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Technology-based gamification in sleep medicine: A useful tool for physicians?

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Abstract

In recent years, individuals' nightly sleep quality, hygiene and duration have declined significantly. Gamification, the addition of game-based elements to non-game contexts, is an emerging tool in medical education and may be readily applicable to sleep medicine. Initially developed for use in retail and education, gamification increases productivity and knowledge acquisition and retention. Between the dates of 12/16/2023 and 03/27/2024, we conducted a focused review of eleven recent studies investigating the effectiveness, feasibility, and acceptability of technology-based gamification interventions in improving subjects' sleep duration, quality, and hygiene. Some studies focused primarily on imparting information while others sought to gamify user incentives. Most interventions were effective in improving user knowledge and sleep hygiene, were feasible to implement, and had high acceptability among subjects, measured through qualitative and quantitative data metrics. Effective media included mobile applications, wearable technology, and console-based exercise games ("exergames"). Although valid concerns exist regarding use of technology near bedtime, technology-based games designed for daytime usage offer more immersive experiences and increased user engagement. In the future, we anticipate increased use of gamification by primary care physicians, sleep physicians, and psychologists, particularly in rural areas, within pediatric sleep medicine, and to augment traditional cognitive behavioral therapy. New research should examine the addition of gamification to sleep-focused telemedicine and school-based educational sleep interventions.

Keywords: Gamification; Sleep Hygiene; Consumer Sleep Technology; Adolescent Sleep; Sleep Gamification

1. Introduction

Sleep is an active state of reversible unconsciousness during which the body is at rest. Human sleep primarily alternates between non-rapid eye movement (NREM) and rapid eye movement (REM) sleep. NREM sleep is divided into three shallower stages of rest characterized by unique mental processes.(1) During REM sleep, the brain processes memory and emotion, entering a state of near-total paralysis.(2) Healthy sleep is critical for alertness, emotional regulation, and memory consolidation,(3) while sleep deprivation is associated with negative neurological and physical outcomes, including growth retardation and greater risk of diabetes, obesity and cancer.(4, 5) Despite the importance of restful sleep, mean nightly sleep duration and quality have fallen dramatically over recent decades.(6)

Sleep hygiene—behaviors that induce good quality and duration of sleep—can be improved by therapy and behavioral intervention.(7) These treatments may be made more effective by increasing patient engagement.(8) A growing body of evidence suggests that gamification—the application of game-based elements to non-game contexts to boost motivation and engagement—may be an effective tool to improve patient outcomes.(9, 10) Initially developed in retail and education, gamification spurs productivity and increases knowledge acquisition and retention.(11) For instance, to increase customer spending, Samsung launched a gamified campaign called Samsung Nation to reward customers for

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each purchase.(12) In an increasingly digitized world, technology-based games have emerged as an effective means of implementing gamification in various medical disciplines.(10, 13)

An abundance of literature links technology use, including computers, video games, and mobile devices, to lowered sleep duration and increased daytime sleepiness.(14) Counterintuitively, focused use of technology through gamification may improve patient knowledge and sleep quality. Despite a burgeoning array of for-profit electronic sleep aids available digitally,(15) literature investigating the effectiveness of gamification in improving sleep knowledge and hygiene is scarce, and physicians may be unaware of its potential benefits. We address this knowledge gap by conducting a focused review of the relevant literature regarding technology-based gamification in sleep medicine to evaluate its effectiveness as a tool for instruction and inducing behavioral change in patients.

2. Materials and methods

We conducted a focused search of the National Library of Medicine's PubMed database for literature regarding gamification-based interventions in sleep medicine between 12/16/2023 and 03/27/2024. MeSH terms included combinations of: ("gamification" OR "gamification of" OR "gamify" OR "game" OR "technology-based" OR "technology-based gamification of") AND ("sleep hygiene" OR "adolescent sleep" OR "adult sleep" OR "sleep quality"). This preliminary search yielded 356 results. We identified additional papers using the reference lists of these results.

