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Gamification in eHealth for Chronic Disease Self-Management in Youth: A Systematic Review

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Abstract

This systematic review primarily aims to provide a summary of the game mechanics implemented in eHealth tools supporting young people's self-management of their chronic diseases. This review secondarily investigates the rationale for implementing game mechanics and the effects of these tools. A systematic search was conducted in Embase, Medline, PsycINFO, and Web of Science, from inception until August 30, 2022. Studies were eligible if focus was on the utilization of gamification in eHealth self-management interventions for young people (age = 10–25 years) with chronic diseases. Primary quantitative, qualitative, and mixed-method studies written in English were included. We identified 34 eHealth tools, of which 20 (59%) were gamified tools and 14 (41%) were serious games. We found that 55 unique game mechanics were implemented. The most commonly used were *rewards* (50%), *score* (44%), *creative control* (41%), and *social interaction* (32%). In comparison with gamified tools, the number and diversity of game mechanics applied were higher in serious games. For most tools (85%), a general rationale was provided for utilizing gamification, which often was to promote engaging experiences. A rationale for using specific game mechanics was less commonly provided (only for 45% of the game mechanics). The limited availability of experimental research precludes to test the effectiveness of using gamification in eHealth to support self-management in young people with chronic diseases. In this study, we highlight the importance of reporting the rationale for utilizing specific game mechanics in eHealth tools to ensure a proper alignment with evidence-based practice and the need of conducting experimental research. PROSPERO: CRD42021293037.

Keywords: chronic illness, gamification, mental health, physical health, psychosomatic medicine, telemedicine

Introduction

Chronic diseases are health conditions that last for longer than 3 months (e.g., cancer, chronic fatigue, and depression).[1] Currently, 15%–25% of the young people (defined as 10–25 years old[2–4]) from developed countries have chronic diseases.[5,6] In adolescence and young adulthood, growing up with chronic diseases impacts all developmental

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domains. Self-management, the process allowing young people to maintain satisfactory daily functioning despite their chronic diseases,[7] is essential for alleviating the burden of these conditions, enhancing quality of life, and reducing health care utilization.[7–9] These behaviors are used to manage several aspects of chronic diseases (e.g., symptoms, treatments, and lifestyle changes).[10] Examples of self-management are decision-making, taking action, and using resources, in order to take an active role in medical management, adoption of new behaviors, and coping emotionally.[11] Currently, there is a need for novel interventions in self-management that align with the interests of young people who grow up in a digital world.[12–14]

For supporting chronic disease self-management needs in young people, eHealth interventions, which utilize the internet and related technologies, are promising. eHealth interventions have demonstrated efficacy in enhancing self-management.[15] Particularly, these interventions have the potential to overcome barriers to care such as anonymity and accessibility, which may reduce stigma commonly experienced by the young people, as well as reduce treatment burden in terms of time and costs.[16] Gamification is the utilization of game mechanics (e.g., badges, unlocking milestones, and narrative).[17] In this context, there are two main possibilities. First, incorporating gamification into nongame contexts in eHealth interventions, that is, gamified eHealth tools, hereinafter referred to as gamified tools. Second, designing games for a primary purpose other than pure entertainment in eHealth tools, that is, serious games for eHealth, hereinafter referred to as serious games.[18] Game mechanics align with young people's natural interest in play, which is important for their healthy development.[19] Although incorporating game mechanics into eHealth self-management interventions for young people with chronic diseases may be a particularly promising approach, previous systematic reviews focused on adults,[18,20–24] and thus, a summary of the prior available evidence in youth[18,20–24] is needed. Thus, it is important to provide an overview on game mechanics used in eHealth tools for youth and the reasons to use them, which will inform the development of new eHealth tools by the eHealth Junior Consortium (see, http://ehealthjunior.nl/). This consortium develops, evaluates, and implements eHealth tools for the well-being of young people with chronic diseases.

Objectives

Therefore, the primary aim of this systematic review is to provide an overview of gamified eHealth interventions supporting young people's self-management of chronic diseases, with an emphasis on summarizing the game mechanics implemented in the interventions. The secondary aims are (1) to identify the developer's rationale for implementing such game mechanics and (2) to investigate the effects of these interventions. To provide a comprehensive overview of the current state of the art, we included studies conducted in young people affected with a variety of chronic diseases (e.g., somatic and psychiatric) using gamified tools or serious games.

Research questions

The primary research question is as follows: Which game mechanics have been implemented in eHealth interventions aimed to support young people in their chronic diseases self-management? In addition, the secondary research questions are as follows: (1) What was the rationale behind the implementation of each game mechanic? and, if possible, (2) What were the effects of gamified eHealth interventions on self-management and health-related outcomes?

Materials and Methods

The protocol of this systematic review was approved by the steering committee of the eHealth Junior Consortium, preregistered (PROSPERO: CRD42021293037), and published.[25] Importantly, two independent reviewers, a medical doctor (M.D.S.) and a psychologist (L.L.), were trained to participate in the key processes of the present systematic review by the guarantor of the review (F.E.L.). One of the reviewers (L.L.) was involved in the conceptualization, methodology, and development of the protocol of the review. Both independent reviewers (M.D.S. and L.L.) received explanations on the aim of systematic review, the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, protocol development, search strategy creation, screening, data extraction, quality assessment, synthesis, and reporting. They were provided with practice, feedback, and ongoing support by a highly multidisciplinary team including experts in systematic reviews, pediatrics, psychology, and psychiatry and game experts/designers. This support was particularly intense at the beginning of the training, including pilot testing and detailed consensus meetings to address discrepancies. Consensus meetings to address discrepancies were regularly arranged throughout the review process.

Inclusion criteria

Participants: Adolescents or young adults (between ages 10 and 25 years) with a chronic disease.

Interventions: Gamified eHealth tools or serious games for eHealth tools aiding self-management in young people with a chronic disease. Self-management behaviors are aimed at managing the disease and its effects (e.g., symptoms, treatment, physical and psychosocial consequences, and lifestyle adjustments).[10] An intervention was considered intended for self-management if it addresses at least one of the following behaviors: problem solving, decision making, using resources, forming a relationship with a provider, or taking action,[26,27] performed in the domains of medical management, adopting new behaviors or roles, or psychosocial coping.[27]

Comparator: For studies that included a comparison arm, we compared gamified interventions or serious games versus (1) usual care (comparator) or (2) nongamified (comparator) versions of eHealth interventions.

Outcome measures: To assess the effects of the interventions, we focused on three categories of outcomes: (1) self-management behaviors including problem solving, decision making, using resources, and forming a relationship with a provider and taking action[26]; (2) effects of self-management on outcomes[27,28]; and (3) antecedents of self-management such as adherence to the eHealth tool, acceptability, and user's experience.[27,28]

Studies: We included peer-reviewed articles and conference proceedings reporting primary data.

