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Original Article

Promoting Daily Physical Activity by Means of Mobile Gaming: A Review of the State of the Art

Monique Tabak, PhD,[1,2] Marit Dekker-van Weering, PhD,[2] Hylke van Dijk, PhD,[3]
and Miriam Vollenbroek-Hutten, PhD[1,2]

Abstract

Objectives: To review mobile games and gaming applications that claim to improve physical activity behavior in daily life.

Search Methods: We searched PubMed, Web of Science, and the ACM Digital Library and performed a manual search of relevant journals and reference lists. Studies that reported on a mobile game that requires players to perform physical activity in daily life and where the game has specific goals, rules, and feedback mechanisms were included. This excludes non-mobile exergames. Theoretical foundations, game characteristics, and evaluation methodologies were assessed.

Results: In total, 797 articles were identified through the search, of which 11 articles were included. The reviewed studies show that there is limited theoretical foundation for the game development, and most studies used goal setting as a motivation strategy to engage people in playing the game. There was a large variety in game characteristics found, although the majority of the studies used metaphors or avatars to visualize activity, whereas feedback was mostly provided in relation to the goal. Rewards and competition were the most commonly incorporated game elements. The evaluations were focused on feasibility, and clinical evidence is lacking with only two randomized controlled studies found.

Conclusions: This review provides a first overview of mobile gaming applications to promote daily life physical activity and shows this as a new research area with demonstration of its acceptability and feasibility among the users. Clinical effectiveness and the added value of gaming in changing daily activity behavior have by far not yet been established.

Introduction

Regular physical activity is related to better health and lower mortality and could reduce the risk of (chronic) diseases like coronary heart disease, type 2 diabetes, and some cancers.[1,2] However, two-thirds of the adult populations of European countries are insufficiently active to support physically healthy living.[3] Reviews, moreover, show that treatment programs that aim to reduce inactive behavior and increase physical activity in adults are only marginally effective.[4,5] In these programs, objective measurements of activity are mostly lacking, and persons do not receive feedback and coaching in daily life, only at regular encounters with the healthcare professional. Cognitive behavioral models explaining behavioral change indicate that persons need to be aware of their activity behavior; otherwise, treatment is unlikely to be effective.[6]

Recent advances include the effective use of mobile technologies (e.g., smartphones and activity sensors) to promote a physically active lifestyle.[7] These applications can be especially suitable to provide real-time support and as such improve awareness of activity behavior throughout the day. Text messaging is the primary technology used, for which short-term benefits are reported that could be clinically significant if sustained in the long term.[8] The concept of more comprehensive feedback (e.g., real time and with motivational cues) has recently been investigated among users with chronic low back pain,[9] chronic fatigue syndrome,[10] and chronic obstructive pulmonary disease.[11] Results show that users significantly respond to the feedback, but these applications are still not sufficiently effective as compliance to this feedback decreases over time,[10] and changes in activity behavior seem to diminish after a few weeks of use.[12] Studies have shown that use of an application

[1]Telemedicine Group, Faculty of Electrical Engineering, Mathematics and Computer Science, University of Twente, Enschede, The Netherlands.
[2]Telemedicine Group, Roessingh Research and Development, Enschede, The Netherlands.
[3]Serious Gaming Group, NHL University of Applied Sciences, Leeuwarden, The Netherlands.

significantly relates to improvement in health outcomes,[12,13] and engagement in the technology thus seems important.

The incorporation of motivational strategies by the use of game design has been shown to have a positive effect on motivation and engagement.[14] The numbers of publications on games that aim to stimulate physical activity have been rapidly growing in the past years. However, the majority of these games concern non-mobile ''exergames,'' which focus on exercise sessions to be executed at home or at a rehabilitation center.[15] Although these are positively received, they fail to accomplish the transfer of physical activities to daily life (e.g., gardening, walking) and thus in changing actual activity behavior in the long term. To achieve this, gaming should go beyond the walls of the home or care center into the users' everyday lives, where real-world activity can interact with a game.[16] These games are not as common as exergames but are the up and coming focus of mobile technologies, increasing in both research and commercial areas.

