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RESEARCH ARTICLE

The Need to 'Git Gud': A Review of Potential and Pitfalls in Mobile Gamification of Paediatric Health Education

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ABSTRACT

Conventional health initiatives aimed at paediatric populations struggle heavily with inefficacy. The ubiquity and utility of mobile devices offer a promising way to reach broad and distinct populations, cross-cultural demographics, and socioeconomic strata. As children and adolescents are accustomed to smartphones and related technology, this medium potentially can bridge the divide between health interventions and their daily lives. Conventional and previously attempted mobile interventions struggle with a bipartite hurdle that cripples their effectiveness: first, the production and preservation of motivation and second, the lack thereof within youth. Non-adoption, attrition, and eventual abandonment have led to mediocre efficacy. In the face of this challenge, the incorporation of game elements with health behaviours, by way of serious games and gamification, has hinted at a vast, yet untapped ability to circumvent this problem of engagement. However, the current application of game elements has not produced expected levels of results. This review not only examines potential causes for this inefficacious gamification, but also works to delineate a path forward.

Methods: A scoping search of extant academic literature was conducted using three databases, Web of Science, ERIC, and PsycInfo. Articles were evaluated by relevance, being required to pertain to mobile health, gamification, and paediatric populations.

Results: A total of 20 journal articles met the inclusion criteria and consequently were evaluated. The included papers were a plethora of studies including randomized controlled trials, mixed methods experiment, and systematic reviews. The current literature suggests substantial potential is carried by both mobile health applications and gamification, especially in relation to difficult-to-reach paediatric populations. Secondly, examination of the articles brought existing shortcomings to the surface.

Conclusions: Mobile health and gamification present an incredible, pioneering opportunity to reach children and adolescents. Given the challenges associated with the acceptance of conventional interventions, current and future research should continue to explore the utility of mobile health. To combat the lackluster engagement and motivation also connected to the aforementioned initiatives, the incorporation of game elements should not simply be implemented, but further investigated and improved.

Introduction

Health initiatives supporting children and adolescents are often didactically information-focused by nature, and thusly struggle with limited effectiveness^{1,2}. This lack of productivity calls for new, innovative ways to reach youth, and one such area of research just beginning to step into the spotlight has been mobile gamification^{3,4}. The formidable combination of the ubiquity and handiness of mobile devices and the promising potential of effective gamification have spurred recent, widespread interest in the topics. A plethora of studies and analyses were initiated, and nearly all were confined to the past decade. Given the relative recency of gamification and “serious games”, a majority of the literature represents similarly superficial depth. Much of the aforementioned potential lies untapped, and the purpose of this literature review is not to fully exposit this potential, but rather to present a framework of support for its practical application.

Mobile health, or *mHealth*, can be defined as “mobile devices such as mobile phones, PDAs, and other wireless devices supporting a medical or public health practice”⁵. The presence of technology, and more recently smartphone devices, is steadily increasing within the medical field, and many parties, from government bodies to health organizations, clamour for increased function within patient care^{6,7,1}. “Serious games” are games specifically created to deliver knowledge or skills to effect change in attitudes or beliefs and behaviours⁸. “Gamification” is the application of gaming elements in non-gaming contexts for the purpose of heightening player traits such as engagement or motivation⁴. In this review, references to the latter two will be used to denote the incorporation and manifestation of gaming elements to incur positive benefits.

Obvious to even a casual observer of popular culture and globally available entertainment, the societal influence of videogames is incredible. With a market in the billions and high-ranking social presence in myriad forms of media, they boast a global audience piercing through socioeconomic strata regardless of culture, age, or background.^{1,9,10,11,12} The mushrooming number of people playing “casually” and the parallel preference for playing on mobile devices⁸ have only served to broaden the reach of games. A few standout examples of consumer games have seen tremendous popularity and, in the case of Pokémon Go, statistically significant increases to walking habits.^{13, 4} Another game designed to promote exercise, Nintendo’s Ring-Fit Adventure, presented a unique experience that had suppliers struggling

to keep up with demand.¹⁴ The former was an app that, through immense audience appeal and entertainment value, obliquely led to health behaviour change; the latter was a game that made no effort to hide its intent but managed to package health in a captivatingly singular manner. Such specially developed games could serve as effective alternatives for engaging youth.⁸

Children are uniquely vulnerable populations⁷ due to their often-non-voluntary participation in both treatments and long-term care¹⁵ as well as their usually total dependence on parents and family. Because parents bear most of the responsibility of care, public health interventions tend to focus on “top-down” dissemination of information,¹⁶ such as family, schools, and communities. However, instilling a sense self-efficacy into individuals is correlated with an increase in positive health outcomes.¹⁷ With less dependence on healthcare workers and instead a co-operative relationship with them,¹⁷ paediatric populations thusly can engage with and tailor their own well-being to their unique needs.^{18,15,17,8}

Methods

This literature review was performed by searching three databases, Web of Science, ERIC, and PsycInfo. They resulted in fifty-eight, zero, and nine results, respectively. Subjectively sorted for relevance, Web of Science finished with eighteen studies, and PsycInfo offered two. Duplicates and studies focused solely on gamification or gamification on non-health topics were excluded. Sexual health studies were excluded, as this was outside of the initially determined scope of this paper. The final list of studies were on gamified, health-related, and relevant to paediatric populations, as well as being published in a journal with an Impact Factor greater than two, thus excluding proceedings papers as well. The search terms were as follows:

(gamif* OR game NEAR/2 (edu* OR learning) OR (augmented OR videogam* OR “computer game”) NEAR/3 learning OR “serious game” OR edutainment OR “education”)
AND (ehealth OR mhealth OR (mobile OR telephone OR phone) NEAR/2 app*)
AND ((primary OR elementary OR youth) NEAR/2 education OR (primary OR elementary OR middle) NEAR/2 school OR school OR “grade school” OR child* OR “young people” OR “young person” OR pediatric* OR paediatric* OR grade 4 OR grade 5 OR grade 6 OR grade 7)
AND (health OR nutrition OR exercise OR well-being OR self-care OR fitness OR

(media OR info* OR tech* OR science)
NEAR/1 literacy)

Results

On analysis of the articles found as per the Methods section, several themes emerged. Firstly, the stellar opportunity offered by mobile technology as a medium for beneficence; secondly, the immense, untapped potential possessed by gamification elements with respect to the creation of new, effective methods of health promotion; and thirdly, hurdles that inhibit implementation of the same in health and health education for the paediatric populations. These are outlined in this section.

1. UNIQUE POTENTIAL OF MOBILE AND SMARTPHONE TECHNOLOGY

1.1 – Smartphone ubiquity

The ubiquity of mobile technology in the hands of today's youth, and the increasing interest in mHealth present a new opportunity for healthcare: the ability to promote health behaviours directly to paediatric populations in a way palatable to them.^{19,20} With paediatric populations already using the Internet as a primary source of information for health topics, more online resources are required to maintain this advantage of accessibility.^{7,5} The general public is increasingly adopting mobile phone and related technologies as the norm.^{21,16,2} Unsurprisingly, the adoption rate of smartphones is the fastest of all consumer technologies.²² Amongst youth, ownership of mobile phones starkly shot up from 45% of 12-17 year-olds in 2004 to 75% in 2012, and that number has only been increasing over the years.^{23,20,2} Over 75% of teenagers access social networking services, and they spend an average of roughly 90 minutes messaging and sending over a hundred text messages every single day.^{23,1}

With developers having created close to 600 000 apps available to users and a quarter of a million of those focused on health, the audience for mobile applications is significant; ^{21,1} teenagers are reported already to prefer technology-enhanced education programs.¹ Concurrently, a growing number of digital health initiatives are targeting youth.¹⁸ This potentiates a widened breadth of clinical models.²⁴ Many of the commercially available mHealth apps focus on increasing one or more healthy behaviours or mitigating risks, with nutrition and diet representing the most rapidly burgeoning division.⁵ Facilitating the widespread distribution of meaningful health information, smartphones support participatory healthcare.¹⁸ From the top down, public health authorities can distribute key messages directly to users, conveying

relevant health promotion, decision-making, and lifestyle habits.¹⁶

1.2 – Challenges with acceptance and shortcomings of resource cost of conventional health promotion

The opportunity that mobile technology affords needs to be explored. Conventional interventions have proven ineffective in reaching paediatric populations in a variety of health aspects, from Type 1 Diabetes management, to mental health and anxiety, to general health promotion.^{17,15,1} Due to the familiarity they command, interventions based on technology often are more readily accepted by users, increasing engagement and thus improving self-management skills and behaviours.^{23,6,3} They can confer knowledge, teach coping strategies, and support motivation in younger populations.^{17,15,18} Diabetes and asthma patients have seen better self-care with technologically supplemented interventions,⁶ and similar eHealth programs are being applied to hypertension and sickle cell disease.⁶ Weight management studies have seen efficacy with paediatric populations, thanks in part to the ability to monitor intake and ongoing status through mobile technology.^{5,7,4,2} Currently, late disease management is common practice, but Information Communication Technologies (ICTs) can be used to encourage early health promotion.^{3,7,1} This is beneficial not only for lowering overall health costs, but also working as a preventive measure.^{7,1,4} Adolescent neurocognitive functions can be improved, and depressive symptoms decreased through appropriately designed computer-based programs.¹ E-Health literacy skills are associated with healthier behaviours, improved weight management, and increased self-efficacy and body image satisfaction.¹⁸ Although many previous studies were focused on specific targets, such as cardiac disease, obesity, or motivational factors promoting app adoption,⁴ mobile phones also have been effective platforms for personalizing general well-being and showcasing a unique usefulness in changing habits relevant to physical activity, diet, and sleep.^{4,16} The medical community needs to develop pioneering, unorthodox approaches to match the unique needs of paediatric populations, and the Internet and mobile-associated technologies offer unparalleled speed, versatility, and visual presentability to the future of health initiatives.^{22,16,2}