Search strategy

On August 30, 2022, we conducted an electronic search in Embase, Medline, PsycINFO Ovid, and Web of Science Core Collection. We used these databases because the topic of our review is at the intersection of biomedicine and psychology fields. Supplementary File S1 shows the search strategy. In brief, an experienced information specialist (W.M.B.) designed a search consisting of terms (both controlled thesaurus terms and terms in title or abstract) for chronic diseases such as asthma or diabetes, combined with gamification, eHealth or mobile phone applications, and self-care or coping behavior and limited to youth or adolescents. The search results were limited to articles in the English language only. To identify gray literature, the eHealth Junior Consortium members were emailed for unpublished eligible studies. To gain deeper insights in the tools identified from the included studies, we conducted a snowballing technique (using references and cites of the included studies) and a Google search (e.g., trailers and intervention websites).

Selection of studies

Metadata were imported into Mendeley Desktop, and duplicates were automatically deleted. Two researchers (M.D.S. and L.L.) independently screened records by title and abstract and then by full text for inclusion. Disagreements were resolved through discussion with a third researcher (F.E.L.).

Data extraction

The information to describe each of the eligible studies was extracted (1) by two researchers independently when presented in the main text (M.D.S. and L.L., or M.D.S. and M.M.H.; disagreements were resolved through discussion with a third researcher [F.E.L.]) or (2) by one researcher only when presented in supplementary files (M.D.S., who consulted with other researchers when needed). To guide the extraction of the game mechanics implemented in each eligible study, we used the framework of game design patterns by Björk and Holopainen[29] because it offers a comprehensive overview and description of game mechanics, including detailed definitions and examples. Thus, this framework was instrumental in guiding data extraction for the present review. Brief definitions of each game mechanic are provided in Supplementary File S2; for further details, readers are directed to the original source.[29] We carefully considered other frameworks, but we found that they were not adequate for this review because they focus on nonserious games,[30] the educational domain specifically[31] or broad groups of game elements,[32] or general drivers for engagement.[33] The rationale was extracted literally from the included study (see Supplementary File S3).

Risk of bias (quality) assessment

The Mixed-Methods Appraisal Tool[34] was used to assess the risk of bias of each eligible study (M.D.S. or L.L., who consulted with other researchers when needed).

Funding information

In line with the PRISMA statement, which advocates for transparent reporting and comprehensive documentation of the review process, we extracted the funding information from the included studies (M.D.S. or L.L., who consulted with other researchers when needed). This addition ensures transparency regarding potential additional sources of bias or conflict of interest in the included studies.

Data synthesis

A narrative (descriptive) synthesis was provided for the primary and secondary review questions. Gephi Graph Visualization and Manipulation software version 0.10 was used to create a network of game mechanics.

Results

Selection process

From 2357 records identified in the primary search, we included 34 studies.[35–64,72–76] Using a snowballing technique, we included seven additional studies[65–71] (Fig. 1 for flowchart). From the 41 studies included in this review, 34 unique eHealth tools with gamification were identified. The main characteristics of these tools are summarized in Table 1. Of the 41 studies, 24 focused on developing tools or investigating their usability/feasibility[36,39,41–47,49,51,53,58–62,64–67,69,72,73], 15 on testing the effects of the interventions (eight were randomized controlled trials [RCTs][37,40,48,50,54,56,70,71], two were protocols for RCTs[57,74], four had a pre-post design[38,52,55,75] and one had a single case experimental design [SCED[63]] and two were descriptives[35,68]). The quality assessment revealed that the different components within the mixed-method studies did not meet the quality criteria for each respective method, and none of the quantitative nonrandomized controlled trials adequately addressed confounders in design and analysis (see Supplementary File S4). A summary of the funding information from the included studies is presented in Supplementary File S5. When needed, a complementary Google search (e.g., trailers and intervention websites) was conducted to obtain additional information (see Supplementary File S6).

Characteristics of eHealth tools

Regarding the type of gamification, 20 tools were gamified[36,37,39,41,44–47,50,53–56,58,59,61,62,64–67,69,72–75] and 14 tools were serious games.[35,38,40,42,43,48,49,51,52,57,60,63,68,70,71] Tools were developed for a broad range of chronic diseases, including somatic,[35,36,38,39,41,43–46,49–58,60–62,65,67,69,72–75] psychiatric,[40,42,47,48,63,64,66,68,70,71] and those at the intersection of both (i.e., chronic pain).[37,59]

Most tools (n = 26) aimed at multiple self-management domains and behaviors.[36–42,44–51,53–56,58,59,61–73] Twenty-nine tools supported *taking action,*[36–47,49–51,53–56,58–64,66,67,69,71–74] such as taking medication[44,49,60,73] or increasing physical activity.[36,48,50] *Using resources* was targeted in 27 tools,[36–39,41–55,59,61,63,64,66,68–75] for example, through monitoring disease activity or self-management behaviors.[37,44–46,56,59,61,62,65,72,73] Ten tools supported *forming a relationship with a provider*[39,45,46,50,51,54,55,59,64–66,69,72,74] and *decision making*, respectively.[36,39,42,46,51,53,56,58,59,62,65,67,73] Only the anorexia nervosa companionship app targeted *problem solving* directly, with a module on how to manage emotional dysregulation.[47]

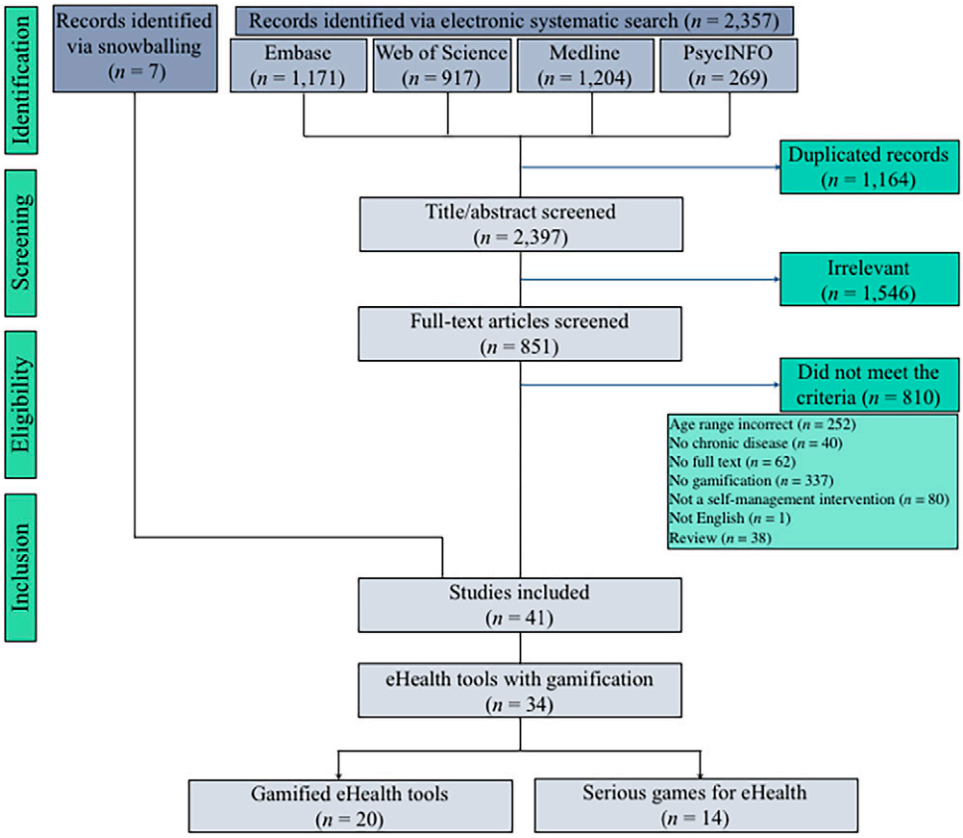

FIG. 1. Flowchart of the selection process.