We would expect that mobile games could have an added value in changing daily activity behavior compared with non-game interventions as mobile gaming (1) triggers activity throughout the day given players' actions, (2) enables advanced awareness and personalization, which are important aspects in behavioral models, and (3) enables increased engagement in using technology by applying game mechanics. However, no reviews exist that provide an overview of mobile games that aim to improve activity behavior in daily life. Therefore, this review reports on such state-of-the-art mobile activity games and reviews the following:

- theoretical foundations—from the point of view of both behavioral science and game design,
- game characteristics, such as the applied feedback mechanisms, and
- evaluation methodologies.

Materials and Methods

Selection criteria

The scope of the review includes scientific publications that involve mobile games or gamified applications that aim to improve daily physical activity in everyday life (i.e., focus on opportunistic physical activity),[17] excluding structured exercise (i.e., exergaming). For this review we follow the definition of McGonigal[18] to define a game or gamified application: a game identifies goals defining what the player is expected to do (i.e., save the world, solve the mystery, etc.); using actions regulated by a framework of rules; a feedback system that lets the players know how they are doing; and voluntary participation, so it is experienced as a safe and pleasurable activity. In addition, studies should include an evaluation of the mobile game or gamified application. As this research area is still in its infancy, we report on all scientific publications, including noncontrolled trials and early-phase pilots.

Search procedures

A systematic search in literature databases (PubMed, Web of Science, and the Association for Computing Machinery [ACM] Digital Library) was performed. Articles in English or Dutch published between January 2004 and June 2014 were included. Key terms used in an array of arrangements with Boolean operators to conduct searches were as follows: ''game'' or ''persuasive'' or ''play'' AND ''daily activity'' or ''physical activity'' AND ''mobile'' or ''ambient'' or ''ubiquitous'' or ''ambulant'' or ''daily life.'' Medical subject heading terms were used in PubMed. The thesaurus available in Web of Science and ACM was used to ensure that relevant key words were properly searched in each database. In addition, a manual search of relevant journals was carried out up to July 2014. Finally, the reference lists of the included studies were scanned to find further potentially relevant studies.

Data collection and extraction

The initial screening was based on the titles and abstracts against the inclusion criteria to identify possible relevant studies. Next, the relevant articles were screened based on their full text for final inclusion, done separately by M.T. and M.D-v.W. Possible disagreements about study inclusion were discussed among the authors. For data extraction, two review tables were constructed. The data extraction was again conducted by the same reviewers (M.T. and M.D.-v.W.).

The first table focused on the theoretical foundations (behavioral and gaming) and game characteristics (description, goal setting in relation to physical activity, game elements, and feedback mechanisms). For the game elements, we used the ''Ten Ingredients of Great Games''[19]: (1) self-representation using metaphors or avatars, (2) three-dimensional environments, (3) narrative context, (4) feedback, (5) reputations, ranks, and levels, (6) marketplaces and economies, (7) competition under rules that are explicit and enforced, (8) teams, (9) parallel communication systems, and (10) time pressure. Feedback mechanisms were categorized according to the framework of Dunwell et al.[20]: ''a framework for the consideration of feedback in serious games,'' which is an adapted version of the classification of Rogers[21] of feedback types. These feedback types are feedback on status or scores (current and/or historical), feedback on (goal) progression (current and/or historical), feedback to encourage, feedback with a user interaction model, and feedback with experience to understanding.