All studies were evaluated based on title and abstract, leaving us with 22 results. Papers with relevant titles and abstracts were reviewed in full by two authors (AP, SG). Disagreement on the inclusion of specific papers was discussed and if necessary adjudicated by GG.

3. Results

Our final evaluation yielded 11 studies detailing the application of gamification in addressing sleep knowledge and/or quality (Table 1). Gamification media employed ranged from board games to virtual reality (VR) simulations. We focused on games' effectiveness, feasibility of implementation, and acceptability as outcomes of interest. Several studies included quantitative and qualitative assessments.

Table 1 Summary of recent gamification literature

First author	Year published	Participants	Intervention/methodology	Evaluation of effectiveness	Evaluation of acceptability
Almondes	2019	13 seven- and eight-year-olds	Serious board game "Perfect Bedroom: Learn to sleep well"	USHS responses, actigraphy, sleep diaries	N/A
de Lima	2021	29 inactive people aged ≥60	18 sessions playing Xbox Kinect Sports exergame	PSQI and STAI scores	N/A
Lee	2020	48 cardiac ICU patients	30-minute VR meditation session	PSQI and Korean Sleep Scale A scores	N/A
Ilhan	2021	26 people aged 18-35	Android game "Sleepy Bird"	Sleep quality measurement, snooze number	Post-use questionnaires, user feedback
Ollier	2023	698 adults	Informational lifestyle care intervention Elena+: Care for COVID-19	ISI scores	N/A
Tanriverdi	2022	38 children with ALL and healthy siblings	VRBE intervention using Nintendo Wii Fit Plus	CSHQ, polysomnography	N/A

Vollert	2023	371 participants across all ages	Information-based CBT-I application Refresh	RIS and PHQ-9 scores, sleep diaries	WAI-SR responses
Wang	2023	1779 medical interns	Competition between teams to maximize daily step count and sleep duration	Daily step count and sleep duration competition	N/A
Wan Yunus	2020	36 undergraduate students	18 sessions playing Kinect Sports	DASS-21 and FOSQ-30 scores	Feasibility questionnaire and participant reflections
Werner-Seidler	2017	50 adolescents with sleep difficulties	CBT-I informational game Sleep Ninja	ISI, PSQI, PHQ-A, and GAD-7 scores; sleep diaries	Post-intervention acceptability questionnaires
You	2020	12 players aged 16-30	Simulation-style game *SleepTown*	Interviews with subjects	Interviews with subjects

ICU: Intensive care unit
Serious games: games "that focus on education, information delivery, and practice of skills"(16)
CBT-I: Cognitive behavioral therapy for insomnia
USHS: Sao Pãolo State University Sleep Habits and Hygiene Scale
PSQI: Pittsburgh Sleep Quality Index
STAI: Spielberger State-Trait Anxiety Inventory
ISI: Insomnia Severity Index
ALL: Acute lymphoblastic leukemia
VRBE: Virtual reality-based exercise
CSHQ: Children's Sleep Health Questionnaire
RIS: Regensburg Insomnia Scale
PHQ-9: Patient Health Questionnaire-9
WAI-SR: Working Alliance Inventory-Short Revised
DASS-21: Depression, Anxiety, and Stress Scale-21
FOSQ-30: Functional Outcomes of Sleep Questionnaire-30
PHQ-A: Patient Health Questionnaire-Adolescent Version
GAD-7: Generalized Anxiety Disorder-7

3.1. Foundations of gamification in sleep medicine

Although our research focuses on technology-based gamification interventions, we include two papers that present a framework for applying technology-based gamification in sleep medicine.