Implemented game mechanics (primary research question)

We identified 55 distinct game mechanics; Figure 2 presents an overview. The most commonly used were *rewards* (n = 17 [50%]), *score* (n = 15 [44%]), *creative control* (n = 14 [41%]), and *social interaction* (n = 11 [32%]). In comparison with gamified tools, the number and diversity of game mechanics applied were higher in serious games (Fig. 3). A small group of game mechanics was combined in several tools; for example, 11 tools combined *rewards* and *score* (Fig. 4, see Supplementary File S7 for the more detailed figure[41,43–46,51,53,55,56,60–62,69]). Of the 55 distinct game mechanics, 51 were used in serious games compared with 27 in gamified tools, of which 23 were found in both.

Rationale for gamification (secondary research question)

A rationale for implementing gamification in general was provided for 29 eHealth tools (85%, Table 2 depicts an overview, whereas Supplementary File S3 contains detailed information). The most common rationale for gamification was *promoting engagement,*[37,38,40,41,44,45,47,49,55,57,59,62–64,67,68,72,75] *behavioral change,*[43,46,47,60,64,68,75] and *effectiveness.*[40,43,55,60,68,71] For serious games in specific, authors saw games as an effective tool to learn,[35,38,42,48,60,68,70,71,76], specifying special needs of children with specific psychiatric diseases[42,63] and explaining the preference for *game-based learning* by the *young age* of the users.[38] Moreover, in rationales within serious games, the young age was brought into connection with their *interest in games*[63] and *technology*[60] in general.[38] Games are tailored to the special needs of children with diseases[42,63] and intellectual and social maturation levels.[38] A rationale to use a specific game mechanic was provided for 97 instances (45%, Table 3). Most of these rationales were directly related to increasing *engagement* with the *tool* or the *targeted self-management behavior*. Although for more than half of the tools, the design of the self-management intervention was based on a behavioral change,[36,39,44,46,50,51,54,58,60,61,65,67] learning theory,[40,52,63] or a psychological therapy,[40,42,47,48,68,70,71] only seven tools[36,40,46,48,50,51,58,67,68,70] directly linked the implementation of specific game mechanics to this theoretical basis. For instance, ATOMIC,[36] COOL Passport,[50] and Reactivate[46] were based on the social cognitive theory.[77] Consequently, they used game mechanics that were largely similar. However, how the mechanics were linked to theory constructs differed; for example, *social interaction* was used in all three tools but for different reasons: for *self-efficacy* and *outcome expectations,*[36] *social support,*[36,46] or *self-judgment.*[50]

Importantly, involving patients in codesign processes yielded rationales for implementing certain game mechanics, as these were most appealing to the target population.[41,50,59,61,65] In serious games, a broad range of game mechanics facilitated the practice of self-management skills. For this rationale, FUN QUEST, among others, included *characters, avatars, roleplaying,* and *narrative structures.*[38]

Table 1. Overview of the eHealth Tools Identified from the Included Studies

	N *gamified tools**	N *serious game tools**
Total	20[36,37,39,41,44–47,50,53–56,58,59,61,62,64–67,69,72–75]	14[35,38,40,42,43,48,49,51,52,57,60,63,68,70,71]
Type of disease targeted		
Somatic	16[36,39,41,44–46,50,53–56,58,61,62,65,67,69,72–75]	10[35,38,43,49,51,52,57,60]
Psychiatric	2[47,64,66]	4[40,42,48,63,68,70,71]
Intersection of somatic and psychiatric	2[37,59]	—
Study design		
Usability/feasibility	16[36,39,41,44–47,53,55,58,59,61,62,64–67,69,72,73]	7[42,43,49,51,60]
Randomized controlled trial	4[37,50,54,56]	3[40,48,70,71]
Pre-post design	2[55,75]	2[38,52]
Protocols for Randomized controlled trial	1[74]	1[57]
Descriptive	—	2[35,68]
Single-case experimental	—	1[63]
Type of tool and platform**		
Smartphone (and tablet) application	16[36,37,39,41,44–47,50,53,55,56,58,61,62,65,67,69,73–75]	3[43,49,57]
Website	2[54,64,66]	1[52]
Combination of smartphone application and website	1[59]	2[48,68,70]
Videogame on gaming device (Wii/Xbox/Nintendo/computer)	1[72]	4[38,60]
Videogame on computer or laptop with biofeedback	—	2[40,42,71]
Virtual reality with biofeedback	—	1[63]
Self-management domain targeted		
Medical management	16[36,37,41,44–47,50,53,55,56,58,61,62,67,69,72–75]	11[35,38,42,43,48,49,51,52,60,68,70,71]
Adopting new behaviors/roles	11[36,37,39,41,46,50,53,58,59,61,64–67]	7[38,40,42,48,51,57,63,68,70,71]
Psychosocial coping	13[36,39,41,45–47,50,53–55,59,61,64–66,69,74]	4[40,42,51,63,71]
Self-management behavior targeted		
Taking action	19[6,37,39,41,44–47,50,53–56,58,59,61,62,64–66,67,69,72–74]	10[38,40,42,43,49,51,60,63,71]
Using resources	18[6,37,39,41,44–47,50,53–55,59,61,64–66,69,72–75]	9[35,38,42,43,48,49,51,52,63,68,70,71]
Forming relationship with provider	9[39,45,46,50,54,55,59,64–66,69,72,74]	1[51]
Decision-making	8[36,39,46,53,56,58,59,62,65,67,73]	2[42,51,71]
Problem solving	1[47]	—

Note. *As some tools were described and evaluated in multiple studies (with different designs) and some studies described multiple tools, the number of supporting references does not always match the frequency of tools with specific characteristics.
**The type and platform of one tool were unclear.[35]

Efficacy of gamification and serious games (secondary research question)

We did not perform meta-analyses because only eight RCTs were included and primary outcomes and control conditions were diverse (Supplementary File S8). There was no effect observed in six (75%) RCTs[37,50,54,56,70,71] and positive effects in two RCTs, both testing a serious game.[40,48] A consistent finding across studies with and without control groups was that higher engagement was associated with larger effect sizes.[37,39,55,56,64] Studies gave little insight on mediators for engagement. The effect of gamification in general could only be deduced from the study on TEENCOPE, which was compared with a nongamified eHealth intervention and did not perform better in engaging.[54] The effect of specific game mechanics on engagement or other outcomes was not assessed in any of the included studies.

