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# Gamified Health: A Systematic Review of Digital Programs that Attempt to Encourage Positive Health Behaviors

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## ABSTRACT

***Background**: Past research has found that gamification, the process of adding games or game-like elements to a task to encourage participation, can enhance the efficacy of digital health interventions. However, the various components of gamification have yet to be systematically compared to determine which, if any, produce the greatest results.*

***Objective**: For-profit game developers have successfully used gamification to promote learning and drive business. This paper first reviews the literature on gamification from the for-profit gaming industry and from health research in order to identify components of gamification with potential applications in digital health interventions. Existing health interventions utilizing gamification are then examined in order to describe current practices and identify common characteristics of successful programs.*

***Methods**: Randomized control trials utilizing gamification reward elements were analyzed to determine the success, as well as utilization, of known practices from for-profit industries.*

***Results**: While interventions were successful in promoting health change, several important components of gamification were not included, and inconsistent data reporting limits conclusions.*

***Conclusion**: Further research is required to establish the efficacy and relative value of different gamification components and determine best practices in digital health interventions.*

## Keywords
Games, Electronic Devices, Health Behaviors, Addiction.

## Introduction
Technology adoption, especially of tablets and smartphones, has seen a substantial increase over the past 5 years. For example, from 2010 to 2015 smartphone ownership among adults nearly doubled from 35% to 68%, while tablet ownership increased from 3% to 45% [1]. These numbers are even more remarkable among younger Americans; 86% of adults between the ages of 18-29, and 83% between 30-49, own a smartphone [1].

This proliferation of electronic devices presents novel opportunities to deliver health information and interventions. For instance, a 2015 consumer report found that 80% of adult Americans have tried at least one digital health platform during the past year, including mobile health tracking, online health information (i.e. WebMD), and telemedicine services, with 17% of respondents reporting that they currently use a mobile application to track health data such as physical activity and heart rate [2]. Interestingly, adoption of health platforms was found to be comparable across age, sex/gender, education and income levels.

Reviews of health interventions have found that media delivered through digital platforms can assist with the management of diabetes, cystic fibrosis, and asthma, improve psychological therapy and physical activity outcomes, and improve health education outcomes [For a review see: 3, 4].

Lessons learned from the for-profit gaming industry may provide a lens through which to better understand the success and failures of digital health interventions. Gamification, in particular, provides both explanations for programmatic outcomes as well avenues for future research.

## Gamification

Gamification, sometimes called serious games, advergaming, and games-for-change, is the process of adding games or game-like elements to a task to encourage participation [5-7]. There is, however, an important distinction between simply using a game to change behavior and adding gamification elements to an intervention. Specifically, games can be thought of as the core mechanic (e.g. saving the princess, winning the race, teaching an exercise), while gamification is the use of gaming principles in a structured process to influence behavior. Whereas the main goal of games is to entertain, the primary goal of gamification is to motivate players to accomplish predefined tasks [8].

A common structure for examining gamification is known as the Mechanics, Dynamics, and Aesthetics (MDA) Framework [9]. Mechanics involve the components of the game that guide user behaviors, including things like leaderboards, external rewards, and feedback loops [10,11]. Dynamics is the consideration of how users interact with the mechanical components of the game, examining users' behaviors in relation to the intention of the mechanics. Aesthetics refer to how the program makes participants feel during use. In other words, did the mechanics and dynamics produce a meaningful response from users (i.e. positive or negative emotions). Interestingly, industry research has suggested that game mechanics, and not general aesthetics, are what make programs fun and engaging for users [9]. This is a critical concern for health interventionists, as while dynamics and aesthetics may be an intuitive area to focus on when designing digital health interventions, the often less well understood game mechanics may be more critical for programmatic success.

Together the three dimensions of the MDA Framework provide an overview of the assets necessary for effective gamification. However, successful deployment of these assets in health interventions also depends on an understanding the reward pathway and learning theories as the theoretical underpinnings of gamification.

## Gamification and the Reward Pathway

Theoretically, interventions utilizing gamification enhance participants' motivation primarily through activation of the reward pathway. This pathway has evolved over time to regulate behavior through the core structures of the ventral tegmental area (VTA), nucleus accumbens (NA) and several interconnected secondary systems [12-14]. Together, these structures influence reward-mediated behaviors through the release and reuptake of neurotransmitters and underlie several theories of motivation.