When delivered by conventional means, treatments often require significant amounts of resources to implement. Furthermore, many are already well-suited to technological supplementation or off-loading, such as with Cognitive Behavioural Therapy (CBT).^{25,18} Mobile applications also can be

designed for self-instruction, helping to offset demanding health needs such as the mental health burden increasing in younger demographics.²⁵ They can assist with boosting motivation, mitigating forgetfulness, and filling in gaps where understanding is lacking.¹⁵ For general health maintenance, nutrition and physical activity counselling can be supported through ICTs.^{7,18} In specific areas, mHealth can also be a cost-effective alternative when compared to conventional interventions which require legislation, engineering, or design support.^{21,7,2} Although this benefit varies in scale depending on the comparative therapies, evidence is growing for the feasibility, acceptance, and efficacy of mobile interventions in low to middle income countries.⁶ E-Health can serve to fill the gap caused by social or practical barriers, such as distance, time, or education.^{24,3,7,1} Disparities in health services, as those present in mental health, demand such alternative methods of delivery,²⁴ and the advances in artificial environment simulations and hardware capabilities can emulate in-person treatments.^{24,15} Responsive virtual environments facilitate the transfer of learned therapies into daily life, possibly allowing for more services such as rehabilitation to occur remotely.^{3,5} When the need arises for patients to engage in face-to-face contact with healthcare workers, the management of medical information afforded by ICTs allows for reliable distribution of said information and consequent increased quality of care.^{3,7,1} With further research, mHealth could be implemented effectively in future clinical settings.²⁰ Internet-supported mHealth interventions also correlate to a greater degree of rational health services use by patients.^{7,18} Heightened accessibility and capacity for decision-making tailor health management to individual needs, thereby increasing efficiency and quality of service.^{3,18,4} Patient-relevant research also fits well with mobile technology: relative cost, scalability, ease-of-use, zero-geography, low participant burden, real-time monitoring, automatic data collection, and even data analysis can be provided by modern mobiles.^{5,26,20,2} Digital tools are a promising medium for comprehensive support of paediatric populations when supporting from home or combined with standard care.²⁰

1.3 – Connecting social influences

Guidance is essential for interventions targeted at youth, since children and teens are often “non-voluntary patients”¹⁵ and can lack both insight and motivation in areas such as mental health.^{25,15} External help, through peer-to-peer encouragement and parental support, can be implemented in a variety of ways. Online connections can cross socioeconomic strata.¹⁶ Appropriate social networking can bring positive peer support and

vicarious learning through a perceived shared experience.^{17,1} Computer-based “teams” for health promotion have proven effective for young adults, and such eHealth programs could create a new paradigm for wellness initiatives.¹ Patients themselves show interest in using self-management apps,⁶ and parents are more willing to support the use of technology when they believe it will help their child manage chronic symptoms, especially if a feeling of unmet need exists.²³ Strides are being taken to put healthcare management quite literally into the hands of parents, offering support for nutrition and weight management straight to these key players in a child’s lifestyle.⁵ This also encourages role-modelling.⁵ Despite the growing evidence of potential and promise, very few applications have been researched and developed for youth that take advantage of social supports, and the few that have been were limited in scale and short in duration.¹⁶

1.4 – Not a dead-end road

Technology usage has foreseeable potential to continue improving as well: while communication technology increases frequency of contact with healthcare workers,²³ the longstanding outcomes of telehealth are still unclear.²³ Virtual Reality and Augmented Reality can be paired with telehealth to augment efficacy,³ and gamification in mobile applications carries potential to bolster engagement and motivation.³ Smartphones and Global Positioning Systems (GPS) already have been similarly implemented in telehealth and Emergency Medicine. Nearly emulating a Heads-Up-Display level of quick accessibility, mobiles can provide status displays and immediate feedback to users at a whim.^{24,3,5,15} Heron and Smyth (2010) title this “Ecological momentary intervention”, meeting users where they are.¹⁵ Well-made apps also carry a “replay factor”, which assists in combating relapse common to long-term health behaviour management.⁵ Behaviour tracking can identify patterns to improve setting future goals.¹ Even simple pedometer use led to increased physical activity in multiple age groups, including children.¹ More complex iterations such as Fitocracy and 7 Minutes, or app and wearable combinations such as Runkeeper and GoGoYu, are also being used to track steps, distance travelled, and daily sleep and diet.^{1,4} Researchers, clinicians, and public health are reaching a growing consensus that Internet and mobile apps should be explored for health endeavours such as weight management.^{6,5,7,4} As technology becomes more ingrained in everyday life and advancements lead to blossoming capabilities, so will the prospect for greater use in health applications.

Mobile technology has well-documented potential for supporting health interventions due to its global ubiquity and cross-population penetration, personal attachment and connectivity, and programmability which facilitates customization, context-awareness, and collaborative self-sensors.^{5,7}

2. USING GAMING TO ENCOURAGE HEALTHY BEHAVIOURS

2.1 – Wide appeal

Gamifying clinical models suits a tech savvy generation by facilitating “visual, rapid, and multi-task learning”.²⁴ With technology use increasing amongst children, serious games can be tailored to ages even as low as preschoolers and promote motivation and alertness, lower therapy attrition, and increase the neural mechanism of attention.³ The personalized flexibility and Web-based environment can be designed to adapt content and challenge to particular users' needs;^{24,4} this leads to more involvement and individualized learning, as is seen in games geared towards patients dealing with developmental dyslexia and impaired neurocognitive abilities.^{24,3} Among paediatric patients with sensory disabilities, videogames incited a desire for self-improvement and acquisition of skills related to independence, reading (to better understand their condition), and finding similar apps to the intervention.³ Virtual and Augmented Reality can accommodate unique needs, mitigate physical limitations, improve life skills, assist mobility, and train cognitive abilities; the engaging experience increases adherence to beneficial health behaviours.³ Knowledge structures “improve interactivity, [self-insertion in fantasy genres], retention, attention, motivation, and mastery and promote health-behaviour change”.³ For children both in the general population and bearing chronic health conditions, games' intrinsic and extrinsic motivation, active and realistic opportunity, and immediate feedback can elicit improvement for both self-awareness and management behaviours.^{24,4}

