers. Playing the Wii offered a safe place for learning the new technology enhanced by mutual support. The quality of this study is low because of the lack of treatment control and missing standardised tests and surveys. Concerning the 4LM, three levels of effects confirmed surplus effects of SG: psychological, behavioural and social levels.

Young et al. [80] developed two games based on the Wii balance board: The centre of pressure was measured to control the position of a basket for catching apples or the position of an avatar to pop rising bubbles. In a pilot study, after a 4-week training period including ten sessions of 20 min game play, a sample of six healthy elderly people (mean age, 84.1±5.1 years) showed both increased balance skill and self-efficacy. In addition, all participants confirmed to be ready to continue game training for the next 6 months. Due to the missing control group, these effects must not be attributed to the game treatment. According to the EMPB, sustainable game training can be expected because of the positive impact of self-efficacy on intention. According to the 4LM, only two levels have been addressed: the psychological and the behavioural levels.

Complex training intervention

Homma [30] performed a one-group pre-post study including elderly people (age, M=87.3 years; SD=4.2; range, 80–94 years.). After 6 weeks of training (three sessions of 30 min per week), hand and quadriceps strength improved significantly. However, endurance, joint flexibility and coordination (stand up and reaction) did not improve. Furthermore, all participants experienced enjoyment and flow whereas one person reported problems with the handling of the numerous buttons of the Wiimote interface. Only two participants perceived physical improvements. Unfortunately, Homma neither controlled training sufficiently nor included a control group. Furthermore, the variables indicating an additional benefit were assessed only by qualitative methods (interview). Attitude was positive, whereas self-efficacy was low leading to antagonistic effects in the EMPB.

Neufeldt [46] performed a qualitative study with six participants. After introduction to the video game (Wii sport), the attitude of the participants changed from scepticism to curiosity and enjoyment. On the other hand, the participants experienced severe control problems with the Wii interface leading to the covering of the unused buttons. An important side effect was the spontaneous development of new player communities. According to the EMPB, by change of attitude and enhanced self-efficacy and sense of control, the intention to engage in PA may be positively affected. There is also a significant interaction of the sense of control and enjoyment [40]. Concerning the 4LM, three levels show an additional benefit of SG: the psychological, the behavioural and the social level.

Voida, Carpendale and Greenberg [70] (see also [69]) examined 12 playing groups including two groups of three female residents of a retirement community (age, 68–84 years) and a family group including two mature adults (age, 52–59 years). The qualitative studies reveal the great importance of social gaming for older people: Particularly, mutual encouragement was observed in the game groups. Fun and enjoyment seemed to be elicited primarily by the collective game experience rather than the game design.

Further preventive effects

Other application fields of serious games are perception, sensory–motor control, asthma prevention, prevention of drug abuse, smoking prevention, HIV prevention, prevention of violence, and nutrition [5, 36, 39]. Most of the studies find positive short-term effects of serious gaming on attitude, knowledge, motivation, volition and behaviour.

Almost nothing is known about long-term effects and dose–response relationships. According to the EMPB, positive effects can be expected because of the positive impact of SG on attitude, volition and behaviour. Concerning the 4LM, studies neglected two levels: the physiological and the social level. With very few exceptions, all studies tested children, youth or young adults.

Summary: prevention

Summing up the existing evidence, the following effects of exergames and games for health have received at least partial support:

- Rise of EE (to be confirmed in elderly persons)
- Improvement of strength
- Improvement of basic motor control (e.g. simple reactions, balance)
- Improvement of health-related knowledge
- Improvement of self-efficacy and other motivational, emotional and volitional components
- Improvement of social interactions and communication

On the one hand, research shows encouraging results concerning the effectivity and additional benefits of SG; in general, relevant factors in the EMPB and 4LM seem to be positively affected. However, in the studies, the complex concept of game experience has not been completely examined. On the other hand, SG also provoke new barriers. One important aspect that needs to be considered is the usability of the game technology. In most studies with older people, at least some subjects experienced difficulties with the interface. Therefore, appropriate user interfaces have to be developed for the specific target group of older gamers. Usability of the game controller seems to be an important contributor to game experience [20, 40].