Almondes and Leonardo(17) investigated the effectiveness of serious board game "Perfect Bedroom: learn to sleep well" in improving sleep hygiene in seven- and eight-year-old children. Made with inexpensive materials, "Perfect Bedroom" included two minigames: "Set up your bedroom" and "Mapping activities before bedtime," where children identified healthy bedtime habits.(18) The experimental group (n=8) completed six 50-minute sessions playing "Perfect Bedroom" over three weeks, while the control (n=5) did not. Actigraphy (objective measurement of sleep/wake behavior through a wearable device) and sleep diaries tracked sleep duration, latency, and efficiency. Parents/guardians responded to the USHS pre-intervention, immediately post-intervention, and at one-month follow-up. Sleep quality and habits between the experimental and control groups post-intervention were similar, although electronic device use decreased in the experimental group.

In 2020, Lee and Kang(19) explored the effect of VR meditation on sleep quality of 48 cardiac ICU patients. The day of ICU admission, the experimental group (n=24) used a VR headset to block external stimuli and meditate in a calming environment for 30 minutes. The control (n=24) slept normally as per ICU protocol. Post-intervention sleep quality was measured objectively through a wearable activity tracker and subjectively through Korean Sleep Scale A. Although overall sleep duration measured through actigraphy was similar between the groups, mean Korean Sleep Scale A scores were significantly higher in the experimental group compared to the control (2.25 vs. 2.06), indicating higher quality of sleep. Mean sleep efficacy was 85.68 in the experimental group versus 83.36 in the control (p=0.018).

3.2. Tracker-type mobile applications to improve sleep

Increasingly, individuals use mobile applications to track daily activity and other metrics, including sleep.(20) We identified two studies investigating tracker-type mobile applications gamified to improve sleep. These applications did not "teach" any information. Instead, they influenced behavior by altering users' incentives.

Ilhan et al(21) investigated "Sleepy Bird," a game designed primarily for daytime use modeled off of popular video game "Flappy Bird." Two versions were created. The non-gamified version contained an alarm clock and measured sleep duration, providing players with feedback. The gamified version also included the "Sleepy Bird" game, featuring leaderboards, lives, and scores. Based on their sleep quality, the gamified group received in-game rewards and penalties. Sleep/wake times, sleep duration, and number of alarm "snoozes" were recorded in the gamified (n=13) and non-gamified groups (n=13). Following the two-week intervention, sleep/wake times and sleep duration were similar, but mean daily snooze number decreased in the gamified group. Post-questionnaire feedback and user comments were overwhelmingly positive.

A 2020 study by You(22) examined *SleepTown*, a collaborative game allowing users to build healthy sleep habits by creating virtual "towns" (Figure 1). *SleepTown* is downloadable for $1.69 on many mobile devices. Within *SleepTown*, users set individual goals for sleep latency and duration and were rewarded or penalized based on goal completion. To assess acceptability, 50-90-minute semi-structured interviews were conducted with 12 participants who used *SleepTown* consistently for three weeks. Interviews revealed that users were extremely responsive to both positive and negative feedback in the game (rewards and penalties) and consequently altered their sleep hygiene. Other users noted that *SleepTown* motivated them to prioritize their mental and physical well-being and encouraged them to connect with other like-minded players. Overall, the author concluded that SleepTown positively impacted users' sleep metrics and was perceived positively.

Figure 1 User interface and descriptions of *SleepTown*(23) (from Google Play)

3.3. Information-focused games

While some studies investigated games without an informational component, we found three papers focused on improving players' sleep habits by imparting knowledge through technology-based gamification.