Widely distributed games can provide low cost interventions to a diverse range of people,²¹ separated possibly by geography⁵ or socioeconomic barriers.⁷ Games and related technology are already in the hands of the youth:²¹ 80% of 6-14 year-olds in Europe and 72% of 13-17 year-olds in the USA report playing videogames.⁸ An increasing preference for mobile games presents a parallel opportunity to reach youth through mobile games.⁸ Through the use of the Internet and mobiles, both of which approach global ubiquity, digital games could provide affordable means to support chronic conditions and long-term healthcare.^{17,20}

2.2 – Pushing players to play

The simple provision of information has not proven demonstrably effective in changing health-related behaviours.^{21,1} A greater motivation is required to facilitate engagement and secure the longevity of health management.^{23,15} To fill this void, researchers have brought gamification into the spotlight.¹⁵ Videogames are becoming ubiquitous entities in recreation and have shown surprising utility not only for creating motivation in industry-developed games, but also for bolstering health promotion efforts.

The effectiveness of gamification and serious games is well-documented in studies aimed at young people.^{19,20,15} With myriad conventional methods of health promotion falling short, many in healthcare are looking for new avenues forward.^{23,17,20,1,2} One major hurdle often faced by conventional initiatives is user engagement, and game environments have the potential to bridge the gap between attractive mediums and effective programs.²⁰ They potentially provide an enjoyable avenue through which to learn, and the “replay factor”²⁵ can facilitate repetition of comfortably consumable amounts of educational elements.^{7,2} Games designed to be patient-centric increase engagement while concurrently providing a safe environment for learning.^{25,3,20} A sense of self-efficacious control is reinforced by the potent cause-and-effect inherent to and often immediately apparent within gameplay;⁴ this has also led to increased expertise in proficiencies such as communication and problem solving.²⁵ The ability to provide not only implicit, health-related goals, but also explicit, game-centric goals can serve to circumvent the abysmal adherence seen in other interventions.

Furthermore, demographics that tend to show disinterest in health self-management, young and self-proclaimed healthy populations, could be reached by gamification.^{22,4} Gamification increases player intention to use and adopt mHealth, especially amongst this “healthy” youth demographic,^{22,4} and one study focusing on paediatric anxiety showed that gamification led to increased usage and time spent on the associated app.¹⁵ Through motivating players to complete in-game tasks, it accomplishes psychological and behavioural outcomes by proxy. Even habits difficult to promote, such as abstinence from risky behaviours, see heightened adherence when the tasks are presented in an adequately engaging manner and are associated with reward.⁴ Interestingly, two studies offering external prizes saw few subjects redeem their earnings, suggesting that external rewards may not be required to

secure motivation in parents and youth.^{21,23} Captivating story narratives can be used as both serially delivered rewards and immersive exemplification of positive health behaviours delivered through a game medium.¹⁷ The versatility of videogame genres can lead to more individualized care, in turn supporting more sustainable behaviour.² Serious videogames demonstrate the ability to effect positive health change in physical activity as well as develop psychological elements including attention, functional knowledge, self-regulatory skill development, and internal motivation.³

Ultimately, every study evaluated in this review also reported an overall positive response by users towards the games.

2.3 – Use directly in assisting treatments

Games can assist with treatments, decreasing the direct load on healthcare workers over telehealth³ For example, the passive data recording within a game can alleviate the burden of occupational therapists.³ Re-Mission, an action adventure game supporting children with acute lymphoblastic leukemia, saw an increase in adherence to chemotherapy and a tripling of patient self-efficacy.¹ Therapeutic games can enact clinically significant reduction of symptoms.²⁴ In a study focused on mental disorders, children reported not only less depression and anxiety, but also fewer general health problems.²⁰ Tark *et al.* demonstrated an especially pertinent example of research as they compared a previous iteration of smartCAT (a technologically hosted mental health intervention) to a nascently *gamified* version, which proffered statistically significant improvements.²⁰ In longitudinal care, the process of gamification lends itself to the production of clear, well-defined goals of health.¹⁵

The wide appeal of games is conducive to the broad promotion of physical therapy and physical activity to large swaths of the population.³ Videogames such as exergames have been garnering acceptance and show promise in heightening activity levels,^{3,22,8} especially if focused on lower body exercise.¹ Cycling videogames outperformed traditional cycling training in physiological outcomes (energy use, oxygen uptake, and heartrate) for the tested populations reviewed by Warburton *et al.* (2007).³ The most researched exergames, dance-pad games, combine a strong appeal to a broad fanbase with stress, weight, fitness, and general health management.⁸ With an efficacy similar to exercise equipment, exergames may work best for rehabilitation or other specific populations.¹

