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How Effective Is "Exergamification"? A Systematic Review on the Effectiveness of Gamification Features in Exergames

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Abstract

Physical activity is very important to public health and exergames represent one potential way to enact it. The promotion of physical activity through gamification and enhanced anticipated affect also holds promise to aid in exercise adherence beyond more traditional educational and social cognitive approaches. This paper reviews empirical studies on gamified systems and serious games for exercising. In order to gain a better understanding of these systems, this review examines the types and aims (e.g. controlling body weight, enjoying indoor jogging…) of the corresponding studies as well as their psychological and physical outcomes. This paper particularly reviews the deployed motivational affordances and the effectiveness of incorporating gamification features in exergames. The review shows overall positive psychological outcomes (e.g. enjoying exercise) as well as behavioral ones (e.g. decreasing sedentariness) about exergames. Its findings inform about the current state of the research on the topic, based on which, suggestions for further research are outlined.

1. Introduction

Recent years have seen a rapid increase in the use of games and game elements for motivating people towards various behaviors. Approaches such as gamification and serious games [1] [2] are increasingly adopted in various contexts ranging from exercise and health [3] to education [4], ecological behavior [5] and work productivity [6]. More specifically these developments refer to the application of elements familiar from games to new contexts, i.e. gamification, or developing a full-fledged game for a certain purpose other than entertainment alone, i.e. serious games [1], [2].

One of the most prominent fields where gamification and other gameful approaches have been implemented is the health and exercise field [7], [3]. Digital games and gameful systems for exercise, commonly shortened as exergames, have been developed extensively during the past few decades [8]. However, due to the technological advancements allowing for more widespread and affordable use of various sensor technologies, the exergaming field has been proliferating in recent years. As the ultimate goal of implementing the game elements to any non-entertainment context is most often to induce motivation towards the given behavior, similarly the goal of the exergaming approaches is supporting the user to engage in various physical activities and promoting health benefits via the system use.

A common problem in the use of the systems is the novelty effect [9], [10] , which refers to the initial increase in use of the system due to the excitement and interest over a novel system. To overcome this challenge, various design elements common to games may be employed in exergaming approaches [11] similarly to digital games in general. Since gamification presents an innovative and subtle set of solutions for enhancing user motivation and engagement with the systems [11], we found it important to explore to which extent the gamification concepts were applied. This analysis would help exergame designers as well as further research to effectively integrate gamification features into their systems.

In this study we review the current body of literature of empirical research on virtual reality-based exergaming. We map the current state of research on the topic by analyzing and reporting the types of studied systems and their contexts, the game elements employed, the psychological and behavioral outcomes of the systems studies as well as the results reported in the literature. The findings of the review provide insight on the state of empirical research on using,

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amongst others, virtual reality-based exergaming systems as well as on the effectiveness of the approach for motivating users towards physical activity. Furthermore, potential gaps in the current body of literature are identified.

2. Related Works

Different works have attempted to review current studies on the effectiveness of exergames in enhancing physical activity and decreasing sedentariness. In our work however, we also review the extent to which motivational affordances and gamification elements (i.e. badges, levels…) are actually deployed in exergaming in order to sustain behavior change and promote physical activity.

In [12], the authors present a systematic review that provides a quantitative outcome of the current state of the art of active video gaming (AVG). They thereby precisely assess its effectiveness in overcoming different barriers to physical activity in children and youth and in helping them promote their health and well-being. To conclude, the review, which includes (n=18) case studies, states that AV games enable “light to moderate physical activity”.

In [13], the authors provide as well a systematic review delivering a quantitative synthesis of the current studies considering the physical effect of exergames. The review only considered the effects in healthy elderly and reports several results varying from remarkable improvements to no mentionable effects. Thus, it was difficult to the authors to generalize their findings into broad recommendations. The small number of the reviewed studies (n=7) might also form a limitation for this work.

In [14], the authors review existing literature concerning interactive exercise video games. The reviewed papers (n=19) show positive results regarding the physical activity of both adults and children. The authors state for instance an increase in oxygen uptake and heart rate in contrast to traditional video games.

The stated works as well as various others [15] [16] [17] mutually review the effectiveness of exergaming in enhancing rehabilitation and stimulating physical activity. These works did exclusively consider reviewing the outcomes of exergames focusing rather on motion controls. Although practically sharing the same outcome, namely assenting that exergames present a potential way to enact physical activity, none of the reviews has emphasized on the exergame design and the integration of game mechanics. It is worth mentioning here that the authors of the recently published review [18] go beyond the mere investigation of the outcomes of the studied gamified health systems (n=15) to analyzing their different depicted persuasion contexts.