Werner-Seidler et al(24) developed Sleep Ninja, a gamified CBT-I app, and investigated its effectiveness, feasibility, and acceptability in 50 adolescents with sleep difficulties. Sleep Ninja included six lessons delivered through a chatbot and used psychoeducation and stimulus control to teach about sleep hygiene and provide personalized recommendations. Players "leveled up" by completing lessons and tracking their sleep through the app. Pre- and post-intervention, participants responded to the ISI, PSQI, PHQ-A, and GAD-7. Eighty-four percent of participants completed a majority of the lessons. Results from an acceptability survey and qualitative forms of feedback indicated high levels of satisfaction and engagement. Post-intervention, participant sleep duration increased by 33 minutes, and participants awoke fewer times during the night ($p=0.011$). Mean ISI scores decreased from 14.12 to 9.62 post-intervention, and PSQI scores decreased from 10.43 to 8.03, indicating a significant decrease in severity of insomnia and improvement in overall sleep

quality (both $p<0.001$). Rates of depression and anxiety (measured by the PHQ-A and GAD-7) decreased significantly. Sleep diaries indicated correlated improvements in subjective sleep quality.

In 2023, Vollert et al(25) studied Refresh, an unguided app that didactically presented eight chapters of content on CBT-I. The experimental group (n=186) used Refresh during the eight-week intervention, while the control (n=185) did not. Pre-intervention, post-intervention, and at six-month follow-up, participants completed the RIS and PHQ-9 to assess sleep quality, perceived insomnia-related impairment, and depression. Similarly to traditional CBT-I, patient adherence was modest:(26) 32% percent of participants in the experimental group never used the app, and only 31% completed all chapters. Despite suboptimal adherence, insomnia symptoms and perceived impairment improved post-intervention and at follow-up. Depressive symptoms did not significantly change. Responses to the acceptability questionnaire WAI-SR indicated positive perceptions of the app and its content.

During the COVID-19 pandemic, Ollier et al(27) designed gamified app Elena+: Care for COVID-19 as a lifestyle care intervention to deliver lessons on subtopics including COVID-19 information, mental and physical well-being, and healthy sleep. In the free app, users selected lessons (taught by a chatbot) of appropriate difficulty in subject areas that interested them. In 2023, authors analyzed the effectiveness of Elena+ among 176 users who selected sleep as a subtopic of interest.(28) Pre- and post-intervention, subjects responded to the ISI, but no significant score differences were observed.

3.4. Exergames

Certain interventions aimed to improve sleep quality by encouraging exercise—physical activity is correlated with improved sleep quality.(29) We include three studies that investigate "exergames," which utilize digital media to stimulate a more physically-active gaming experience.(30)

In 2020, Wan Yunus et al(31) explored the effectiveness, feasibility, and acceptability of commercially available exergame Kinect Sports in improving sleep quality and emotional well-being of 36 undergraduate students. While playing Kinect Sports, users selected one of several sports (basketball, soccer, etc.) and simulated play, directed by on-screen cues. The system monitored player movements and awarded points. Students in the intervention group played Kinect Sports during eighteen 30-minute sessions over six weeks, while the control continued with their daily routines. Post-intervention, self-reported scores of depression and anxiety in the intervention group (measured by the DASS-21) decreased from 4.06 to 2.83 and from 4.61 to 2.94, respectively, indicating significant improvements. Daytime functionality also improved significantly, and FOSQ-30 scores in the intervention group increased from 9.12 pre-intervention to 11.10 post-intervention. According to a feasibility questionnaire, the activity was enjoyable and effective, and some participants even suggested minor changes to enhance its effectiveness.

A similar study by de Lima et al(32) examined the effectiveness of Kinect Sports exergame Your Shape Fitness Evolved (Figure 2) on sleep quality of elderly participants (≥60 years old) who had no movement limitations and did not exercise regularly. The experimental group (n=15) played the game during eighteen 60-minute sessions over six weeks, while the control (n=14) did not. Gameplay improved sleep quality and anxiety symptoms (measured by the PSQI and STAI) in the experimental group.