Discussion

In this systematic review, we observed that 55 distinct game mechanics were implemented in 34 eHealth tools. The most used were *rewards, score, creative control,* and *social interaction*. We also showed that the most common rationale for gamifying eHealth tools was to provide young people with an engaging experience. Experimental research is scarce, precluding to quantify the effects of gamified eHealth interventions in improving young people's self-management of chronic diseases.

Implemented game mechanics (primary research question)

A total of 55 distinct game mechanics were implemented in the included studies, 216 times in total altogether. *Rewards, score,* and *social interaction* were frequently used. A previous review also identified these game mechanics as common in eHealth tools for medical education.[24] The common use of the same game mechanics in diverse populations, with different characteristics and needs, may raise concerns,[78] particularly in relation to effectiveness and integration.[79,80] Tailoring the game mechanics in eHealth tools to support self-management, considering the age and specific needs associated with a particular chronic disease, may be important for optimal outcomes.[79–81] However, the present

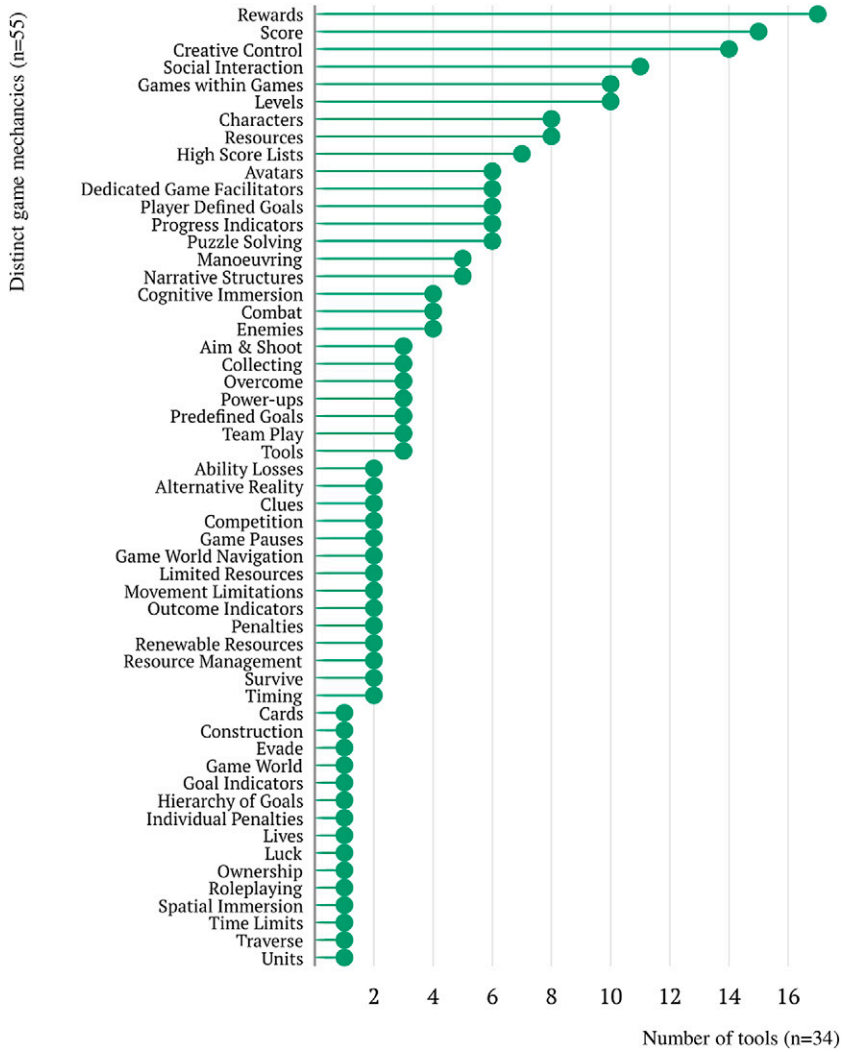

FIG. 2. Number of tools using specific game mechanics. The total number of tools and distinct game mechanics is included between brackets.

review does not allow us to determine which specific combination of game mechanics may best suit a particular disease, as the studies included involved a wide range of diseases.

From the 34 eHealth tools included in this review, 20 (59%) were gamified and 14 (41%) were serious games. Of the 55 game mechanics implemented, 4 were unique in gamified tools, 28 in serious games, and 23 were utilized in both types of tools. In general, the level of gamification (i.e., the number and diversity of implemented game mechanics) was higher in serious games in comparison with gamified tools. In line with prior literature,[24] the use of gamification for self-management purposes may have been insufficient in certain gamified eHealth tools, as it was solely based on *point* or *reward systems.*[37,61] However, other gamified eHealth tools integrated *point* or *reward systems* with additional mechanics such as *creative control*[36,39,44,47,55,59,65,69] or *social interaction.*[36,39,45,46,50,55,56,59,62,65,69] While these types of gamified tools may be more effective, the current state of the art does not provide firm conclusions. The lack of concrete insights might be explained by the paucity of efficacy studies. In addition, RCTs have been suggested to be unappropriated to assess complex interventions like mHealth.[82] For gaining insight into the working mechanism of game mechanics, more adaptive study designs might be a solution. Examples are a SCED[83] (n = 1, 1 study found in this review[63]) and a multiphase optimization strategy trial, which allows for testing individual intervention components and their combinations.[84] Even with these adaptive designs, it needs to be considered that a game mechanic is not a sole entity and depends on its integration in the tool and combination with other mechanics.

Rationale for gamification (secondary research question)

One of the secondary aims of this review was to identify the rationale for gamification in self-management facilitated by eHealth. This aim was conducted at two levels: the general rationale for using gamification in eHealth tools and the rationale for implementing a specific game mechanic. We found that providing a general rationale for using gamification or serious games was more common than for a specific game mechanic; 85% of the tools versus 45% of the times. The rationale most frequently given for both implementing game mechanics in general and for the choice of specific

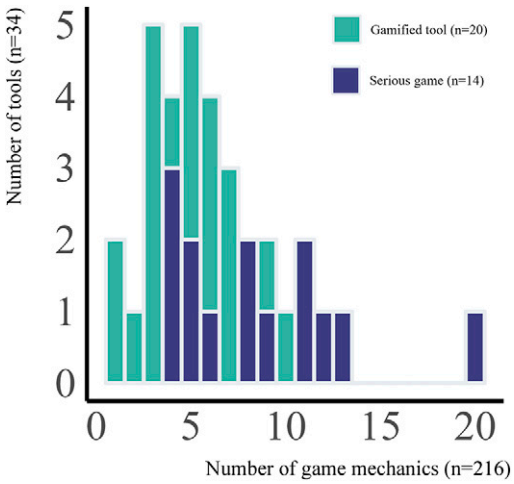

FIG. 3. Number of game mechanics implemented per tool. The total number of tools per category is included between brackets. The median number (range) of game mechanics implemented per tool for gamified tools was 5 (1–10) and for serious games was 8 (4–20).