3. Conceptualization of exergaming

In accordance with [1] and [11] we consider the exergames to comprise of three essential elements: 1) the motivational affordances, i.e. the game elements employed in the system, e.g. progress, badges, or leader boards, 2) the psychological outcomes that are induced by the motivational affordances, i.e. the psychological processes (e.g. competition, achievement, self-expression) through which the affordances motivate the user towards the encouraged activities, and finally, 3) the resulting and pursued behavioral and quasi-medical outcomes (attitudes) (e.g. increased physical activity, measured health benefits) (see figure 1).

Hence, in this literature review, and based on this conceptualization, we collect the different motivational affordances implemented in the reviewed studies, the resulting psychological outcomes and the behavioral & quasi-medical outcomes.

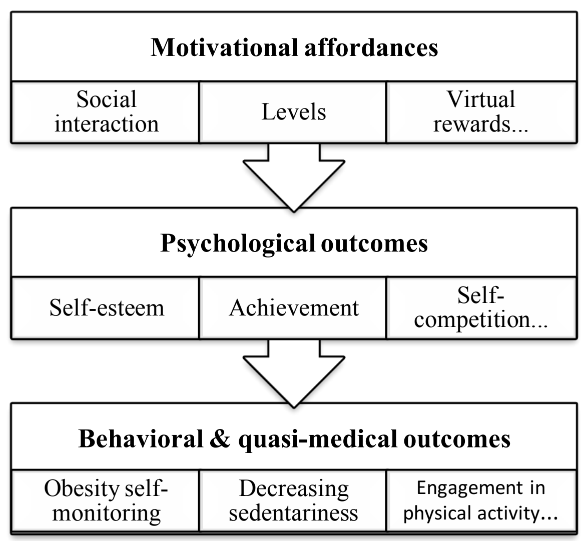

Figure 1. Conceptualizing exergaming

4. Literature review

The literature review was conducted by following the guidelines provided by Webster & Watson [19]. See figure 2 for the flowchart regarding the literature review process.

Firstly, literature searches were conducted in the Scopus database, which was chosen as it is the largest database of academic works. We defined the following search query that was used for the literature search: (TITLE-ABS-KEY ("virtual realit*") AND (TITLE-

ABS-KEY (exerc*) OR TITLE-ABS-KEY("physical activ*")) AND TITLE-ABS-KEY (gam*) AND NOT (TITLE-ABS-KEY (therap*) OR TITLE-ABS-KEY (rehab*))). We targeted by using the term “gam*” both games and gamified systems. The terms “exerc*” and “physical activ*” were used to identify the papers dealing with exercise and active playing. With this search query the search terms were looked for from the metadata (title, abstract, and keywords) of the papers. The search was conducted in 5/2015, included all papers written prior to this date and at that time resulted in 164 hits.

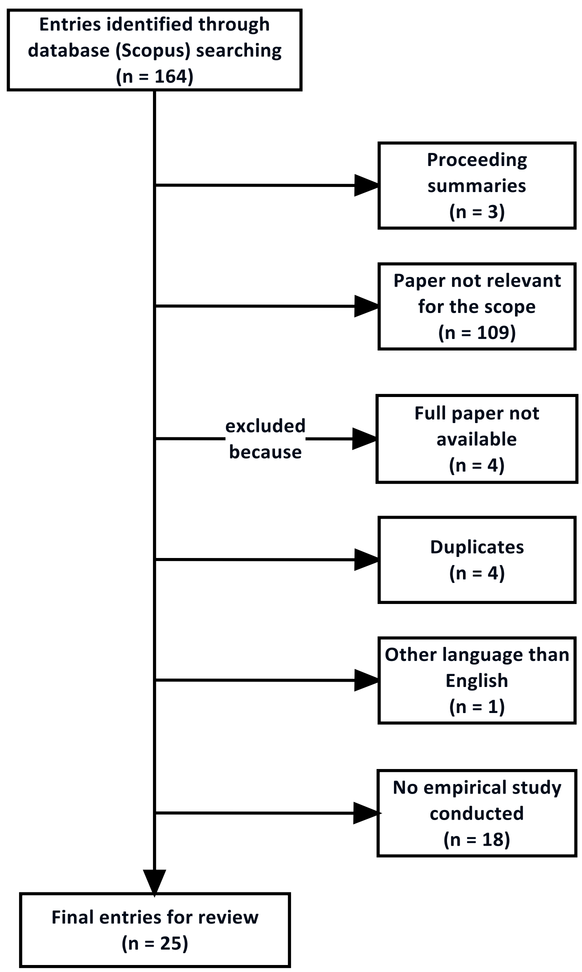

Figure 2. Flowchart of literature review process

The initial search results were then screened for inclusion based on the following criteria:

1. The paper is in English
2. The paper is published on a peer-reviewed venue.
3. The full paper is available (abstracts only studies are eliminated).
4. The paper is relevant for the scope, i.e. it is about the use of virtual reality (as a gameful element) to motivate exercise and physical activity, but not used as a form of *institutional* therapy/rehabilitation. The paper must describe the system in detail and thus may also be considered if it comprises gamification and game design).
5. The paper is empirical (data has been gathered from research subjects).
6. The methodology of the study is clearly defined.

Following the example of [13], we implicitly deployed McGonigal’s definition of a game [20] to point ***game-based physical activities***. The definition states that games should consist of four main components, namely: (1) a goal to achieve, (2) rules to follow, (3) a feedback system for people to track their progress and (4) the voluntary acceptance of the three first elements. Hence, the selected studies meet the following definition adopted from [21] [20] [13]: “‘a digital game that require players to (voluntary) perform physical exertion to play and where the game has specific goals, rules, and a feedback mechanism”

Further, we denote by ***Quasi-medical*** the type of different gamified systems and exergames that were designed and developed for therapeutic and rehabilitation purposes.

We designate by ***virtual-Reality based exergames*** different immersive systems using a virtual world and typically involving visuals and sound. Although some studies did not meet our definition and requirements for VR systems (e.g. [22]), we decided to retain them since they did deal with game design and mechanics and were therefore relevant to our review.

After this process, 25 papers were identified as relevant for the literature review (see Figure 2).

5. Analysis & results

The high-level research inquiry shared between the reviewed papers is whether amongst others virtual reality-based exergaming can effectively promote physical activity. In our analysis process, the following elements of the studies were scrutinized and identified.

1. The aims of the presented studies.
2. The types of the used systems.
3. The types of the physical activities that were targeted by the studies.
4. The motivational affordances implemented in the studies.
5. The psychological outcomes of the exergaming systems.
6. The types of the conducted studies in terms of methodology.
7. The findings of the studies.

Besides grouping the studies according to their types (quantitative, qualitative or mixed) and how positive their reported results were (points 6,7), we believe that classifying these former in regard to the points (1 to 5) would enable further research to efficiently design and analyze gamification systems. In addition to these criteria, we have also investigated the different systems for their home-compatibility. This point however will be presented in future work. The findings of the review are reported in the following subsections. For a more detailed summary of the reviewed studies, see the Appendix A.

5.1. Study purpose & behavioral outcomes

The aims of the studies were analyzed and the purposes were categorized as behavioral, quasi-medial or mixed (behavioral & quasi-medical together). Based on the analysis, the majority of the papers explored the effectiveness of exergaming in engaging and motivating people to exercise (see table 1). Furthermore, many of the reviewed papers also investigated the value of exergames as a means of cure and treatment for various medical conditions.

None of the studies had the intention to investigate how appropriate the used systems ware for the aimed behavioral or quasi-medical purposes

Table 1. Types of the study purpose

Study purpose	Paper
Behavioral	[23] [24] [25] [26] [27] [28] [29] [30] [31] [32] [22] [33] [34] [7] [35] [36] [37] [3] [38]
Quasi-medical	[39] [26] [30] [40] [41] [42] [36] [3] [43]

5.2. System types

Next, we analyzed the system types employed in the studies. These were categorized in terms of being either 1) existing gaming technologies (e.g. Nintendo Wii, Xbox Kinect) with which existing physical activity-oriented games (e.g. Wii Fit, Kinect Sports Rivals) were used; 2) gamification of an existing system (e.g. modifying an existing game by adding motion-based input to fulfill the targeted behavior); or 3) an exclusively developed custom-tailored system for the purposes of the study.

While the majority of the studies (see table 2) have exclusively developed custom-tailored systems for the study's purpose, some did simply use existing commercial technologies. A limited number of studies however, tried to take advantage of existing games and to change the sedentary playing mode to an active one by implementing motion-based game input.

None of the studies however have outlined the challenges of creating a whole system from scratch or the compromises made for the mere use of available systems.