For example, as the origin of dopamine producing cells, the VTA is widely implicated in reward, motivation, and drug addiction processes [14,15]. It contains neurons that span the brain, extending from the limbic system to the prefrontal cortex. These neurons respond to novel stimuli and unexpected rewards and reward predictive sensory cues [16,17]. The NA, in turn, is a subregion of the striatum that plays a central role in reinforcement, motivation, and reward [18-20]. In addition to these structures, a tapestry of secondary systems connected to the VTA, including the ventral pallidum, hypothalamus, and amygdala, also influences the reward pathway. For example, the ventral pallidum is highly active during rewarding activities and is involved in the regulation of emotion and motivation [21].

Considered through the lens of the MDA Framework, the reward pathway suggests that digital health interventions focusing on intrinsically rewarding game mechanics can activate participants' reward pathways, even when the health behavior being targeted is not rewarding in and of itself [22-25]. When examined alongside literature on learning theories, several specific opportunities to employ gamification emerge.

## Gamification and Learning Theory

Several learning theories further explain reward-mediated behaviors [26,27]. Broadly, these theories can be organized based on their examination of cognitive versus associative processes. Cognitive learning mechanisms focus on conscious efforts to acquire new information [28], use this information to predict future events, and then develop goal-directed plans [27]. These processes are regulated by deliberation and based on actions' expected outcomes [29].

Associative learning processes, on the other hand, are based on implicitly linking concepts (e.g. actions, places, people) to a stimulus or cue and can take place without any conscious introspection, self-reflection, or causal attribution [26]. For example, investigations with amnesic populations have demonstrated that learned associations function independently of explicit memory [30-34]. While this linking is unconscious, it is most likely to occur when stimuli are predictive of reward [35]; that is, stimuli gain associative strength only after repeated pairings with rewards, eventually influencing behaviors independently of the reward itself [12, 36-43].

Illustrations of associative learning's role in health include studies of substance use, food consumption, and sex, among others [39,44-46]. For example, among substance users, associative learning explains how environmental stimuli can trigger drug use and relapse. After repeated pairings of environment and substance use, environments can induce expectations of drug availability and past drug euphoria without need for any deliberate recollection [47,48]. These expectations activate brain reward mechanisms, prompting the individual to ultimately engage in the rewarding behavior (i.e. drug use) [26].

Relevant to health intervention design, research indicates that once behaviors are paired with rewarding stimuli, a feedback loop may occur where getting rewarded becomes a behavioral goal, and goal attainment becomes intrinsically rewarding [22,24,49]. Stimulus-response theories suggests that behaviors developed in this manner may eventually become habits, behaviors performed somewhat independently of a goal [50,51]. In situations where health behaviors are viewed as not intrinsically motivating, reward-based gamification could help participants in their early attempts at behavior change and could support the development of healthier habits [8].

## Gamification and Health Intervention

Informed by research into the reward pathway and learning theories, gamification offers several concrete suggestions for elements to include in digital health interventions. These components can be grouped broadly into those related to providing feedback, those related to social influence, and those related to adaptive difficulty. While utilizing gamification in health interventions remains a novel approach, with limited formal evaluation [52], early evidence suggests the benefits are manifold.

### *Gamification and Health Intervention:* Feedback Loops: Points, Levels, Badges

In commercial software, developers deploy feedback systems based on goals (e.g. earning points, achievements, etc) to elicit desired behaviors and maintain excitement with their products [9]. Similarly, within health literature, goal setting has been found to improve performance across a range of health-related behaviors among diverse populations [53-57].

The most common feedback mechanisms used in software development are Points, Badges, Levels, and Leaderboards (PBLLs). These are akin to the tokens (i.e. coins, tickets) awarded in token economy systems [58-60], which have proven successful in reinforcing on-task behavior, reducing disruptive classroom behavior, and improving social skills of youth with emotional problems [61,62].

## Points

As a measure of users' accomplishments, points form the groundwork of many games, serve as a primary feedback metric in gamified interventions, and define a users' progress. The benefits of these systems are immediate; providing users with feedback in the form of points and sub-goals may allow participants in health interventions to focus on progress towards health goals rather than evaluating their success as a simple dichotomous "win" or "loss" [23,57,63].