game mechanics was to provide young people with an engaging experience,[37,38,40,41,44,45,47,49,55,57,59,62–64,67,68,75] which was robustly observed from previous reviews without age restrictions on eHealth interventions for mental health and well-being[18] and chronic disease management and healthy lifestyle.[23] Collectively, for young people, incorporating game mechanics into eHealth self-management interventions seems appropriate because of their natural interest in play, which was reflected by the rationales for serious games.[19]

In some studies included in the present review, it was highlighted that involving young people with chronic diseases in codesign when gamifying eHealth tools for self-management may help to identify which game mechanics are the most appealing to the target population.[41,50,59,61,65] However, this speculation remains to be corroborated in experimental research.[85] Indeed, a previous review concluded that gamification in mental health apps lacked a clear rationale.[22] We additionally showed that the link between specific game mechanics and self-management theory was not explicitly stated for most of the tools included in the present review. Thus, on behalf of the eHealth Junior Consortium, we recommend that future research reports the rationale for utilizing specific game mechanics in eHealth tools to ensure a proper alignment with evidence-based practice, which is highly valued in healthcare.[80]

Efficacy of gamification and serious games (secondary research question)

In this study, we found that experimental designs (i.e., RCT and SCED) were scarce and heterogeneous. This limitation does not seem to be specific to research on eHealth or young people, as it has also been observed in other reviews that do not focus on eHealth and do not have age restrictions.[86–89] In general, the limited experimental evidence makes it difficult to quantify the effects of gamification in the self-management of chronic diseases in young people. Only two (25%) of the eight RCTs included in this review showed that eHealth interventions utilizing gamification may improve self-management of chronic diseases. Consistent with previous reviews,[86,89,90] the studies that we included had small sample sizes and may have been underpowered. Consequently, it is challenging to draw quantitative conclusions from our review. Thus, future studies should be well-powered. In our risk of bias (quality) assessment, we also identified that future nonexperimental research should adequately control for confounders as is a common limitation in the available literature.

Limitations and strengths

This review has some limitations. First, the small number of RCTs included in this review precluded to conduct meta-analysis to quantify the effects of eHealth interventions using gamification. At least, we provided a qualitative synthesis, which was not conducted by previous reviews on different populations.[24] Second, the inclusion of studies published in English only may limit the generalizability of our results. Third, the rapidly evolving nature of eHealth terminology may have resulted in failing to identify relevant studies despite our carefully designed search term combinations. Fourth, common limitations in the field, such as incomplete descriptions of eHealth tools, may have negatively impacted our findings. Fifth, a deeper level of understanding on how specific game mechanics were used to engage users may be of interest,[91] which would require to conduct qualitative studies in the targeted population. Sixth, we paid scarce attention to how well several game mechanics were integrated in each of the tools and if they aligned with the therapeutic goal(s) of the tools, which might impact the efficacy of game mechanics.[80,92]

This review also has several strengths. First, the inclusion of heterogeneous samples and interventions, such as somatic and psychiatric diseases, as well as gamified tools and serious games, helped us to provide a comprehensive overview of the current state of the art. Our comprehensive overview may serve as a valuable resource for game developers, health professionals, and researchers offering starting points for further development and evaluation of gamified eHealth interventions. A priority of the eHealth Junior Consortium for further research is to identify both universal/transdiagnostic and individual/personal mechanisms promoting self-management acknowledging the importance of both types of mechanisms. Second, we carefully designed our search strategy, inclusion/exclusion criteria, and time span coverage, searching in four major databases (Embase, Medline, PsycINFO, and Web of Science). In addition, two independent researchers were involved in all the information provided in the main text of this review (e.g., electronic search, selection of studies, and extraction of information for main tables and figures). Third, this work is embedded within the eHealth Junior Consortium, providing a highly multidisciplinary vision from diverse fields including pediatrics, psychiatry, psychology, game design, and eHealth, among others.

Conclusions

This review provides an overview of the use of game mechanics in eHealth tools focusing on improving self-management of chronic diseases in youth. We identified 34 eHealth tools utilizing 55 distinct game mechanics; the most common were *rewards*, *score*, *creative control*, and *social*