Table 2. Used system

System type	Paper
Existing system	[26] [28] [33] [7] [35] [36] [43]
Gamified system	[23] [27] [3]
Exclusively developed system	[39] [24] [25] [26] [29] [30] [40] [31] [32] [41] [22] [42] [34] [37] [44] [38]

5.3. Targeted activities

Furthermore, we analyzed the types of activities targeted by the systems employed in the reviewed studies. Exercising activities such as cycling and running were common implementations. In addition to these, we have noticed a vast deployment of the existing commercial console-based exergames such as Wii Fit and Kinect-based games.

In this review, we have designated by "fun sports" the simulated recreational activities usually offered in bundle-like video games (e.g. Wii Sports which include amongst others boxing, golf and bowling). Moreover, more specific activities such as muscle conditioning were also present in the reviewed studies (see table 3).

Table 3. Targeted physical activity

Physical activity	Paper
Fun sport	[23] [27] [31] [41] [7] [36] [43]
Cycling	[38] [3] [37] [35]
Aerobics	[24] [25] [26] [32] [22] [42] [33] [34] [35] [37] [44] [3] [38]
Muscle conditioning	[39] [42]
Balance	[24] [25] [26] [28] [29] [36] [40] [34]
Speed	[25] [27] [29] [30] [31]

5.4. Motivational affordances

We have collected in this literature review various types of motivational affordances (see table 4). Whether deployed together or individually, these components, also referred to as game mechanics, may highly push forward the users' motivation and engagement. Studies that deployed existing commercial exergames (e.g. Wii Fit) took advantage of the provided game design and mechanics (points, levels, leaderboards…), whereas the authors of the papers presenting both, gamified systems and exclusively developed systems, had to implement their own mechanics.

Given this fact, it is curious that none of the studies that were based on an exclusively developed application reported deploying a badge system. Since badges are one of the most commonly used mechanics in gamification [11] for motivating the users, it is interesting that the effectiveness of this mechanic has not been studied in the exclusively developed systems.

It is important to mention that only very few papers described the principles and guidelines on which they based their affordance designs. The majority however, have merely integrated given game mechanics without considering the underlying theories such as [45].

Table 4. Deployed motivational affordances

Mechanic	Paper
Avatars	[24] [29] [30] [22] [32] [42] [33] [34] [7] [36] [35] [37] [38]
Points	[39] [25] [26] [30] [7] [35] [36] [38]
Progress	[27] [28] [22] [7] [33] [36] [37]
Social interaction	[24] [31] [22] [33] [37] [38]
Levels	[26] [28] [27] [31] [22] [38]
Story	[30]
Virtual goods	[23] [25] [29] [31] [38]
Ranking	[25] [22] [38]
Rewards	[23] [25] [36]

5.5. Psychological outcomes

Psychological outcomes, which may also be considered as the system dynamics according to Hunicke's MDA framework [46], form the reason behind the user's motivational behavior towards the deployed motivational affordances. It is hence essential for exergame designers to target and satisfy the common desires of the different users. For instance, the need to accomplish a given task and to have goals to *achieve* is required by most people. Hence, these usually tend to look for new challenges and to set new achievable goals to reach.

People are steadily looking for experiences that give them the possibility and the opportunity to *express themselves* and to show that they are unique and distinguishable from others.

People usually also tend to *compete* and compare themselves against others. Thus targeting this dynamic would help them achieve higher level of performance.

Table 5 summarizes the different psychological outcomes found in the reviewed studies.

Table 5. Psychological outcomes & dynamics

Dynamic	Paper
Competition	[23] [39] [25] [28] [27] [31] [34] [7] [37]
Enjoyment	[23] [31] [32] [34] [7] [33] [22] [35] [38]
Achievement	[39] [26] [27] [28] [22] [31] [33] [44]
Self-expression	[24] [25] [29]
Status	[24] [26] [28] [30] [40] [42] [33] [36] [43]
Self-competition	[30] [41] [22] [36] [42] [44] [43]

5.6. Type of conducted studies

Table 6 categorizes the reviewed studies based on the type of the conducted study. As we can notice in the table, the majority of the studies followed a quantitative approach. This is rather understandable and was expected since quantitative research is frequently used for evaluations focusing on impacts such as user satisfaction, system usage rates and effectiveness.

Table 6. Type of conducted studies

Method	Paper
Qualitative*	[27] [28] [41] [7]
Quantitative**	[23] [39] [24] [26] [40] [31] [32] [42] [33] [34] [36] [37] [35] [38] [3] [43] [44]
Mixed methods***	[30] [29] [22]

* including interviews and other qualitative observations.