Since a single long-term outcome in health interventions (e.g. losing 15 pounds) may not be enough to fully engage and motivate users, points can be assigned for a wide range of accomplishments (e.g. number of steps walked, number of calories consumed, etc) to form feedback-loops providing frequent activation of the reward pathway. Frequent feedback is important, as the length and frequency of feedback-loops is known to affect consumer participation and satisfaction [9]. When feedback is infrequent, tasks can become arduous. Alternatively, too frequent feedback can make tasks feel trivial or overwhelm participants [9].

Points-based feedback provides additional benefits, such as allowing participants to build on successes and to modify their behaviors in an ongoing manner [57]. Similarly, providing players a points-based assessment of their growing mastery may keep them playing longer than they initially intended [64]. In addition, providing automatic, instantaneous visual feedback regarding progress towards goals can encourage adherence to interventions without the need for any direct action from the interventionist.

Several distinct types of points exist (experience points, skill points, redeemable points), and each can be used in an intervention to allow tracking of user achievement and progress.

### *Points: Experience*

The most basic level of points are experience points, which document the player's progress through both mundane tasks and higher level challenges. Unlike in traditional token economies, experience points cannot be traded for goods or services in the real or virtual world. However, studies have found that experience points, while having no tangible value, often set larger goals for the player to achieve [65], even though they may not be consciously perceived as rewarding by the player [66]. This aligns with previous findings that rewards can increase performance on cognitive tasks, regardless of whether participants are consciously aware of the goals they pursue [66].

### *Points: Skill*

Skill points are similar to experience points, but they allow the player to gain specialized achievements and rewards alongside the core mechanic. Skill points are typically used as a bonus system, allowing the player to customize their experience by utilizing extra developer designed challenges. Skill points are typically automatically redeemed for a token reward after a specific number have been accumulated.

### *Points: Redeemable*

Redeemable points form the foundation of virtual economies, where points are exchanged for virtual or physical goods. In modern games, redeemable points can often be earned in-game or purchased with real money. These are analogous to practices in the credit card and airline industries where customers accumulate 'frequent flyer miles' or 'cash back rewards' for purchases made under a customer loyalty reward system.

For example, in a digital support group redeemable points might be exchanged by participants to purchase unique, customizable avatars or accessories (e.g. clothing). Patients could accumulate redeemable points through specific activities in the platform. The more active they are (or the more components of the intervention they complete), the more redeemable points they would accumulate. The downside to this method is that once all possible rewards are acquired, motivation to continue with the program may be lost. As a result, this mechanism may be best suited to short term interventions where motivation to begin a task is low, as opposed to interventions focusing on long term behavior change [8].

***Levels***

Levels are markers that give participants a sense of scale regarding where they stand in the game experience. Levels include demarcations of percentage completed and milestone markers for mastery of skill. This is analogous to the colored belts awarded in martial arts; novices start off with white belts, but as they master new skills, different colored belts are awarded. Each belt serves as a progress bar, a clear indication of where martial artists stand and how much further they have to go. Zichermann and colleagues [67] suggest good progress bars never reach 100%; the journey to mastery of a skill or concept should never end.

***Badges***

Badges are similar to levels but function as a more visual identifier of user skill level and progress, often within multiplayer systems emphasizing social comparison. While level attainment focuses on sequential attainment of levels of greater value, badges incorporate a more collection-based approach (i.e. goal is to collect as many badges as possible). For example, the merit badge awards used in the Boy Scouts of America represent awards for skill or knowledge; the more badges collected, the higher the rank of the scout is. In gamification, badges are used similarly to visualize achievement. For instance, in an online support group badges could reflect a variety of achievements such as months in the group, number of posts, or acknowledgment of referrals.

### *Gamification and Health Intervention:* Social Networks

Research suggests that incorporating social networks into health interventions can be beneficial. For example in a study of physical activity among nurses in the UK, allowing participants to view and comment on each other's step data online was positively associated with physical activity [68].