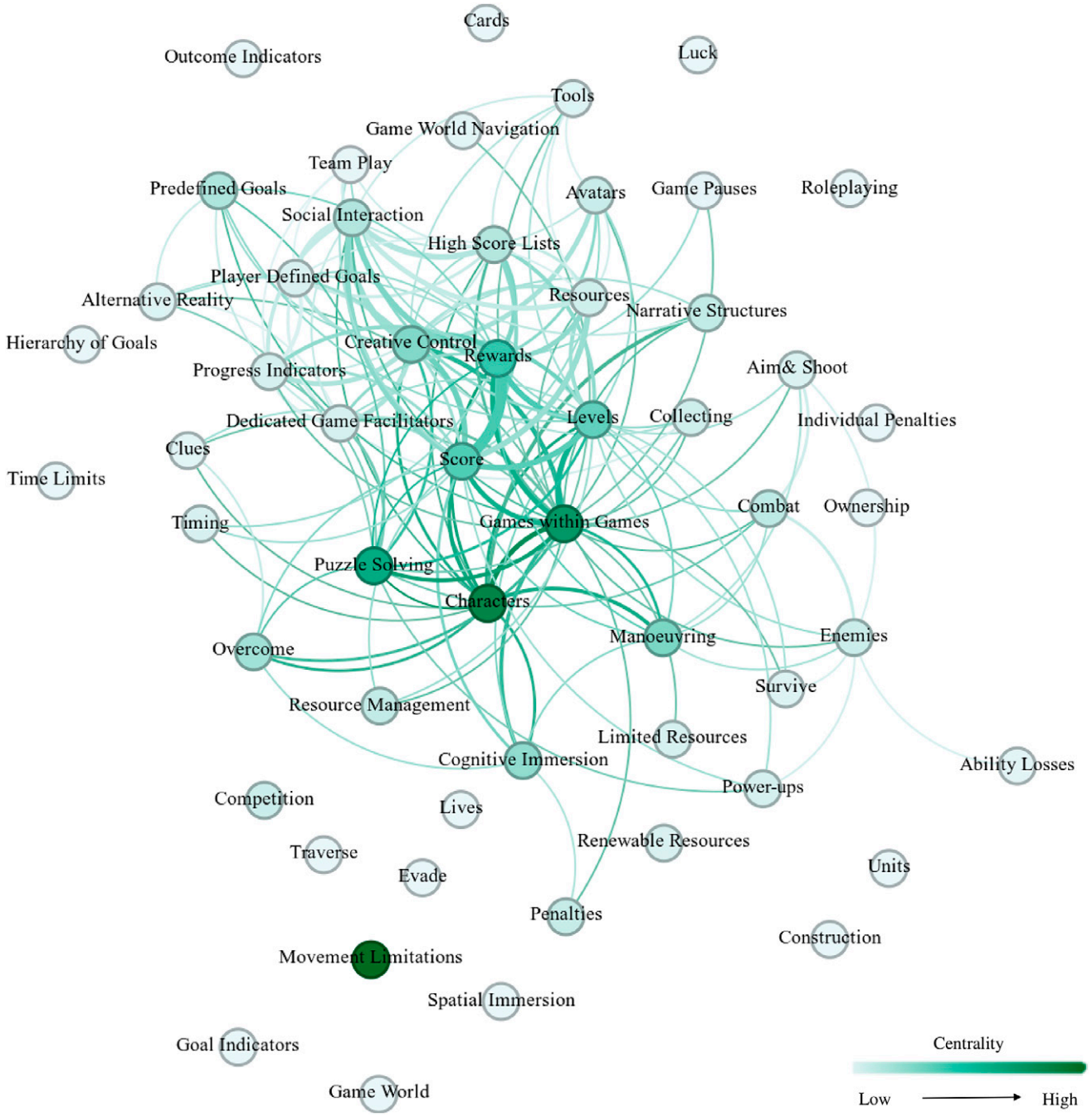

FIG. 4. Combinations of game mechanics. All nodes represent a game mechanic (see label). Links between nodes represent common use in a tool. The thickness of the links represents the frequency of co-occurrence (the thicker the link, the more often the connected game mechanics are used in the same tool). For readability, we chose to filter out links with a weight of only 1 (see Supplementary File S7 for the unfiltered network). The color of the node reflects betweenness centrality (the frequency of the node being on the shortest path between other nodes; the darker the node, the larger the dependency of other nodes). The high betweenness centrality of some game mechanics (e.g., *Games within Games, Puzzle Solving,* and *Characters*) reflects their frequent use in serious games, causing co-occurrence in tools with a large variety of other rare game mechanics (e.g., *Lives, Evade,* and *Units*). This is contrasted by the relatively low betweenness centrality of the common game mechanics Rewards and Social Interaction, illustrating their main occurrence in gamified tools.

interaction. For most of the tools (85%), a general rationale for utilizing gamification was provided, which often was to facilitate engaging experiences. A rationale for using specific game mechanics was less commonly provided (only for 45% of the game mechanics). Thus, future research should report the rationale for utilizing specific game mechanics in eHealth tools. The scarce experimental research available precludes testing the effectiveness of using gamification in the eHealth tools identified in the present review. The general rationale for gamifying and

Table 2. eHealth Tools with Gamification for Chronic Disease Self-Management in Youth and Their Rationale

Tool, chronic condition, country, year	*System, aim, and description*	*Rationale for gamification*
L'Affaire Birman, DM1, France, 2016[52]	Web-based serious game to educate on flexible insulin therapy. The player manages the DM1 of character "Alex" during a playful investigation.	None given
Anorexia nervosa companionship app, anorexia nervosa, France, 2021[47]	App, to evaluate and manage negative emotions and behaviors focused on weight loss, an unguided self-help program. Based on cognitive behavioral therapy it has the following modules: psychoeducation, symptoms management, and emotional evaluation.	Engagement for participation and behavioral change
Asthma self-management app, asthma, United States, 2017[44]	App, wireframes, to increase asthma self-management by providing information, logging medications, symptoms, and triggers, and sending notifications and alerts.	Engagement
ASTHMAXcel Adventures, Asthma, United States, 2020[75]	App, for smartphones and tablets on iOS and Android platform, to improve asthma control. It consists of short educational videos followed by games in which knowledge is tested.	• Engagement to retain users • User-friendly • Behavior change
ATOMIC, multiple sclerosis, Canada, 2022[36]	App, to promote physical activity in order to lower disease activity, perceived barriers, depression, and fatigue, as well as heighten self-efficacy and goal setting. Part of an intervention program. The app contains goal setting and facilitates social support through leader and discussion board, educational modules, and personalized feedback and coaching.	Reward, incentive
AYA STEPS, survivors of childhood cancer, United States, 2019[41]	App (Adolescent and Young Adult Self-management via Texting, Education, and Plans for Survivorship), to enhance health and well-being. It combines: • Delivery and storage of tailored text messages to support adjustment and health after treatment; • Digital survivorship care plans; • Applets for facilitating survivorship self-management.	Engagement
Bant, DM1, Canada, 2012,[62] 2017[56]	App, iPhone-based, connected to glucometer, aims to improve health outcomes by increasing self-care behavior and treatment adherence. It prompts participants to improve blood glucose trends by warning if trends are out of range, providing trending screens and decision support.	Engagement[62]
Bim, chronic kidney disease, Brazil, 2020[43]	App, for phones and tablets on Android platform, to improve adherence to medical nutritional instructions by encouraging users to take care of a character "Bim" with daily self-management (e.g., food and water intake, hygiene, use of medication, dialysis at home and hospital) to be used during hemodialysis.	[about games] • Effective for behavioral change; • Increase access to information on the disease
DEEP, attention deficit hyperactivity disorder and/or autism spectrum disorder, Netherlands, 2020[63]	Video reality biofeedback game, to cope with anxiety and as a result diminish disruptive classroom behavior (anxiety) by exploring an underwater fantasy world using the participant's own breathing (measured with a waist belt) to control their movement.	[about videogames] • Teach new strategies by their immersive emotional experience • Suitable for population with special needs • Motivate and engage children • Practice skills • Low cost

(*continued*)

Table 2. (Continued)

Tool, chronic condition, country, year	*System, aim, and description*	*Rationale for gamification*
Diabetes self-management platform, DM1, United States, 2013[45]	app, on Android platform, to increase diabetic self-management by recording key metrics per day. Social media component by 'friending' other users to track health progress of friend, comment on key metrics.	Engagement
Digital games (Adherence Warrior, Berry Match Game, Cat O'Polt), HIV, United States, 2018[60]	Videogames, to be played on videogame device, connected to medication dispenser aimed at improving adherence to medication and teaching players about the effect of HIV by getting rewarded in the game when opening the pillbox on time.	• Adherence • Interest of youth in electronics. • Effective for behavior change by making learning entertaining and by changing attitudes
Dojo, externalizing problems or anxiety, Netherlands, 2015[42]; 2016[71]	Videogame, helps youths to recognize and control their physiological and emotional arousal. It incorporates relaxation tutorials and the teaching of emotion regulation techniques. Players are provided with real-time biofeedback (heart rate), reinforcing the relaxation abilities and helping them to master the techniques. Controlling physiological reactions facilitates success in the game, which encourages the player to learn to recognize the association between emotional arousal and physical reactivity and to regulate physiological arousal more effectively as the game progresses.	• Learning by doing, suited for youth with intellectual disabilities[42] • Practice[42] • Engaging[42] • Training opportunity for emotions, electing behaviors[42] • Effectiveness[71]
FUN QUEST, childhood cancer survivors, Japan, 2022[38]	Game-based learning program on computer, to improve adherence to survivorship care. Role-playing game in which the main character is requested to answer health-related questions after which he/she receives advice from other characters.	[about games] • Accepted by youth • Simulation • Preference of learning of youth • Learning on own initiative • Engagement • Tailored to social and intellectual maturation • Pleasure • Incentive
Care & Organize Our Lifestyle (COOL) passport, congenital heart disease, 2021[50]	App, self-regulation-based mHealth program that provides information on health management and policies coupled with gameplay. It is combined with the Health Promotion cloud, a Web-based interactive platform that facilitates communication between users, shows health promotion messages. The overall goal of the interventions is increasing disease knowledge and physical activity.	
Home Telecare for monitoring CF, Australia, 2005[72]	Computer-based measurement module/spirometer/ measurement device connected to a computer, to monitor long function of patients with cystic fibrosis from home. It guides patients through conducting the measurements and gives instant feedback (represented by a boat race). Includes symptom diary.	Incentive
iManage, sickle cell disease, Canada, 2017[65]; United States, 2021[39]	App, accessible through smartphone and tablet, adjunct to a group intervention to increase self-management and self-efficacy. Functionalities: • Track daily pain and mood • Create, monitor, and complete self-management goals • See progress of others	None given