Interactive games can also be used as a low-cost training program to encourage daily physical activity.³ Applications featuring GPS capabilities reward players for checking into new places, indirectly encourage physical activity and outdoor play by layering gamification overtop their location-based activities.^{15,22} These apps make geocaching, geodashing, and waymarking accessible to a wider audience and can feature custom, user-generated content.²² An excellent example of this broad appeal is Pokémon Go, an augmented reality mobile game that took the world by storm, sending its myriad players outside not only willingly but also wanting to participate.^{4,13} Games can also be augmented by equipment.^{17,16} They can be integrated with smart devices, such as smart watches and wrist-worn fitness trackers;¹⁶ however, equipment does raise the cost of implementing such interventions.¹⁷ Some digital games also are designed to include supervisory guidance, such as from parents,^{21,17} which can help mitigate negative behaviours commonly associated with videogames: excessively prolonged play, forgetting to hydrate during sessions²² sedentariness, and antisocial behaviour.¹ Furthermore, most other mediators for self-efficacious physical activity were shown to increase following gamified interventions.⁸ Although sports are often touted as preferential activities for encouraging physical activity, exergames could serve as possible alternative or augmentative interventions.^{22,8}

2.4 – Social benefit of games and to games

Games can be linked to social networking. The dynamic flexibility with which games can be designed mirrors the uniqueness of patients: facilitating self-directed goals or featuring social connections, keeping long-term goals in sight or providing instant gratification for small victories, and providing the opportunity to work competitively or co-operatively with peers.^{17,20} Multiplayer, networked games have been shown to be especially effective when compared to conventional promotions.³ Social or multiplayer console exergames also led to more energy expenditure and higher sustained heartrates than single-player experiences.²² Games provide social common ground and vicarious experiences, and that social connection in turn facilitates a greater influential effect by games on motivation.

3. CHALLENGES INHIBITING THE PROGRESS OF MOBILE HEALTH GAMES

Studies on gamified mobile health face many "firsts". Many are pioneers in selecting effective, scientifically based theories, study design formats, and result metrics. Armed with the currently meager

supporting literature, they foray into exploratory areas of research.^{26,8,2} As a result, that meager body of evidence is rapidly growing. Given that much of it appraises an immense potential in gamified, mobile interventions, the trend of mediocre, lackluster results in applied research is surprising, if not disconcerting.¹⁸ Tools with such varied and blatant benefits would be expected to present similarly stellar outcomes. However, tools are only as useful as the hands that hold them. An evaluation of the studies using these promising newcomers brings several possible, overarching causes to the surface, and provides suggestions for ways forward.

3.1 – Lack of engagement, a war of attrition

Despite the promise of increasing both intention-to-use and motivation to participate, many gamified health apps face low engagement and non-adoption.^{19,20} This attrition remained whether the subjects were clinically supervised populations or self-assessed “healthy” groups.^{19,20,22,4} While the length of interventions initially appears to be causal, as many studies claim longer interventions demonstrated less significant results, the correlation may not be as direct as at first glance.^{21,20,15,24} One study noted a novelty effect that wore off over time, leading an initially high participation to eventually drop off.¹⁷ Feedback from the subjects touted bland repetitiveness and lack of variety that led to boredom and abandonment.^{19,24,15} Child participants reported being overwhelmed by the amount of reading, calling it too much of an information dump.²⁰ Therefore, better design, such as increasing the variety of content, reimagining the presentation of information, or culling the material to consumable portions may preserve longevity. Roughly 25% of all mobile apps do not see continued operation after the first use, and only a third of users remain after a few months.^{25,5,18} This could imply that a large contingent of users base continuance on first impressions,⁵ an idea expected in such a visually well-endowed medium.^{15,16,2} This also underscores the importance of polished prototypes in intervention studies.

Social support was also shown to be beneficial to engagement. Subjects working alone showed less initiative to maintain longevity.²¹ For younger populations, support from family and friends is important. Unfortunately, eHealth interventions such as telehealth were associated with reports of decreased parental assistance.²³ Compounding this further, few apps include parents in managing their children’s health.⁵ Social validation from peer groups also greatly assisted app acceptance.^{5,1} Adolescent populations especially tended to reach out by social networking for difficult-to-discuss

topics such as mental health, preferring privacy until desperation coerced a distress signal.²⁶ Peer-to-peer instructions and active learning increased compliance and efficacy of interventions.^{17,1}

The ubiquity of smartphones also presents a surprising possible cause behind low intervention engagement: many subjects possessed personal devices separate from the mobile phones on which the treatments were delivered.¹⁵ This nullified the benefit of using a widespread medium, as patients likely returned to personal phones in later stages of the intervention, and the handiness of the app was lost.