Figure 2 Home menu of Xbox Kinect Sports and exergame Your Shape Fitness Evolved(33, 34) (from IGN and eBay)

Tanriverdi et al(35) investigated the effectiveness of a VRBE intervention in improving the sleep quality of children with ALL and their healthy siblings. The experimental group (n=17) played VR-based exergames using the Nintendo Wii Fit Plus console twice per week for 12 weeks, while the control (n=21) did not. Pre-intervention sleep duration and quality

(measured using polysomnography and the CSHQ) were similar between groups. Adherence to the intervention was 97.67%. Post-intervention, mean CSHQ scores among children with ALL decreased significantly in several categories, including sleep duration and sleep onset time. Overall CSHQ scores decreased from 57.45 to 48.27, marking significant improvement. RDI of hypopnea decreased from 3.10 to 1.97 among ALL patients in the experimental group, indicating a significant decrease in frequency of breathing-related incidents during sleep.

3.5. Team-based gamification of sleep

Finally, team-based gamification may improve camaraderie and minimize potential adverse psychological effects of one-on-one competition.(36) We present one study that investigates the impact on sleep of team-based competition.

A 2023 study by Wang et al(37) determined the effectiveness of gamified team competition. Medical interns (n=1779) were divided into five-member teams and used a smartwatch to record daily step count and sleep duration for 12 weeks. Each week, teams either competed head-to-head to maximize step count or sleep duration or continued to monitor these metrics without competing. Throughout, participants could view competition scoreboards and history on the Intern+ app. Competition significantly increased mean daily step count but did not impact sleep duration.

4. Discussion

The evidence on technology-based gamification in sleep medicine indicates that these interventions positively influence sleep knowledge and quality. Secondary outcomes indicate correlated improvements in mental health, and perceptions are extremely positive. Gamification can be feasibly implemented into patient care through a variety of user-friendly media.

Gamification stimulates the release of endorphins and dopamine, neurotransmitters that induce pleasure.(38, 39) This enhances motivation, encourages further play, and amplifies changes in behavior and knowledge.(40) Gamification is most effective in extroverted and already-motivated users,(41) as it reinforces intrinsic motivation through the addition of an external reward (Figure 3).(42)

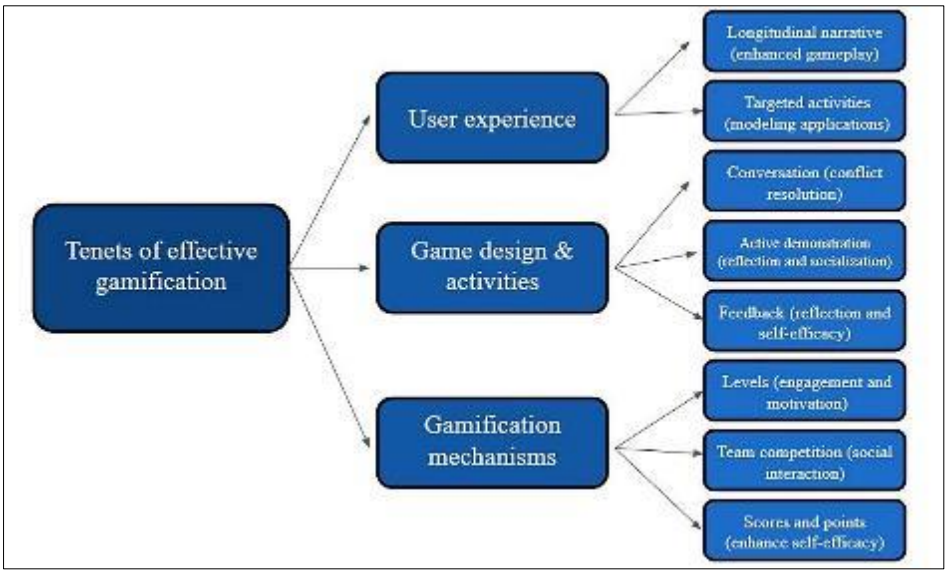

Figure 3 Simplified schematic of elements and benefits of effective gamification (adapted from Chong)(43)