Generally, there are two forms of social networking used in commercial games: engagement between users through in-game mechanics (e.g. leaderboards, shared goals, shared gameplay) and engagement in external social spaces (e.g. forums, discussion boards, user profiles) [8]. Gamified interventions can employ both social networking systems; however there are potential pitfalls that must be considered. For instance, while leaderboard systems can inspire those at the top [8], they run the risk of demotivating those at the bottom and discouraging engagement [10].

Fortunately, two common leaderboard formats, non-disincentive and infinite leaderboards, help to minimize potential demotivation. Non-disincentive leaderboards rank new players in the middle of the leaderboard rather than at the bottom. This approach gives new players a cohort of rivals to compete against while also ensuring that there's a cohort of rivals below them to incentivize maintaining their "lead" [9]. The infinite leaderboard, in contrast, groups and ranks users in smaller cohorts, as opposed to against all users. For example, an intervention could display a player's ranking on different leaderboards such as local users (e.g. city, classroom), social network users (e.g. friends, family), and even global users [9]. This approach deploys multiple sources of motivation, such as competiveness with friends, pride in one's classroom, etc.

Another approach to motivating behaviors through social networks is creating parallel systems for participants to compete against themselves and others. For example, Nike Plus, a commercial gamification application, includes both 'single player' and 'multi-player' experiences [9]. In single player, the app automatically posts about the user's exercise behaviors on their social media. Each time a friend "likes" the post, the app plays the sound of a roaring crowd, letting the user know of their friends' support and creating a positive feed-back loop [9]. This approach capitalizes on research into goal commitment, which suggests that public spaces displaying one's progress toward goals can enhance personal commitment [69].

The 'multi-player' experience targets competitive players by allowing users to challenge friends and players around the world to complete milestone events, or to play a game of tag where failure to complete a challenge/goal makes the person 'it' [9].

### *Gamification and Health Intervention:* Adaptive Difficulty

While research suggests that challenges should be moderately difficult, health interventions commonly deploy a single, standardized difficulty setting that fails to take into account participants' talent levels [70]. While using a single difficulty level makes developing digital health interventions easier, it risks driving away participants who find the goals too easy or too hard to complete. When goals are too hard, task performance and self-efficacy decline, and progress toward the goal becomes unrewarding [63].

To address this issue, commercial games typically employ adaptive difficulty in which the difficulty of tasks increases as players make progress through the game. A common approach is to deploy hierarchical levels. As players progress through levels within a game, they are presented with progressively more challenging tasks. Alternately, in some games difficulty is matched to players' performance to provide a consistently challenging experience.

Regardless of the exact mechanism chosen to modify difficulty, the inclusion of points, levels, and/or badges in gamified health interventions should provide opportunities to challenge participants to demonstrate progressively higher skills and knowledge.

### Overview

While previous reviews of health interventions employing games and gamification have found primarily positive results [3], the terms "games" and "gamification" have often been used interchangeably, with minimal distinction between interventions using games to facilitate behavior change (i.e. peddling a bicycle while playing a race game) and interventions using gamification mechanics to facilitate learning and reproduction of behavior. Further, the specific components of gamification (i.e. points, social networks, etc) have not been rigorously compared, limiting any discussion of best practices for health interventions or the relative impact of different gamification elements. Given the cost and difficulty of developing high-quality gamified digital health interventions, data on each component's relative value is needed in order to address such applied considerations as, "Do we really need this intervention to link with social media?" or, "Do we need to create a way for players to communicate in the game, or will external message boards be enough?"

The present review focuses on identifying and evaluating public health interventions that utilized gamified interventions to modify health behaviors. Specifically, based on research in cognition, basic neuroscience, and game development, this review aims to determine what elements would potentially work in translating gamification into a successful health intervention. However, many questions about practice still remain. Past interventions have utilized video games in an effort to change behavior [3].

However, these interventions, many of which possibly contained gamification elements, did not explicitly state the difference between gamifying an intervention or simply using a game to change behavior. While interventions were well researched, they unfortunately rarely discussed or acknowledged potential underlying mechanics of their success. The possibility exists that the mechanics common to a variety of digital interventions engage a neurological reward system that could have been, in part, responsible for the behavior change observed. Further, the concepts of reward, gamification and incentives are ill-defined, and these components are not necessarily measured to determine what has the greatest effect on behavior. As the field moves forward, it is important to catalog these mechanics and begin to identify best practices for any future programs that wish to implement a gamified intervention.