3.2 – Widespread branching of studies, no depth of roots by research

The relative infancy of mobile app interventions means relevant studies have been very diverse, representing the beginnings of many new branches of research. Consequent heterogeneity both discourages systematic reviews due to the wild variety of interventions under the same umbrella and outright prevents meta-analyses of the same.^{6,8}

Applications were accessed in a variety of locations, with most being used in clinical settings, a few in school,¹⁷ and nearly none designed for home use.⁸ The one mobile game designed for children’s at-home use did not report significant results but was also the only intervention operating completely voluntarily.⁸ Clinical settings can affect general health, and qualitative responses can be altered by clinically associated anxiety.²⁰

Multi-component studies, which have been seen to deliver greater results than standalone apps,¹⁶ were not always applied as one intervention: RegnaTales was given in piecemeal, which limited measurement of its overall results.²⁵ Studies were delivered as solo or supplementary interventions.^{18,8} Adding games to other interventions obscures the direct effect of the gamified portion.⁸

Most research had small sample sizes, which made drawing generalizations difficult.^{21,24,3,26,15} Pramana *et al.* (2018) noted extreme outliers, as is possible with low sample numbers.¹⁵ While some studies conducted internal analyses of data, focusing on subsets reduces the total number within that evaluated sub-population.⁴ This also contributes to the limited amount of evidence on youth-related interventions, as several papers covered a spectrum of ages.

Demographic differences both amongst the study participants and amongst the studies’ sample populations further muddied conclusions.^{17,24,6,3,4}

Trends in preferences also inhibited singular conclusions. For mental health among adolescents, older teenagers with more experience with mental health struggles preferred serious and direct support resources, while younger and more naïve teenagers expressed greater interest in non-threatening, gamified approaches that normalized mental health struggles.²⁶ The latter looked to resources that focused on everyday approaches, well-being, and strengths or inspiration: content relevant to “the now”.²⁶ Feedback included the concern that highlighting disordered eating behaviours could counterproductively increase the harmful habits.¹ Similarly, invoking a purely fear-based response or focusing on punishment could produce adverse effects.^{1,2} Disorders affecting individuals such as depression can decrease compliance in the present, and habits formed in youth have been shown to develop into adulthood behaviours.^{15,20} In one study, the patient who rated the intervention the lowest also played the game the least and required a greater degree of clinical assistance.²⁰ This study also reported that boys compared to girls tended to have lower motivation and less positive attitudes towards mobile game interventions; conversely, they also displayed a greater home use, paradoxically suggesting a greater propensity for voluntary exploratory behaviour within the app.²⁰ Wildly varying preferences of individuals may contribute to difficulty in future research: creating a one-size-fits-all intervention might not be possible for paediatric populations.²⁶

3.3 – No guiding lights

No consistent guidelines exist to pilot the development of therapeutic games.^{24,5} Little is known about the mechanism by which gamification leads healthy populations to adopt healthcare apps.⁴ As of the writing of this paper, the medical community still needs to complete further groundwork and examine evidence-based theories on which to base research.^{5,16} Graafland *et al.* (2014) cites inconsistent evidence gathering as another major difficulty in conglomerating the total efficacy of mobile health games.¹⁷ Study designs included in this literature review ranged from Randomized Controlled Trials to Pre/Post-Methodological studies to Mixed Methods.²⁴ Some studies lacked controls.^{25,24} Measurement of results were similarly disparate.³ Consensus on the most pertinent evaluations of usage has not been reached, with time spent in the app, number of times accessed, and consistency of use as potential candidates.²⁰ Logistics surrounding the supplementation of therapy with mHealth can limit adequate blinding of researchers.⁷ The lack of unified standards is underscored by the erratic

findings. One sedentary, education-focused game led only to marginal results.⁸ A study on personal management of Type 1 Diabetes resulted in greater self-care and satisfaction while lacking clinically significant improvement, and a separate study on paediatric mental health noted little change in psychological benefit and no statistically significant improvement to sleep.^{23,20}

Basis in theory is important, as changes in knowledge were shown to not automatically equal changes in behaviour.^{21,1} Out of 57 paediatric weight management apps examined by Schoffman *et al.* (2013), 61% did not use evidence-based strategies, few targeted families, and the most scientifically grounded apps were the least popular amongst users.⁵ For mental health apps, less than 3% were backed by psychological theories.²⁰ Compounded onto that, many theories used in health interventions fail to include context and reflection.⁵ Many theories are static and do not have a consistent, explicit translation into methodology.⁵ Even when theories are applied, research or otherwise, they are not applied consistently.²² The lack of guiding theories has led most research to focus more on external metrics, such as effects on pain, impact on physical activity, or mastery of material, and less on psychological mediators.⁸ Existing intervention development frameworks have been called incoherent, uncomprehensive, and devoid of supporting behavioural theories.⁵

The short-term nature of almost all research on mobile health may have precluded the observation of long-term changes.^{17,20,18,16} One study was limited to only preliminary effectiveness due to time restraints.²⁰ Habit formation time is a unique quality of each particular user and must be taken into consideration when designing interventions.²⁰

3.4 – Lack of experience with gaming elements

Inexperience plagues many studies. Researchers occasionally conducted research in a way that was counterproductive to accurate understanding of the results. One study admitted the need to conduct a more complete evaluation of outcomes and that the initial metrics were insufficient.²⁵ In other trials, confounding factors such as external prizes were included.^{21,23} Despite the scarce prize redemptions, this still may have distracted from motivation stemming solely from in-game rewards. One study made a “behavioural contract”, exchanging adherence for fewer reminders from the healthcare worker; this obscured the effect of the app on protocol compliance.²³