Although excessive technology use near bedtime may harm sleep quality, technology-based gamification can be used non-harmfully to enhance sleep quality. Many games do not require full attention to a device screen,(31, 32, 37) and some are specifically designed for use during the day to minimize disruptions to sleep.(21) Additionally, compared with non-technical forms of gamification, technology-based gamification offers a more immersive experience.(44) In-game elements including leaderboards, achievements, and advertisements can be manipulated to promote engagement and create collaborative, compelling narratives.(45) Recently, sleep medicine has shifted toward more advanced technology in both diagnosis and treatment. Incorporating elements of technology-based gamification into patient care treatments aligns with recent guidelines from the American Academy of Sleep Medicine regarding the use of consumer sleep technologies (CSTs).(46)

Common media in gamification include VR simulation, mobile applications, wearable technology, and exergames. Although VR is widely accepted and effective in improving sleep quality,(19, 35) its steep price is a drawback,(47) rendering it infeasible as a widespread intervention. A significantly cheaper alternative, gamified mobile applications impart knowledge and track sleep, generally improving sleep quality.(21, 24) However, information-focused applications frequently fail to adequately engage users,(25) while applications that function solely as games may be less effective, particularly at follow-up.(21, 37) By developing and popularizing engaging apps that convey information, we expect to see increased acquisition and retention of knowledge and healthy sleeping practices. Adding these games to wearable CSTs (Apple Watch, Fitbit, etc.) may enhance personalization and tracking accuracy while generating large datasets to support future research.(48) Finally, even without imparting information, exergames effectively improve sleep quality while keeping users engaged.(31, 32) Unfortunately, most exergames may only be played on specific, costly consoles.(30) Adapting exergame elements to mobile devices or CSTs may expand their accessibility.

Despite its clear advantages, gamification is used infrequently by physicians. With increasing awareness, sleep physicians, primary care physicians (PCPs), and psychologists—particularly in CBT-I—may implement effective gamification strategies at the local and regional levels. Particularly in rural areas, ensuring that patients adhere to their physicians' recommendations amid social and cultural obligations remains a challenge.(49) Incorporating elements of technology-based gamification into patient care among rural populations may thus improve outcomes. This is especially relevant as the number of smartphone owners increases rapidly worldwide.(50) The effectiveness of technology-based gamification in improving user sleep habits may be reduced in individuals with visual or cognitive impairments. However, leaders in the video game industry including Ubisoft and Epic Games are currently working to incorporate feedback from disabled gamers to create more accessible video games.(51) Through the use of haptic feedback, text-to-speech, and other forms of assistive technology, games designed to improve user sleep may be adapted to better suit the needs of the disabled without compromising on the gameplay experience for able-bodied players.(52)

Gamification also builds patient autonomy by encouraging individuals to take charge of their own treatment regimens, which may alleviate stress from overburdened physicians.(53) Furthermore, principles of technology-based gamification can be readily adapted to telemedicine,(54) a growing method of care within sleep medicine that enables increased convenience and availability for patient and physician alike.(55) To our knowledge, no clinical trials investigating gamification in sleep-focused telemedicine have been conducted, making this a key opportunity for future research.

Technology-based gamification of sleep may be equally useful within pediatric sleep medicine. Studies have demonstrated that adolescents respond well to interventions involving digital media.(56) In recent years, we have observed an increase in educational sleep interventions conducted through schools.(57) Incorporating technology-based (especially team-based) gamification into such programs in schools may more efficiently engage students. This can be effectively implemented through cell phones.(21, 22, 24) Justified concerns exist regarding exposing young children to technology,(58) but when used in moderation, the benefits of educational gaming likely outweigh any associated risks.(59).

5. Conclusion

Altogether, technology-based gamification of sleep knowledge and quality shows promising results, with significant effectiveness, acceptability, and potential for implementation in patient care. We anticipate further research to define its ideal applications in sleep medicine. In the future, we hope to see technology-based gamification used more widely as a tool in the arsenal of sleep physicians, psychologists, and PCPs.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

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