The second table focused on the evaluation methodology with the following categories: study characteristics (purpose, setting), sample characteristics (target group, sample size, age), and evaluation stage. For the latter, we used the Staged Approach to evaluation of telemedicine of DeChant et al.,[22] which suggests tailoring the type of assessment to the development cycle of the technology. Broadly, the framework differentiates between technology evaluation at application levels (Stage 1–2) and global levels (Stage 3–4). Outcomes of evaluation can be expressed in terms of a potential to increase accessibility, to improve quality of care, or to decrease costs. Articles were assigned to one of the DeChant stages as follows:

- Stage 1: Technical efficacy (assess accuracy, reliability, and usability)
- Stage 2: Specific system objectives (assess single end points of access, quality, or cost)
- Stage 3: System analysis (assess global impact on access, quality, and cost)
- Stage 4: External validity (as in Stage 3 but applied in a different system)

Results

In total, 797 articles were identified through the database search. After title and abstract were reviewed, 40 articles were considered for full review. In addition, seven articles were identified from reference tracking and searching relevant journals. Finally, 11 studies met all inclusion and exclusion criteria as described in the flow diagram of the inclusion process (Fig. 1) and were included in this review. The main reason for studies to be excluded was that the application did not include a game goal or gaming rules or did not focus on daily life activities, but rather on specific movements/exercises. The included studies[23–33] were published between 2006 and 2014, and most of them within the last 5 years. Each of the studies described the evaluation of a distinct game concept for promoting physical activity in daily life.

Theoretical foundations

Table 1 shows limited theoretical foundation for the game development in the included studies. In Xu et al.,[32] their game was founded on the ecological model of health behavior change for physical activity of Sallis et al.[34] Instead of treating health behaviors as personal responsibilities, ecological models emphasize the environmental, social, and policy contexts of human behaviors. Other studies used parts from theories or models for their game design. Rodríguez et al.[29] used triggers for physical activity, based on the behavioral model of Fogg,[35] and incorporated historical information and reflection, based on the Cognitive Dissonance Theory, to help the user to remain focused on the commitment to change by making him or her aware of past behavior as it relates to set goals. Both Munson and Consolvo[28] and Zuckerman and Gal-Oz[33] incorporated goal setting as a design element in their applications, thereby referring to the Goal Setting Theory.[36] Zuckerman and Gal-Oz[33] in addition incorporated two gamification elements to identify their effectiveness: virtual rewards, as they can reduce intrinsic motivation according to the self-determination theory, and social comparison, thereby referring to Festinger.[37]

Game characteristics

Table 1 shows the game characteristics of the 11 games from the included articles. All studies focused on activity behavior, the one more in general and the other more specific, such as increase in number of steps. The majority of the games were played on a mobile phone alone[23,25,26,28,29,33]; of the remaining games evaluated, one was with connection to a computer display,[24] versus others on a computer display alone.[27,30–32] Some applications made connection to third parties (like Facebook).[24,28] Activity was designed to be