## Methods

### Selection Criteria

For inclusion in this review, studies had to 1) be a Randomized Control Trial (RCT), 2) have an intervention that utilized a digital gamification-based mechanism including a reward feedback system, 3) measure a health outcome, and 4) be published in English. Inclusion was not limited by sample size, publication date, or sample demographics. While past reviews [3] only included interventions that met the definition of 'video games,' for the purposes of this review, a gamified intervention was defined as one that included any incentivized reward. Studies were excluded from analysis if they simply used a video game to change behavior without a behavior education component. This study was restricted to RCTs, as they are generally considered to be the most rigorous way of determining whether a causal relationship exists between treatment and outcome [54].

### Literature Search

A systematic search in Pubmed, Google Scholar, and Web of Science was performed during the Spring of 2016 to compile relevant studies. The search terms used included the words "gamification", "mHealth", "digital health", "health intervention", "behavior change" and "RCT." The search terms were used separately and together.

Initial searches were conducted between May and August 2016, with a final updated search conducted in November 2016. The search terms chosen were designed to focus on electronic gamification systems, as general searches using broader keywords [3] such as 'video game' yielded interventions that used games to change behavior but did not include gamification elements. Two researchers reviewed retrieved literature to identify articles that met inclusion criteria. A third researcher then analyzed articles that met inclusion criteria to verify that they were appropriate for analysis.

The search criteria yielded a total of 326 articles. Of these, 17 met inclusion criteria. The most common reasons for exclusion were: lack of gamification principles applied to the intervention (i.e. rewards, feedback); study was not a randomized control trial; or the intervention was not on a digital platform.

### Data Review

This review analyzed all true experimental (or RCT) interventions that used gamified systems to modify one or more health behaviors. Authors cataloged the studies' population demographics, purpose, and reported outcomes (Appendix A). The game mechanics that may have contributed to these outcomes were organized and recorded as learning mechanics (Table 1), social mechanics (Table 2), and reward mechanics (Tables 3 & 4).

This review analyzed studies' primary outcomes as well as the means in which the outcomes were obtained. Analysis attempted to determine if software gamification standards were used (i.e. if studies made distinctions between types of reward used, implemented social networking materials appropriately, etc) and if their methodology was designed to create rewarding experiences consistent with the literature on the reward pathway.

## Results

Seventeen interventions fit the previously described inclusion criteria and were included for analysis. However, only 16 interventions (94.12%) reported sufficient participant usage statistics (e.g. amount of time spent on application, number of unique logins, number of trials completed) for inclusion and analysis.

### Study Characteristics

Appendix A examines the included studies' demographics, including sex/gender, age, ethnicity, length of intervention, length of follow-up, attrition rate, theory used, and health outcome measured.

Among the 16 interventions that fit inclusion criteria and included sufficient data for analysis, 13 (81.25%) used a validated public health theory. Of these 13, the most common theory reported was social cognitive theory, which was used by 6 interventions (46.15%). Five interventions (31.25%) lasted less than a month, 5 (31.25%) lasted between 1-2 months, and 6 (37.50%) lasted for 3+ months. Nine interventions (56.25%) included only an immediate post-intervention assessment to document behavior/attitude changes, with the other studies including assessments ranging from two weeks to three months post-intervention. Attrition rates varied widely; 12 (75.00%) studies had attrition rates below 25%, 2 (12.50%) lost between 25%-50% of participants, 1 (6.25%) had an attrition rate above 50%, and 1 (6.25%) did not report attrition rates.

However, there was little consistency in the usage metrics reported. Five studies (31.25%) reported mean number of logins per individual, and 4 (25.00%) reported the average time spent accessing the intervention. Three interventions (18.75%) reported 'number of trials completed' or 'number of page views' without any other descriptors. Two studies (12.50%) reported other metrics (e.g. % of participants who logged in at least once for more than 1 minute), and the final two (12.50%) did not report any usage statistics. These categories were all mutually exclusive; for example, no study reported on both number of logins and time spent utilizing content.