(*continued*)

Table 2. (Continued)

Tool, chronic condition, country, year	*System, aim, and description*	*Rationale for gamification*
JIApp, juvenile idiopathic arthritis, United Kingdom, 2017[61]	App, on smartphone, to monitor disease activity and side effects and support self-management (treatment adherence and engagement in health promoting behaviors). Functionalities: • Provide general information • Monitor symptoms, thoughts, and feelings • Diary section for questions to ask in consultation • Remind for treatment adherence	Reward
Kiss MyAsthma, asthma, Australia, 2018[67]; 2021[58]	A goal-setting app, on smartphone (cross-platform), to improve asthma self-management. Eight sections, including asthma history, goals, inspirations, reminder, and information.	Engagement[67]
Mobile Asthma Action Plan (AAP), asthma, United States, 2015[73]	App, for smartphone on iOS or Android platform, to support asthma control by daily prompts to symptoms or peak flow measurements and reminders for taking medication. Feedback consists of positive messaging or follow-up actions.	None given
MOST+, Mental health condition, Australia, 2017[66]; 2020[64]	Enhanced Moderated Online Social Therapy, Web-based, aims to increase mental health. It is a merge of interactive web therapy, peer-to-peer Web-based social networking, peer and clinical moderation, and on demand web chat with registered clinicians.	• Engagement[66] • Behavioral change[66]
MyPainPal, chronic pain, Australia, 2021[59]	App, cloud-based (cross-platform Web- and mobile-based), to support chronic pain self-management. Functionalities: • Self-monitoring diary and calendar • Goal setting • Tips and strategies • Social	Engagement
MyREADY Transition BBD, brain-based disabilities, Canada, 2021[57]	App, to educate and empower for transition from pediatric to adult care. Journey in the city with a virtual coach that helps to navigate through buildings and introduces educational sections.	Engagement
MyT1DHero, DM1, United States, 2017[69], 2021[55]	App, to facilitate diabetes-specific positive parent-adolescent communication and improve diabetes-related outcomes. It links an adolescent and their parent through 2 separate app interfaces and prompts adolescents to test blood glucose. Informs on how to address out-of-range blood glucose values.	• Engagement[55] • Effectiveness[55]
Pain Squad+, Cancer, Canada, 2017[53]	App, Web-based smartphone application, to give real-time pain support by giving self-management advice based on reported pain. Users play the role of law-enforcement officers investigating pain cases.	None given
PERGAMON, DM1, Netherlands, 2018[51]	Educational gaming and coaching platform that consists of a website, mobile app, and sensor device. It combines games with a virtual coach to enhance self-management. It consists of the main adventure and puzzle game "Mystery of TikoTako" and seven mini-games. Users complete in-game and real-world goals related to monitoring blood glucose levels, acquiring skills and knowledge, and social activities.	• Adherence • Reward

(*continued*)

Table 2. (Continued)

Tool, chronic condition, country, year	*System, aim, and description*	*Rationale for gamification*
Power Defense, DM1, Canada, 2011[35]	Videogame, to improve diabetes numeracy skills by controlling a power base station, symbolic for someone with DM1, training skills mainly implicitly. The player has to balance the amount of energy under challenging circumstances.	Interactivity of learning environment
Reactivate, obesity, Ireland, 2014[46]	App, on android smartphone, as a remote treatment aid, consisting of self-monitoring, goal setting, rewards system, and peer support. It has tips for weight management (text, video, image) and encourages to engage in daily goal setting and goal review.	Behavioral change
RAGE-Control, anger dyscontrol, Germany, 2021[40]	Videogame, coupled to a heart rate monitor, to train emotional regulation by practicing modulation of physiological arousal during a challenging task. In the game players maneuver a spaceship and fire at enemy spaceships. Firing is disabled when heart rate increases above a threshold.	• Engagement, motivation, challenge • Train emotional regulation skills • Efficacy
SPARX, mild to moderate depression, New Zealand, 2012[48]; The Netherlands, 2016[70]; New Zealand, 2021[68]	Interactive fantasy game on CD-ROM for the treatment of depression by delivering cognitive behavioral therapy in seven modules. A self-chosen avatar undertakes challenges to restore the balance in a fantasy world. A computerized guide opens and ends every module to put game into real-life perspective and give homework challenges.	• Adherence[48] • Learning[68] • Behavioral change[68] • Engagement[68] • Effective[68]
T1D, DM1, United Kingdom, 2017[49]	App, on iOS platform, to increase disease knowledge and medication adherence. It has links to relevant websites, an educational game situated in the pancreas, and an avatar.	Engagement
TEENCOPE, DM1, United States, 2014[54]	Web-based psychoeducational intervention, to train coping skills. Interactive lessons, tailored computer-generated feedback based upon user responses, video animations, and the ability for users to interact with each other using a discussion board and profile viewing.	None given
WebMAP Mobile, chronic pain, United States, 2020[37]	App, on Android and iOS platform, to learn pain self-management skills, combined with parent program through website. Interactive, self-guided app with four components: • Treatment modules • Skills library (audio clips, videos of peers, infographics) • Daily check-in (record and track pain, sleep, activity, mood) • Skills tracker (record and track skills practice)	• Engagement • Encourage skills practice

Additional information on implemented game mechanics was found with Google search for the following tools: L'Affaire Birman, MyREADY Transition BBD, and Pain Squat+ (S6). CF, cystic fibrosis; DM1, diabetes mellitus type 1.

the rationale for using specific game mechanics identified in this review may inform priorities for testing their effectiveness in future experimental research.