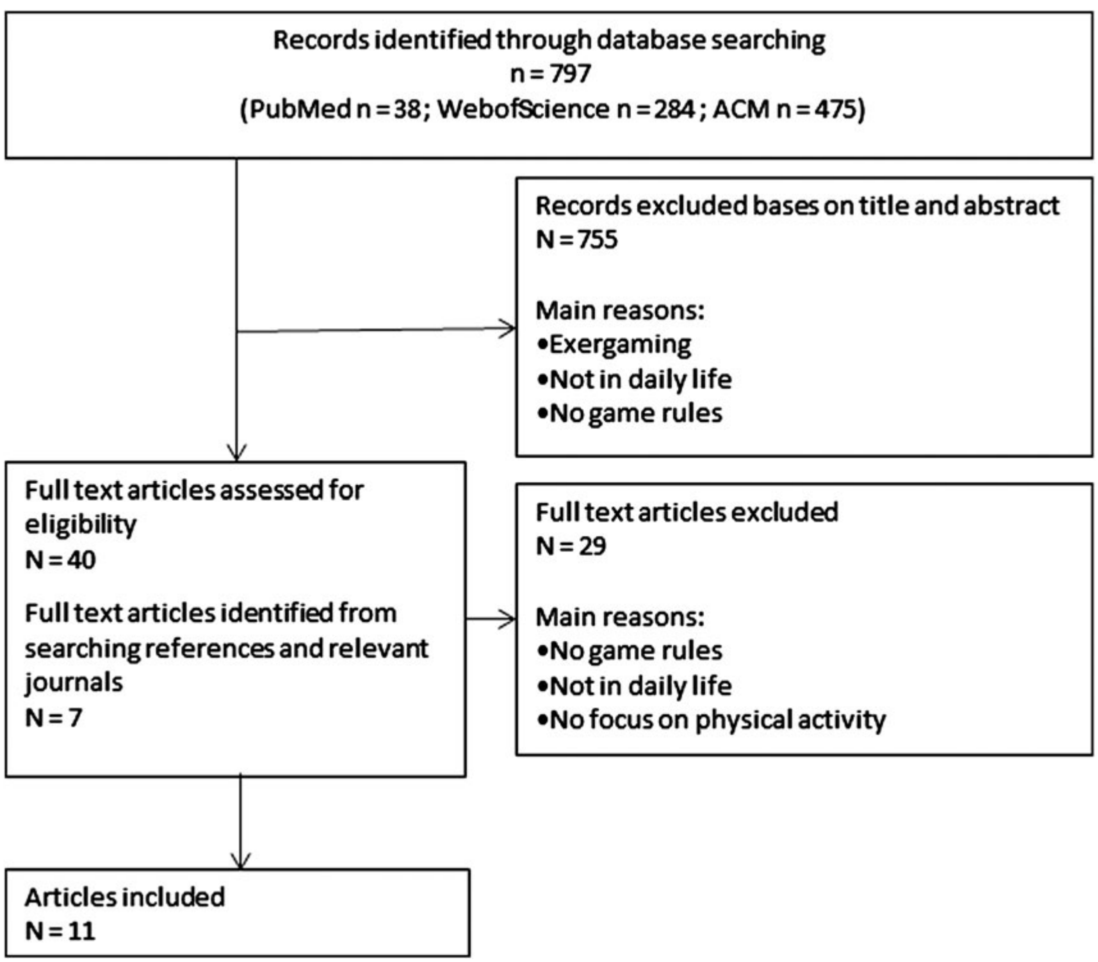

FIG. 1. Flow diagram of inclusion process. ACM, Association for Computing Machinery.

Table 1. Theoretical Foundations and Game Characteristics

Reference (year)	Game	Theoretical foundation	Game characteristics: Description of the game	Game goal relative to PA	Game elements[a]	Feedback mechanism[b]
Athinen et al.[23] (2010)	"Into"	Not stated	Users set challenge and travel on a map based on their step count. PA is visualized as a virtual trip on a map. Play alone or on a team	Challenge by user (e.g., from Helsinki to Tampere)	Use of metaphors Teams/cooperation Competition Rewards	• Feedback on status (current) • Feedback on progress (current)
Bielik et al.[24] (2012)	"Move2PlayKids"	Not stated	Personalized activity recommendation for children using an avatar, with monitoring application for parents	Rule-based PA recommendation as daily/weekly plans	Competition Sharing (social network) Levels Teams Rewards Avatars	• Feedback on status or scores (current) • Feedback on goal progression (current and historical)
Fujiki et al.[25] (2008)	"Neat-o-games"	Not stated	Player chooses a couch avatar. When the player moves, the avatar moves, and activity points are accumulated. Players can compete with opponents for activity points.	—	Competition Avatars Rewards	• Feedback on status or score (current and historical) • Feedback to encourage
Jensen et al.[26] (2010)	"PH.A.N.T.O.M."	Not stated	Mixed reality game merging real everyday life with the game world. The player is put in a role of an agent working undercover as a student at a university.	Mission to complete with three objectives and a bonus task	Use of metaphors Narrative context (storyline) Rewards Competition Ranks Levels Time pressure Bonus task	• Feedback on goal progression (current) • Feedback on status and score (current)
Lin et al.[27] (2006)	"Fish'n'Steps"	Not stated	The number of steps is mapped to the growth and emotional state of a fish in a fish tank.	Overall goal in step count based on baseline step count (pre-intervention 4 weeks)	Using metaphors Teams/cooperation Competition between teams Parallel communication Ranks	• Feedback on status or score (current) • Feedback on goal progression
Munson and Consolvo[28] (2012)	"GoalPost/ GoalLine"	Goal Setting Theory (partly)	It supports setting weekly PA goals, journaling PA, receiving virtual rewards, and reviewing past progress.	Users set primary and secondary goals for a calendar week. Goals are broken down by category.	Rewards Reminders Sharing	• Feedback on goal progression (current and historical)
Rodríguez et al.[29] (2013)	"CAMMInA"	Cognitive Dissonance Theory Behavioral model of Fogg[35] (partly)	Provides elders with notifications and representations of their PA performance	Setting a goal in time for exercising	Use of metaphors Rewards	• Feedback on status or score (current) • Feedback to encourage • Feedback on goal progression (current and historical)