## Gamification

The gamification characteristics assessed include learning mechanics (Table 1), player social mechanics (Table 2), and reward mechanics (Tables 3 & 4).

Learning mechanics included creating commitment to the goal, increasing difficulty, self-efficacy training, and feedback. All sixteen interventions created commitment to keeping goals by detailing the importance of the health behaviors promoted (e.g. stating the importance of regular activity). Eight interventions (50.00%) included an adaptive difficulty design paradigm, with 6 (37.50%) utilizing progressively more challenging levels and 2 (12.50%) responding to players' performance. The remaining 8 (50.00%) used only a single universal difficulty level. All sixteen studies explicitly fostered self-efficacy through the inclusion of informative webpages, interviews with patients and doctors, video demonstrations, feedback from a health coach, and/or peer discussions.

Only 9 (56.25%) of the interventions reviewed included multiplayer options, with 8 of the 9 (88.89%) encouraging player interaction through cooperative or competitive play elements (Table 2). Mechanisms for communication between players were not provided in any of the 7 single-player interventions, while 6 of the 9 multiplayer interventions (66.67%) included one or more tools for player communication.

## Reward

Reward Mechanics (Tables 3 and 4) were incorporated into all 16 studies with feedback primarily offered through experience (n = 15, 93.75%) and skill (n = 8, 50.00%) points. The conditions triggering feedback varied, with 9 of the studies (56.25%) providing rewards based on game usage only (e.g. completion of a level, reading a webpage, posting on a message board). Nine interventions (56.25%) utilized a point-based system as a type of reward; 1 (6.25%) used specialty icons (stars), 1 (6.25%) used steps, and 1 (6.25%) used an unspecified reward. Among these interventions, 4 (25.00%) awarded participants for the completion of a specific action, and 13 (81.25%) awarded participants for the completion of specific, pre-defined tasks.

No interventions specified if points were separated by type, if a maximum could be reached, or what, if any, outcomes resulted from point accumulation.

[a]Includes awarding points and cataloging accomplishments.
[b]Includes annoying audio.

| | Objectives Defined By | | Training Instruction | | | Progressive Training Based On | |
|---|---|---|---|---|---|---|---|
| Ref | Game Designer | Player | Written | Video | In-game Interactive | Hierarchical Levels | Player Performance |
| 71 | X | | X | | | | |
| 72 | X | | X | X | | | |
| 73 | X | | | | X | X | |
| 74 | X | | | | X | X | |
| 75 | X | | | | X | X | |
| 76 | X | | X | | | | |
| 77 | X | X | | | X | X | |
| 78 | X | X | X | X | | | X |
| 79 | X | | | | X | X | |
| 80 | X | X | X | | | | |
| 81 | X | | X | | | | |
| 82 | X | | | | X | X | |
| 83 | X | | X | | | | |
| 84 | | X | X | | | | X |
| 85 | X | | X | | | | |
| 86 | X | | | | X | | |

**Table 1:** Learning Mechanics.

| | Players | | | Communication | | | | Leaderboard | Co-op | Competition |
|---|---|---|---|---|---|---|---|---|---|---|
| Ref | 1 | 2 | 3+ | Forum | Chat Room | In-game | Social Media | | | |
| 71 | | | X | X | X | | | X | X | X |
| 72 | | | X | X | | | | | | |
| 73 | X | | | | | | | | | |
| 74 | X | X | | | | | | | X | |
| 75 | X | X | | | | | | | X | |
| 76 | X | | | | | | | | | |
| 77 | | | X | | | X | | X | X | X |
| 78 | X | | | | | | | | | |
| 79 | X | X | | | | | | | X | |
| 80 | | | X | | | | X | X | X | X |
| 81 | X | | | | | | | | | |
| 82 | X | | | | | | | | | |
| 83 | | | X | X | X | | | X | X | X |
| 84 | | | X | X | | | X | | X | X |
| 85 | X | | | | | | | | | |
| 86 | X | | | | | | | | | |