Player motivation is complex, consisting of not only extrinsic but also intrinsic rewards, and

obscuring this critical interplay can lead to the haphazard, ineffectual insertion of gamified elements without potency.^{17,24,20,4}

One study, focusing on teaching self-management of anxiety, reported no significant differences between the designed intervention and control games.²⁴ At first glance, this stands as evidence against the benefits of pairing health education with games; however, the intervention in question was unsuitably unlike the control game.²⁴ Because one of the metrics was anxiety reduction, the time-pressured, reaction-based intervention was not a valid comparator to the free-form, creativity-based puzzler control.²⁴ As emotional exposure was part of the scientific design of the study, this shortcoming most likely stemmed from a lack of familiarity with the gaming experience, and it led to a viewpoint which leaves undetermined whether *designed* health games add something greater than a benefit intrinsic to games themselves.²⁴

In a study focusing on adolescents, researchers noted that older teenagers displayed a greater response to the interventions than younger counterparts.¹⁸ Initially, this appears to suggest that initiatives would be most effective if focused on later stages of adolescence; however, both the nascency of mobile game health research and the concurrent dearth of studies covering paediatric responses leave open the possibility that intervention designs themselves are the cause of this.^{18,16} For example, younger children were observed to struggle with not only the volume but also the complexity of information provided within the apps.²⁰ Kamel Boulos *et al.* (2015) suggest that framing terms and concepts such as “behavioural goals” differently such as under the label of “missions” also help to better convey objectives to patients.¹⁷

Commercially developed games, including Dance Dance Revolution, Wii Sports, and Wii Cardio Games, proved most effective in increasing self-efficacy.⁸ While benefitting from industry-driven resources, such as a projected market value in the billions,¹ these industry-based games potentially demonstrate the lacking element in research-generated interventions.⁸ Well-designed games inherently possess an ability to motivate players, and this polish is too often missed in “edu-tainment” games.²⁴ The label “educational” itself can evoke reactions of distaste.²⁵ Another aspect of design that also escapes current methodology is the full range of gamification: developers are not limited solely to exergames for promoting physical activity, for example. A sedentary game analyzed by Pakarinen *et al.* (2016) produced marginal results;

however, it was also the *only* example of a sedentary game aimed to increase physical activity.⁸

Research would benefit greatly from taking and applying practical lessons learned by industry.⁵

3.5 – Fear of a pay-to-win system

Although cost-effectiveness is touted as a benefit of mHealth initiatives, the need for expertise not only in health subjects but also mobile and game design raises the question of true resource expenditure.^{6,4} Many apps available to consumers are not necessarily based on scientific foundations, leading to both unregulated apps and costs that could inhibit actual benefits to users.^{6,18} When mHealth adjunctive measures are added to patient care, they also require facilitator familiarity with technology, which increases the human resources burden.³ Relevant technology also advances more quickly than concurrent intervention development, presenting a constant struggle against obsolescence.⁵ The time-cost of setting up specialized control configurations for unique user needs in cases of disability can also be substantial.³

One systematic review noted that industry videogame development can stretch out to three or more years and cost millions of dollars.³ Publisher funding and upfront investments are feared to outweigh the cost of the “normal”, conventional interventions.¹ The daunting resource requirement might make future, potential researchers shy away from the promised opportunity offered by mobile gamification. First of all, in response, this cost must be viewed in light of the magnitude of preventable health challenges, whose shadow is only magnified by the resources already thrown into attempting to buoy ineffectual, conventional efforts.^{27,17,3} Secondly, the conception of an inevitable, insurmountable cost stems from unfamiliarity with the modern games market. Although big budget, so-called “Triple A” games can call for sizable expenditures of resources, independent or “indie” developers represent an ironically substantive segment of the game development community. These smaller and occasionally solo creators have created very successful titles at fractions of the aforementioned, formidable budgets.^{28,29} Polished digital platforms do require resource investment, but good design is not a zero-sum game.

3.6 – Imperfect assistance

Researchers recommend that input from target populations, in spite of possible inexperience with design, be included in creating interventions.⁵ This is called co-design.¹⁹ Most research is done from clinicians’ perspectives, which can miss concepts

critical to paediatric populations.⁴ Nevertheless, co-design, while useful,¹⁹ can be inconsistent and has limited evidence of effectiveness.²⁶ It relies on the input of those surveyed, introducing bias from things such as personal tastes or social pressure when providing feedback “in the presence of a clinician”.^{24,26} Fleming *et al.* (2019) conducted a preliminary scoping of adolescent Internet use and noted a strong diversity of preferences among youth, which may have contributed to the erratic engagement response in intervention studies.²⁶ Self-reporting also introduced bias, both in initial designation and in results.^{18,4} Personality Theories suggest that the gap in intervention research is the unknown effectiveness with respect to unique, individual personality traits.² For example, in promotion of general diet health, researchers noted that unhealthy eating is often more hedonic than hunger-related, which changes the approach needed to support healthy eating habits.²