** including experiments, log data analyses and quantitative questionnaires.

*** usually include a larger quantitative part and, for example, user interviews or forum discussion analyses.

5.7. Reported results

5.7.1 Studies' results. Table 7 gives an overview of the reported results. These were generally positive, and concluded that using virtual reality-based exergames may enhance the motivation and engagement for exercise.

Some of the studies however, stated that introducing game elements to older adults did not have the pursued positive effects. This can be clarified with the fact that this target group is typically not familiar with such concepts.

Table 7. Reported results

Results	Paper
positive	[39] [25] [26] [29] [30] [40] [31] [41] [33] [34] [37] [43] [38]
Partially positive	[23] [24] [27] [28] [31] [22] [7] [42] [35] [36] [3] [44]
Not discussed	[32]

5.7.2. Role of gamification features. When mapping table 7 together with table 4 (from 5.4 motivational affordances) we notice that studies reporting fully positive results have deployed in average 2 to 3 game mechanics in contrast to studies [18] reporting partial positive results, which have only deployed 1 to 2 game mechanics. This could support our assumption that gamification elements and motivational affordances should be highly considered when developing exergames.

6. General shortcomings in the literature

In the course of our systematic review we could identify different shortcoming, namely:

- Although 84% of reviewed studies were quantitative, the sample sizes except 3 studies were often relatively small (median N = 21)
- Most of the given statistics were merely descriptive and no inferences and deductions were presented
- Some studies did not deploy validated scales for the measurement of the different behaviors and outcomes
- Different studies were simply based on user evaluation and did lack control groups
- Generally, the studies were carried out in rather short timeframes
- A linkage to prior theory was missing in most of the papers.

7. Strengths & limitations of the review

To the authors' knowledge, this is the first work, in which a systematic review on the deployment of game-based motivational affordances in exergames and gamified exercise systems was conducted. However, the limitations of this work should be mentioned. For instance, the search for this review included only hits for the keywords "virtual reality*" and "gam*" in addition to exercise related terms. Since the use of keywords importantly differs in this rather new area, a further search for keywords, like "interactive computer play" or simply "video game", could have brought more results and broadened the spectrum. Moreover, language and publication biases might have occurred since we have only considered inspecting published studies in English. Besides, we have exclusively used Scopus for our research. Although we estimate that this database encompasses most of the relevant gamification and exergame studies, other databases like PubMed and Web of Knowledge could have also been considered.

8. Conclusion

Physical activity is clearly important to public health and exergames represent one potential way to enact it. The promotion of physical activity through gamification and enhanced anticipated affect also holds promise to aid in exercise adherence beyond more traditional educational and social cognitive approaches that tend to dominate this literature. A review of this literature can help identify what we know so far and highlight important future directions.

In this paper, we reviewed the contemporary literature focused on serious exergaming and its impact on behavioral adherence and potential mediators. We thereby examined the types and aims of the studies as well as their outcomes. This paper focuses precisely on the deployed motivational affordances and the corresponding results. The findings of the paper indicate a partially to fully positive outcomes of the reviewed studies.

Nevertheless, we noticed that the majority of the studies, which developed a new exergame from scratch or tried to 'exergamify' an existing game, did solely concentrate on changing the game input mode from static (e.g. button based) to active one (e.g. motion based) and did not focus on the gamification design principles and guidelines. For instance, quite few studies [25], [34] have considered designing a game experience following the Flow theory [47] and none of the studies had investigated the type of their participants (e.g. according to Bartle's classification [45]). Moreover, none of the studies had implemented an achievement and badges systems for their exergames.

To conclude, several studies were identified, which considered the task of game design and the deployment of gamification features for promoting physical activity. However, further and theory-based studies, granularly examining the effectiveness of different gamification element and mechanics in exergames, are needed.