Another important issue is the setting. Almost nothing is known on which gaming settings favour long-term use of SG. The generally positive effect of SG on game experience, which is normally found in young people, seems not to hold for older gamers. Playing in communities (e.g. peer groups or family) seems to be an important option for older people (e.g., [27, 46, 69, 70]). In this regard, the EMPB needs to be further extended to social variables relevant to sustained PA and RE (e.g. [64, 71]). Furthermore, the quality of most studies is low, and studies with older people have rarely been published.

What are the particular challenges for science? Some key issues should be addressed in the future:

- The development of appropriate game concepts for the effective and enduring enhancement of all components of health behaviour games should be tailored for specific target groups (e.g. older people with or without specific sensory–motor disabilities; see also [31])
- Performing more randomized controlled studies as the gold standard for evidence-based interventions (e.g. [2]) covering the complete range of effects
- Investigating the appropriate dose–response relationship for exergames and games for health
- Searching for the appropriate settings for intervention based on sound theoretical foundations

Serious games for rehabilitation—rehagames

In rehabilitation, numerous applications have been reported [5, 74]. Compared to the realm of prevention, many of the publications are just technical reports, case reports or qualitative studies based on small samples of patients. The following application fields of therapy and rehabilitation are covered:

- Asthma [38]
- Diabetes [6, 38]
- Cancer [32, 49]
- Respiratory diseases [67]
- Cardiac rehabilitation [14]
- Neurological therapy after stroke and other brain injuries [9, 16, 25, 35, 48, 55, 79]
- Leukaemia [58]
- Cystic fibrosis [15]
- Burns [1]
- Wheelchair patients [47]
- Therapeutic robots [26]
- Intellectual and development disability [41]
- Subsyndromal depression [50]

The first published applications date back to the 1980s, where specific interfaces were developed [1] and the motivational impact of games was exploited [49]. In modern medical therapy, analogous to prevention, the effect models comprise numerous relevant aspects of human action and perception, ranging from knowledge to actual behaviour. One important result of these studies is that therapy has to employ meaningful movements, i.e. movements embedded into a context that makes sense to the patients. Using movements to control a game instead of rote movements had a significant positive effect on therapeutic results.

Brain injury

Studies employing physical activities in therapy with older patients are predominantly found in the therapy of brain injuries. Sietsema et al. [55] found that the range of arm motion increased significantly in a sample of 20 patients suffering from traumatic brain injury (age, ranging from 22 to 54 years) when the reaching movements were embedded in a gaming context (Simon game) compared to a rote exercise condition.

In a single-case study, Betker et al. [9] found that a 52-year-old man suffering from complete paraplegia regained the ability to sit independently after attending 12 30- to 45-min exercise sessions two or three times per week (intervention: COP-controlled video games).

Rand, Kizony and Weiss [48] (study 3) found that seven chronic and five subacute stroke patients aged from 50 to 91 years enjoyed playing the video games very much because they improved gradually. Whereas ten patients did not become frustrated despite comparatively low performance, two (subacute) patients showed obvious frustration because they were not able to use their weak upper extremity to control the game. All patients had problems restricting their movements to the frontal plane.

Yavuzer et al. [79] performed a randomized controlled trial including 20 patients with acute stroke (age, mean=61.1 years). One experimental group played video games for 4 weeks (five 30-min sessions a week) in addition to the normal rehabilitation programme, whereas the other group did not attend additional training. The game group improved significantly more (dependent measures: Brunnstrom stages, FIM self-care). There were, however, initial differences in favour of the control group. Therefore, the results of this study are to be considered with caution.

Further diseases

O'Connor et al. [47] examined two groups (group 1: age=42.2±13.9 years; group 2: age=41.9±10.7 years) using a special wheelchair interface to operate video games. Most of the patients enjoyed playing games and were able to reach a zone of 50% to 60% of their maximum oxygen consumption.

Chuang et al. [14] examined 20 male subjects in cardiac rehabilitation after bypass surgery under two conditions: virtual reality (VR) and no VR. The participants of both groups completed an endurance training programme comprising a particular individual target goal (85% of HRmax and 75% of VO_2peak) for about 3 months with two 30-min sessions per week. In the VR condition, an outdoor running track and physiological responses were displayed. Overall, the participants of the VR group reached their target goal significantly earlier than the non-VR group, i.e. after no more than nine training sessions for HRmax and two sessions for VO_2 peak. However, the study suffers from confounding of projection of a natural running environment and biofeedback in the VR group. It is not clear whether increased motivation, distraction, feedback or a mixture of the three conditions caused the results.