(*continued*)

Table 1. (Continued)

Reference (year)	Game	Theoretical foundation	Game characteristics: Description of the game	Game goal relative to PA	Game elements[a]	Feedback mechanism[b]
Stanley et al.[30] (2008)	"RealTime Chess"	Not stated	Real-time multiplayer videogame, allowing 2–32 players to play chess at their own computers. Not turn-based, but pieces should be moved as quickly as possible. Daily activity influences player strategies for the chess game.	—	Rewards Competition Teams	• Feedback on status or scores (current)
Walsh and Golbeck[31] (2014)	"StepCity"	Not stated	A social game that uses FitBit steps as currency. Players can buy buildings in their city that produce gold and increase population. Low-cost buildings have more crime.	—	Use of metaphors Leaderboard Parallel communication Market places	• Feedback on status or scores (current)
Xu et al.[32] (2012)	"American Horsepower Challenge"	Ecological model of health behavior change for PA (Sallis et al.[34])	A pedometer-based pervasive health game. Student can earn points for their school by PA. Step counts are aggregated daily, and position on the racetrack was updated. Schools are presented as school busses on racetracks, and students as horse avatars. The avatar is customizable by the virtual currency (earned by PA).	—	Use of metaphors Competition Teams/cooperation Rewards Avatars Ranks Market places (virtual currency)	• Feedback on status or scores (current and historical)
Zuckerman and Gal-Oz[33] (2014)	"StepByStep"	Goal Setting Theory (partly) Self-Determination Theory (partly) Social comparison	Accelerometer-based mobile application intended to motivate people to incorporate more walking in their daily routine	Daily walking goal set by the participant; if it is reached 3 days in a row, a message suggests a 10 percent increase.	Rewards Ranks (social comparison/ leaderboard) Competition	• Feedback on goal progression (current) • Feedback to encourage • Feedback on status or score (current)

[a]Game elements[19] (i.e., self-representation using metaphors or avatars, three-dimensional environments, narrative context, feedback, reputations, ranks, and levels, marketplaces and economies, competition under rules that are explicit and enforced, teams, parallel communication systems, and time pressure).
[b]Feedback mechanisms[20] (i.e., feedback on status or scores, feedback on [goal] progression, feedback to encourage, feedback with a user interaction model, and feedback with experience to understanding).
PA, physical activity.

assessed by the built-in sensors of the mobile phone[23,24,29,33] or by a separate pedometer[27,32] or accelerometer,[25,30,31] by monitoring GPS data,[26] or by adding activities in a physical activity journal on the phone.[28]

Most studies (63 percent) used goal setting as a motivation strategy to encourage physical activity (e.g., step count, time for exercising). Four studies did not use any goal setting in relation to physical activity.

The present review shows a large variety of gaming concepts, with a minimum of two game elements[29] and a maximum of nine[26] used. Rewards and competition are the game elements that were used the most by the studies: 81 percent and 72 percent, respectively, of the studies. Most studies (72 percent) used metaphors or avatars to visualize activity. For example, Lin et al.[27] presented the level of physical activity with a bowl of growing fish, whereas Fujiki et al.[25] used a couch avatar, which is a caricature of a well-known athlete, politician, or actor.