**Table 2:** Social Mechanics.

| | Type of Reward | | | |
|---|---|---|---|---|
| Ref | Points: Experience | Points: Skill | Points: Redeemable | Badges |
| 71 | X | X | | X |
| 72 | | X | | |
| 73 | X | | | |
| 74 | X | | | |
| 75 | X | | | |
| 76 | X | X | | |
| 77 | X | X | X | |
| 78 | X | | | |
| 79 | X | | | |
| 80 | X | X | | |
| 81 | X | X | | |
| 82 | X | | | |
| 83 | X | X | | X |
| 84 | X | X | | |
| 85 | X | | | |
| 86 | X | | | |

**Table 3:** Reward Mechanisms.

| | Method | | Speed | | | Linked to Behavior | |
|---|---|---|---|---|---|---|---|
| Ref | Positive Reinforcement[a] | Positive Punishment[b] | Immediate | Delayed | | In Game | Real World |
| 71 | X | | X | X | | X | |
| 72 | X | | | X | | X | |
| 73 | X | | X | | | X | |
| 74 | X | | X | | | X | |
| 75 | X | | X | | | X | |
| 76 | X | X | X | | | X | |
| 77 | X | | X | | | | X |
| 78 | X | | X | | | | X |
| 79 | X | | X | | | X | |
| 80 | X | | X | | | | X |
| 81 | X | | X | | | X | |
| 82 | X | | X | | | X | |
| 83 | X | | X | X | | X | |
| 84 | X | | X | | | | X |
| 85 | X | | X | | | X | |
| 86 | X | | X | | | X | |

**Table 4:** Conditions Used to Stimulate Feedback Loops.

## Discussion

While the RCTs examined in this study employed a range of gamified elements, overall, relatively few commonalities emerged across these interventions. While this may be partially an artifact of the few studies that met this study's inclusion criteria, the heterogeneity observed in these studies methodologies and, in particular, in their data collection and assessment warrants discussion.

There remain several common commercial game development practices that have yet to be systematically adopted in health interventions. Specifically, consistently measuring programs' utilization and optimizing reward mechanisms should be considered in future research.

### Measuring Programs' Utilization and Gamification

The ability to quantify levels of engagement with gamified interventions is critical for assessing participants' adherence to directions, understanding the magnitude of the interventions' effects, and making comparisons between studies.

While most of the interventions reviewed reported some usage statistics, varying reporting measures and unstandardized analyses made it difficult to determine the overall effects of interventions (Appendix A). The static measurements reported give limited insights into the process of usage and adherence. In other words, these measures did not capture what participants were actually doing when using the intervention. For instance, in some instances participants could potentially simply log into the program without ever accessing any of the intervention's materials.

Many of the metrics used to define and monitor success in video games, including retention rate, churn rate, stickiness, daily active users, monthly active users, and daily sessions per user (Table 5), may be useful in defining and assessing the success of future gamified health interventions. Usage metrics like these would allow researchers to analyze the health of the application as it fairs in the market, allow for robust, real-time analysis of the progress and adherence of an interventions' patients or cohorts, and may yield insights when interventions fail to yield significant changes in participants' health outcomes.

Aside from measuring usage statistics, quantifying and measuring gamification itself is important. According to the Game Performance Assessment Instrument (GPAI) [8,87,88], three categories of appropriate technical measurements should be used: contextualization, operationalization, and data analysis.

Contextualization refers to gathering information about the special features of the gamified system, including what types of feedback/goals were used, how often users achieved success, information on the design of the program, and complexity of the gamification elements [8].

Operationalization includes pre-during-post intervention measures that examine demographics, prior participant experience with gamification, attitudes towards game-play, pre-existing skills sets, and group/team characteristics. During-intervention operationalization assessments focus on player-performance and game experience, while post-intervention operationalization assessments review the game experience (e.g. was it fun), degree of player satisfaction, as well as information learned.

Finally, data analysis includes analyzing contextualization and operationalization to determine the game's level of impact on behavior change. This is an important element in the review process, as it allows for a more global examination of the game's performance to identify the most influential elements of the intervention and assess the overall efficacy of gamification in the intervention [8]. This, in turn, identifies elements to expand on, change, or remove from future games.

Together, the assessments used in evaluating videogames and examining gamification can complement the measurements traditionally employed to assess health interventions. The addition of these metrics provides crucial context for understanding failed interventions and identifying promising avenues to build upon in future research.