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Authors' Contributions

M.D.S.: search, study selection, data extraction, writing, visualization, and project administration. L.L.: conceptualization, methodology, search, study selection, data extraction, and writing. M.M.H.: conceptualization, data extraction, and review. J.v't.V.: conceptualization and review. V.T.V.: conceptualization and review. W.M.B.: conceptualization, methodology, and review. M.H.J.H.: conceptualization, review, and project administration. R.C.V.: conceptualization and review. S.L.N.: conceptualization, review, and project administration. F.E.-L.: conceptualization, methodology, writing,

Table 3. Rationale for the Use of Specific Game Mechanics

Game mechanic	*Reported rationale for use*	*Tool*
Rewards	Engagement	Asthma self-management app,[44] JIApp,[61] WebMAP Mobile[37]
	Incentive	Asthma self-management app,[44] AYA STEPS[41]
	Incentive to increase medication adherence	Cat O'Polt[60]
	Pleasure as incentive to exercise more frequently	COOL Passport[50]
	Encourage self-management behavior	Bant[56,62]
	Encourage skills practice	WebMAP Mobile[37]
	Rewards system as behavioral change tool	Reactivate[46]
	Enjoyment	JIApp[61]
Score	Engagement, incentive	AYA STEPS[41]
	Encourage self-management behavior	Bant[56,62]
	Learn to understand health needs	Bim[43]
	Appealing to younger users	JIApp[61]
Creative control	Incentive, reward	ATOMIC[36]
	Empowerment	PERGAMON[51]
	Create personal connection	T1D[49]
	Wish of respondents to personalize	AYA STEPS[41]
Social interaction	Social support	ATOMIC,[36] MOST+,[64] MyPainPal[59]
	Peer support as behavioral change tool	Reactivate[46]
	Encourage self-disclosure	MyT1DHero[69]
	Learn from each other	TEENCOPE[54]
	Facilitate peer comparison in the self-judgment dimension	COOL Passport[50]
	Motivate other user for self-management	Diabetes self-management platform[45]
	Outcome Expectations, self-efficacy	ATOMIC[36]
	Empowerment	PERGAMON[51]
	Engagement	MyPainPal[59]
	Adherence, elicit positive health behavior	Bant[62]
Games within games	Enhance learning	ASTHMAXcel Adventures,[75] Power Defense[35]
	Trigger emotion to provide the opportunity to practice acquired techniques	Dojo[42]
	Teach and test knowledge needed for disease self-management	PERGAMON[51]
	Stimulate motor coordination and memory	Bim[43]
	Engagement, incentive	Asthma self-management app[44]
	Interest participants	COOL Passport[50]
	Encourage exploration of the app	MyREADY Transition BBD
Levels	Frequent rewards	Bant[62]
	Pleasure as incentive to exercise more frequently	COOL Passport[50]
Resources	Incentive	ATOMIC[36]
	Incentive to increase medication adherence	Berry Match[60]
	Pleasure as incentive to exercise more frequently	COOL Passport[50]
	Enjoyment	JIApp[61]
	Reward	ATOMIC[36]
Characters	Making therapeutic concepts more accessible, engaging, and compelling	MOST+[64]
	Learn through virtual experiences	FUN QUEST[38]
Avatars	Incentive	Asthma self-management app,[44] ATOMIC[36]
	Engagement	Asthma self-management app[44]
	Reward	ATOMIC[36]
	Learn through virtual experiences	FUN QUEST[38]
	Personal and interactive experience	T1D[38]
Dedicated game facilitators	Engagement, novelty	Kiss MyAsthma[67]
	Game into context, provide education	SPARX[48]
High score lists	Encourage behavior change	ASTHMAXcel Adventures,[75] COOL Passport[50]
	Paradigm to emulate, promote peer interaction	COOL Passport[50]
	Social support, vicarious learning	ATOMIC[36]
	Social comparison	Reactivate[46]

(*continued*)

Table 3. (Continued)

Game mechanic	*Reported rationale for use*	*Tool*
Player-defined goals	Address motivation and confidence to change behavior, effectiveness, relevance	Kiss MyAsthma[67]
	Goal setting as behavioral change tool, to stimulate practice and action planning, to act on antecedents	Reactivate[46]
	Self-efficacy	ATOMIC[36]
	Need of young people	MyPainPal
Progress indicators	Self-monitoring as behavioral change tool, feedback on progress	Reactivate
Puzzle solving	Discover and use CBT knowledge	SPARX[68]
	Teach and test knowledge needed for disease self-management, repetition of playing the game to make best-practice behavior one's own	PERGAMON[51]
	Evoke emotions to use newly acquired emotion regulation strategies	Dojo[71]
Cognitive immersion	Encourage memory	Bim[43]
Maneuvering	Stimulate motor coordination	Bim[43]
	Reinforce the practical use of the relaxation techniques	Dojo[42]
	Creating physiological arousal	RAGE-Control[40]
Narrative structures	Nonthreatening, easy to understand, making therapeutic concepts more accessible, engaging, and compelling	MOST+[64]
	Learn through virtual experiences	FUN QUEST[38]
Collecting	Metaphor for collecting positive thoughts	SPARX[68]
Combat	Creating physiological arousal	RAGE-Control[40]
Enemies	Analog to real-life DM1 management	Power Defense[35]
	Creating physiological arousal	RAGE-Control[40]
Overcome	Reinforce the practical use of the relaxation techniques	Dojo[42]
Power-ups	Incentive to increase medication adherence	Berry Match[60]
Team play	Desire for social interaction	iManage[65]
	Peer support as behavioral change tool	Reactivate[46]
Tools	Incentive, reward	ATOMIC[36]
Ability losses	Analog to real-life DM2 management	Power Defense[35]
	Penalty for not downregulating physiological arousal	RAGE-Control[40]
Movement limitations	Effective for regulating anxiety	DEEP[63]
	Reinforce the practical use of the relaxation techniques	Dojo[42]
Outcome indicators	Incentive	Home Telecare for monitoring CF[72]
	Instruction	Mobile Asthma Action Plan (AAP)[73]
Penalties	Reinforce the practical use of the relaxation techniques	Dojo[42]
Renewable resources	Incentive to increase medication adherence	Adherence Warrior,[60] Cat O'Polt[60]
Resource management	Representation to implicitly train numeracy skills, analog to real-life DM2 management	Power Defense[35]
	Teach and test knowledge needed for disease self-management	PERGAMON[51]
Cards	Exercise (personal strengths to increase psychological well-being)	MOST+[64]
Competition	Increase motivation for self-management tasks	iManage[65]
Contest	Reinforce the practical use of the relaxation techniques	Dojo[42]
Evade	Reinforce the practical use of the relaxation techniques	Dojo[42]
Game pauses	Support learning process of young people, time to engage in practice activities	MyREADY Transition BBD[57]
	Novelty	COOL Passport[50]
Goal indicators	Feedback on breathing	DEEP[63]
Role-playing	Learn through virtual experiences	FUN QUEST[38]

(*continued*)

Table 3. (Continued)

Game mechanic	*Reported rationale for use*	*Tool*
Time limits	Teach and test knowledge needed for disease self-management	PERGAMON[51]
Traverse	Reinforce the practical use of the relaxation techniques	Dojo[42]

Rationales are summarised. For detailed rationales extracted directly from the included studies, see Supplementary File S3.

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Supplementary Material

Supplementary File S1
Supplementary File S2
Supplementary File S3
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Supplementary File S7
Supplementary File S8

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