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Appendix A: Summary table

paper	Used system	Targeted activity	Motivational affordance	Psychological outcomes	Behavioral& quasi- medical outcomes	N	Type of study	Reported results
[23]	gamifying an existing system: adding physical activity to an existing game	fun sport active playing	Rewards time virtual goods	competition enjoyment	decreasing sedentary playing & increasing active playing	284	quant.	partially positive
[39]	excl. dev. sys. 3 new games played using hand grippers	Endurance muscle conditioning	points	achievement competition	treating autism through playing video games	29	quant.	positive
[24]	excl. dev. sys. camera-based tracking (image processing)	aerobics balance	avatars social interaction	self-expression (avatars) status (female audience) altruism (exercise sharing)	enjoying exercising through avatar personalization	30	quant.	Partially positive
[25]	excl. dev. sys. motion capture system with VR projection	balance aerobics strategy speed	points score multiplier score freeze	self-expression competition enjoyment	full body exercising while playing	30	mixed	positive
[26]	1st: Wii Fit on pc 2nd: excl. dev. sys. VR system + motion capture via smart shirt	balance jogging fun sport	points levels	achievement status (fighting obesity)	combatting obesity & sedentariness by exergaming	1st: 87 2nd: 126	quant.	positive
[27]	gamifying an existing system: car racing and controlling using Kinect motion capture	fun sport endurance speed	levels time progress challenge	competition achievement	converting sedentary games to exergames	24	qual.	partially positive
[28]	existing system: Wii Fit Wii balance board	balance	levels progress	competition achievement status (female audience)	physical activity assisted by video game	4	qual.	partially positive
[29]	excl. dev. sys. heart rate & temperature sensors + Kinect motion capture + screen	speed balance	avatars coins collecting	self-expression self-control	self-competition through avatar representation	6	mixed	positive
[30]	excl .dev. sys. a new game developed for Wii and uses the Wii-mote	running speed	avatars levels story	status self-competition enjoyment	obesity monitoring through exergaming	12	mixed	positive
[40]	excl. dev. sys. Kinect based motion capture	balance	points	status (elderly)	monitoring balance for older adults using games	8	quant.	positive
[31]	excl. dev. sys. playground slide (4x3m) + IR-based motion capture	fun sport precision strategy speed	virtual goods levels team work	competition achievement enjoyment	enhancing physical activity through tempo raising	1st: 248 2nd: 178	quant.	1.study positive 2.study partially positive
[32]	excl. dev. sys. camera-based motion capture + screen	jogging walking	avatar	enjoyment	enjoying indoor jogging	20	quant.	n/a
[41]	excl. dev. sys. PC-webcam-based VR game	fun sport	n/a	self-competition	enhancing physical activity for children with disabilities	3	qual.	positive

[22]	excl. dev. sys. PC-based game + pedometer (step counter)	walking running	avatar progress levels social interaction ranking	self- competition achievement enjoyment	encouraging physical and social activity through exergaming	19	mixed	partially positive
[42]	excl. dev. sys. Kinect-based game	water sport muscle conditioning Rehabilitation	avatar	status self- competition	shoulder muscle activation through exergaming	5	quant.	partially positive
[33]	existing system: Wii Free Run game	jogging	avatar progress social interaction	status (female audience) achievement enjoyment	controlling body weight by exergaming for women	25	quant.	positive
[34]	excl. dev. sys. DDR- (dancing pad) based game	aerobics coordination	avatar virtual goods	competition enjoyment	enhancing physical activity through active virtual world exploration	17	quant.	positive
[7]	existing system: Wii Sports	fun sport	avatar points progress	competition enjoyment	enhancing physical activity through immersive experience	4	qual.	partially positive
[35]	existing system: PC-based biking game + ergometer	cycling endurance	avatar time points	social interaction enjoyment	promoting psychological benefits of aerobic exercise	88	quant.	partially positive
[36]	existing system: Wii Fit Wii Balance	balance fun sport	avatar points progress rewards	status (old female audience) self- competition	reducing risk and fear of falls among older women through VR playing	38	quant.	partially positive
[37]	excl. dev. sys. stationary bike + cybercycle sensors + cycling game	cycling endurance	avatar progress social interaction	status competition	moderating exercise intensity through VR-based competitiveness	23	quant.	positive
[44]	excl. dev. sys. exercise bicycle + sensors + three different video games	precision balance cycling	n/a	achievement self- competition	encouraging physical activity for older adults through virtual augmented exercise	22	quant.	partially positive
[3]	Gamifying an existing system: PlayStation 2 games (not exergames) + Biking Game	cycling	n/a	immersion	attendance in training; physical fitness outcomes	14	quant.	partially positive
[43]	existing system: exergames using Xbox 360 Kinect sensors	fun sport	n/a	status	relieving depression in older women with osteoarthritis	40	quant.	positive
[38]	excl. dev. sys.: exergame (Virtual Network Marathon) developed by the authors	cycling	Virtual world avatar feedback social interaction levels ranking	immersion perceived effectiveness perceived competitiveness	learning about Chinese culture	20	quant.	positive