### Creating Appropriate Goals and Feedback Mechanisms

While all of the interventions reviewed incorporated incentives through some form of point system, the awarding of points was incorporated differently across interventions, with no standard

| Metric | Assesses | Calculation | Ref |
|---|---|---|---|
| Retention Rate | % of participants still active after a specified amount of time. | # of participants who opened app / Total # of participants | [84] |
| Churn Rate | The % of participants lost over a specified amount of time. | 1–retention rate | [9,85] |
| Daily Active Users (DAU) | # of participants that opened the app in a day. | n/a<br>User metrics like this are typically recorded directly by the software | [86] |
| Monthly Active Users (MAU) | # of participants that opened the app in a month. | n/a<br>User metrics like this are typically recorded directly by the software | [86] |
| Daily Sessions | # of times participants opened the app in a single day. | Daily Sessions / DAU | |
| Stickiness | How actively and frequently a participant uses a product. | DAU / MAU | [9] |

**Table 5:** Gamification Utilization Metrics.

mechanism in place. While there is value in point systems, additional rewards may enhance program outcomes. In past studies of gamification, various extrinsic and intrinsic rewards have been used as motivators [89,90], and have been found to promote dopamine production, reinforcing desire to play [91,92].

Selecting appropriate rewards for task completion may seem daunting, as they must be rewarding for diverse users. However, investigations into human reward systems suggest that reward processing systems rate the favorability of rewarding outcomes based on the potential outcomes encountered in that particular setting, rather than the best conceivable outcome [63-66]. In other words, participants find pleasure from rewards labeled as a "max prize" irrespective of the rewards' actual market value, making the provision of rewards in gamified interventions less daunting. Research has shown that the reward pathway can even be activated by rewards that don't physically exist. These hypothetical rewards have been found to elicit the same neural response as actual physical rewards. Indeed, there is evidence suggesting that hypothetical rewards can motivate behavior to a similar degree as physical primary or secondary rewards [93-96].

One study even found both monetary and social rewards (social rewards in this study were defined as happy or angry faces) activated the same anatomical structures of the reward system during various probabilistic learning tasks [97]. Hypothetical rewards do not show significant divergence in delay discounting when compared to a real reward [98,99]. Previous studies investigating delay discounting have found that humans often sacrifice a large delayed reward in order to receive a smaller but more immediate reward [100]. At first glance this would not seem to be an important finding, but in fact may suggest that hypothetical rewards can serve as a valid proxy for real rewards. It may be that the brain is unable to physiologically tell the difference between real and non-real rewards.

## Limitations

Due to the development of gamification outside of traditional science fields and laboratory settings, little evidence gathered has been thoroughly investigated in a controlled setting. Indeed, many of the practices discussed are based on industry standards developed using word of mouth or approaches that maximize revenue. Nevertheless, there is evidence software development practices are grounded in neurocognition and apply to public health. For example, research shows that rewards can affect motivation [22] and social components profoundly influence health behaviors [101,102].

Due to the scarcity of public health interventions explicitly utilizing gamification and heterogeneity in gamification elements used, too little data exists to examine the overall efficacy of each gamified mechanism, let alone interaction effects. Further research is necessary to establish best practices, encourage consistency in assessment metrics, and guide the development of new interventions utilizing gamified mechanics.

By restricting analyses to RCTs, it is possible that successful gamification interventions using observational methodologies were overlooked. Similarly, the specific definitions of 'games' and 'gamification' employed may have excluded some relevant experimental studies. While the restriction to RCTs was maintained in order to maximize internal validity, the limitation of specific definitions was partially addressed by initially including studies that did not specifically mention gamification or games; these were subsequently removed only after careful review.

While usage metrics and points-based rewards were central to this review, many studies did not specifically focus on these aspects. The inconsistent reporting of relevant metrics illustrates the need for standardized reporting conventions for interventions employing digital platforms.

## Conclusion

Reward-based electronic interventions have the potential to enhance public health interventions through activation of the reward pathway via immediate feedback, goal setting, and behavior tracking. By combining game development industry practices with public health theory, it may be possible to create interactive, mobile, networked systems to more effectively motivate changes in health behaviors. While the literature in these fields suggests opportunities to enhance public health interventions, further research is still needed to determine the efficacy of various gamification mechanisms, how they interact, and overall best practices.

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