3.7 – Other Pitfalls

While the effect on health and behaviour changes is clinically measurable, evidence conflicts when comparing the actual benefit to the health hazard of introducing mobile applications to paediatric populations.²⁴ The dearth of studies on mobile gamification of health brings difficulty amplified by the low to middling quality of much positive evidence; this brings into question the value of even pursuing further research.⁸ E-Health initiatives are governed by technology limitations – exergames often are bound to consoles and monitors; GPS capabilities are curtailed by the underground, malls, and even foliage; and auto-generated games can create unforeseen safety risks.²² If paired with location-based games, applications could send people to dangerous areas. One app had a bug that generated an in-game black box in a Disney park, causing a bomb scare.²² Location privacy is also an important consideration, requiring not only careful forethought for servers but also stringent vigilance if an intervention is targeted at paediatric populations.²² As with any program-based technology, malware must be circumvented as well.²² Finally, game apps could rapidly deplete phone batteries, decreasing longevity of use.³

Nevertheless, the inadequacy of conventional interventions, the tantalizing potential of mHealth combined with game elements, and the clearly avoidable pitfalls make research endeavours of mobile health games worthwhile.

Discussion

The ubiquity of smartphones lends the platform to the rapid distribution and easy access of health support to broad swaths of the population.

Circumventing the top-down, didactic nature of many conventional initiatives, the familiarity of mobile devices encourages engagement and independent, participatory healthcare, particularly for younger demographics. Owing to the ability to directly communicate with peers, smartphones can facilitate social connections and thusly bolster engagement. If contemporary health promotion takes advantage of currently available technology, future initiatives will have the ability to accompany upcoming scientific advances.

Alongside mobile devices, the incorporation of game elements and game design carries the potential to appeal to widely varying youth populations and cross-cultural demographics. Gamification increases both motivation for and adherence to healthy practices both through motivating elements inherent to games and a sense of community built by sharing challenges, advice, and accomplishments. The flexibly programmable nature of videogames requires creatively applied manifestations, allowing it to not only assist directly with specific therapeutic tasks, but also unique, individualized, long-term healthcare plans.

Attrition and the difficulty with designing readily accepted games present a challenge for future researchers. As the exploration of mobile gamification deepens, the resultant research needs to set the foundation on which the next generation of studies will build and thrive. Presently, the field is rife with the beginnings of many subset branches which focus on particular areas, creating a feeling of wild, untamed disunity. This has consistently curbed efforts to systematically review and analyze results. While researchers examine supporting theories, study designs, and summative data collection practices, a sense of guiding principles hopefully will soon surface: the lack of these makes development of therapeutic games a game of educated trial and error. However, this can be expected in such a nascent field of research. One of the most avoidable inhibiting factors is inexperience with game design and the gaming experience. Researchers well-versed with what “works” in games will circumvent game-related pitfalls associated with less effective study design. They will incorporate the complexities of player-game interaction as theories underpinning motivation and engagement are explored. Along with this familiarity, a better understanding of necessary costs associated with developing effective and top-notch gamified interventions will manifest. Co-design and other participatory efforts need to be implemented with inclusivity and clarity. Finally, as with all technology-related endeavours, precautions need to be executed to mitigate factors relevant to ICTs.

Conclusions

Because of the opportunity afforded by mobile technology and gamified health, future initiatives should take full advantage to increase both adoption and engagement, adherence and motivation, and autonomous, individualized healthcare. To achieve meaningful results, further research is needed to lay the foundational theories and centralize guidelines for effective intervention development. This also will allow for better prognostication of the potential of mHealth games, as meta-analyses then can be performed. As the number of good quality studies using ICT mediums grows, the pitfalls and challenges associated with technology implementation will be mitigated and circumvented. The judicious use of feedback from test populations will lead to more effective designs, facilitating improvements such as the following: customizable, personalized content, age-accessible health modules, peer-to-peer encouragement, in-game tutorials and guides, and an engaging, enjoyable variety of content.^{19,4} The refinement that will produce the greatest change in efficacy is improved health intervention game design. Proactive, organic resources will prove more effective than contrived, one-size-fits-all measures.^{3,26} Currently, much of the struggle with non-adoption, ambivalence, and abandonment of mobile health apps seems to stem from bland and boring content. As player interaction with games is complex, health interventions cannot simply cut-and-paste gamified elements into health education, and the newness of applied gamification is starkly apparent. Researchers need to be willing not only to invest more effort and resources into improving intervention interfaces and information delivery, but also incorporate the polish and "fun" honed by the games development industry. This is not to say that commercial initiatives are the limited future of digital health platforms. Rather, the failure of

conventional health initiatives demands a willingness to pioneer new strategies, experiment with promising mediums, and implement the most effective innovations for the next generation of mobile health interventions and the next generation of youth.

Limits

Despite rigorous search methodology used to promote objective inclusivity, the selection process still carried bias when selecting by subjective relevance. This was mitigated by the strict adherence to three relevance points (mobile health, gamification, and paediatric populations).

Three databases were used, and research from other databases could have been missed. As much on the topic is pioneering work, all the studies were within the past decade and refer to similarly contemporary, previous literature. No oldest date bookending the research was chosen because of this. The newness correlates to a small, albeit growing, body of evidence.

As the impact factor threshold was above two, smaller journals might have been overlooked. Conversely, the low number of included studies also demonstrates the lack of attention given by larger journals, underscoring the recency of the field. Proceedings papers were excluded, which could leave out data as well.

Most journals also focused on applications targeted at specific demographics or treatments and were difficult to generalize.

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