Lotan et al. [41] investigated the effectiveness of a VR-based exercise programme (Sony Playstation II EyeToy) for improving the physical fitness of adults with intellectual and development disability. Significant improvements were demonstrated in the experimental group (N=30, mean age=52.3±5.8 years) compared to the control group (N=30, mean age=54.3±5.4 years) for the modified Cooper test (12-min walking test) and the Total Heart Beat Index[1] (THBI) but not for the Energy Expenditure Index[2] (EEI).

[1] THBI = total heartbeats during exercise/total distance in metres; example: running 1,000 m with a total of 5 min×180 bpm=6,000 heartbeats results in a THBI of 6

[2] EEI = (walking HR − resting HR)/walking velocity; example: walking at a speed of 60 m/min with a resting HR of 70 bpm and a walking HR of 100 bpm results in an EEI of 0.5 beats per minute

Rosenberg et al. [50] performed a 12-week pilot study with three 35-min sessions a week using exergames (Nintendo Wii Sports) in older adults (N=19, mean age=78.7±8.7 years) with subsyndromal depression. This study showed significant improvement in depression symptoms, mental health-related quality of living (QoL), and cognitive functioning, and no major adverse events. There were no significant changes in physical health-related QoL or anxiety. Due to a missing control group, the results cannot be attributed to the exercise treatment.

Summary: rehabilitation

Studies on the impact of SG and VR on different diseases show a great variety of both design and results and often suffer from poor study quality. In principle, SG and VR have been proved to motivate patients to fulfil the therapeutic requirements, to improve physical fitness and to reduce symptoms of diseases. The additional benefit of SG is predominantly evident as an enhancement of compliance or therapeutic effects compared to traditional therapies, whereas components of game experience are rarely or incompletely addressed. In the studies with older people, there are hardly any explicit references to effect models like EMPB or 4LM. Taken together, the existing studies show promising tendencies for additional benefits of SG and VR on the physiological, behavioural and psychological level. Compared to prevention, social aspects only play a marginal role in the studies of SG and VR for rehabilitation. This may be due to the institutional constraints where therapy normally is performed in dyadic interactions of patient and therapist(s).

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

- Selection of appropriate sport or sport-like movements or activities of daily living in order to offer meaningful and motivating exercise contexts for older subjects
- Construction of adequate training devices offering options that combine challenge and support
- Determining appropriate dose–response relationships for the different rehabilitation purposes depending on the stage of the disease
- Performing more randomized controlled trials in order to corroborate effects and to find out moderators of game effects
- Development and evaluation of adequate training settings

Conclusion—chances and challenges

In this contribution, two promising application fields of serious games for older people have been discussed. Models and theoretical frameworks consider four levels of SG effects: physiological, psychological, sensory–motor (behavioural) and social level.

Existing studies clearly show that SG have much to offer to the fields of prevention and rehabilitation. On the other hand, to avoid a new "hype" overestimating the potentials of SG, the new options of SG can only take effect if these games are developed and designed based on an interdisciplinary understanding of the respective application field. The requirements of the field (particularly the heterogeneity of the target group; [31]) have to match the options of digital games including appropriate content, interface design and game demands.

Successful applications show that this synthesis is possible and can produce substantial benefits of SG at least for a considerable portion of older people. However, studies of good quality including older people are rare, and some evidence shows that older people may have specific playing preferences (including social gaming context) and particular difficulties handling digital games and may not generally take advantage of higher motivation and enjoyment as much as younger people. Therefore, game concepts as well as game interventions have to be developed and evaluated that are tailored to the individual prerequisites of older people.

Another key problem to be solved is sustainability. Serious games have been proved to produce transient effects. These effects may be due to initial increase of motivation. However, prevention and rehabilitation aim at enduring effects. Few studies investigating long-term effects are much less promising. In order to ensure sustainability, research has to evaluate which settings support long-term motivation and engagement of older people in SG.

Therefore, to give a preliminary answer to the question posed in the subtitle of this contribution, SG are not a new panacea of older people but can be a valuable option for prevention and rehabilitation if certain constraints are considered.

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