In most studies, feedback on status or scores and feedback on goal progression as feedback mechanisms are used together. They provided real-time feedback based on current physical activity status in relation to the goal setting. Only a few[25,28,29] showed historical information on goals reached in the past. Few included encouraging feedback.[25,29,33] For example, Fujiki et al.[25] sent an alert to the player when the opponent was too far ahead or a congratulatory message when the player was far ahead. Only two studies[25,32] showed feedback on received scores in the past. For example, Xu et al.[32] showed the step history.

Evaluation

The included studies targeted children,[24,32] the elderly,[29] the general public,[31] colleagues,[25,27] university students,[26,30,33] Facebook members,[28] or persons who are in the same social groups.[23] Sample size ranged from 8 to 1743 participants, with a median of 19. The interventions ranged from a single gameplay session[24,26,29] to multiple days[23,30,33] or weeks[25,27,28,31,32] of use, with a median use of 10 days (range, 1–98 days).

As shown in Table 2, the majority of the studies reported on a Stage 1 evaluation study,[23–26,28–30] focusing on usability, feasibility, or acceptability. Usability and acceptability were mainly assessed using interviews or questionnaires. Four studies investigated whether the game could meet the system's objectives (i.e., the effect on behavioral change,[27] the adoption in the real world,[32] the change in physical activity,[31] and walking behavior[33]) and are thus considered a Stage 2 evaluation. For this, two studies used a randomized controlled design: within-subjects (three conditions)[31] and between groups (three conditions),[33] where in both studies a condition was applied for a 10-day period. Lin et al.[27] randomly assigned participants to a team condition or a single player condition but did not have a control group without game elements, whereas Xu et al.[32] had a mixed methods approach. For all Stage 2 studies we could observe that the evaluation methodology was scarcely described, lacking information about, for example, data and statistical analysis, randomization procedure, blinding, or power calculation.

Outcomes

The two studies with a randomized controlled design[31,33] showed no effects for activity behavior based on the condition. In other words, the addition of game elements did not have a beneficial effect in these studies. In the study of Walsh et al.,[31] further analysis showed that newer Fitbit (Fitbit, San Francisco, CA) users took more steps when using the ''StepCity'' game than they did in a control condition, although trending ($P = 0.09$).

Discussion

The present review provides an overview of current mobile games that aim to improve activity behavior in daily life, with regard to the applied theoretical foundations, game characteristics, and evaluation methodologies. Eleven studies were included.

This review shows limited theoretical foundation for the game development for the majority of the mobile games. Instead, most used parts of theories or looked into useful design strategies from existing physical activity applications. For example, Bielik et al.[24] identified key design requirements based on three literature reviews, which resulted in a system that applied several intrinsic and extrinsic motivational factors. However, literature suggests that interventions that are based on behavioral theory or use tailored feedback based on behavioral theories show significantly larger effect sizes than interventions without theory foundation.[38,39] Using health behavior theory to guide intervention design may thus increase intervention effectiveness.[40] Indeed, in our review, the theory-based ''American Horsepower Challenge''[32] showed a significant increase in physical activity compared with baseline, although with a small effect size. Achterkamp et al.,[41] who analyzed data from participants who used an ambulant activity coach in daily life, suggested that especially self-efficacy and stage of change (part of the Transtheoretical Model) are two aspects from behavioral change theories that appear important when developing technology-supported physical activity interventions. As such, we would expect that the incorporation of behavioral theories similarly applied in technology-supported physical activity interventions could positively contribute to the effects of mobile games in changing physical activity behavior. Research into motivational theoretical models for games would be an interesting path to continue research and design methodologies.

Goal setting was a common element in the design of the games in our review, and research regarding physical activity interventions already showed that combining goal setting and (persuasive) technologies can significantly improve the results of interventions that focus on physical activity.[42] Goal setting enables the player to extrapolate what is learned in the game to his or her own real life.[40] Rodríguez et al.[29] incorporated historical information and reflection, to help the user to remain focused on the commitment to change by making him or her aware of past behavior as it relates to set goals. This largely resembles the Goal Setting Theory, in which goals have been shown to be most effective when they are important to the individual, realistic, shown in relation to the user's progress, and combined with positive feedback as progress toward the goal is made.[36] Zuckerman and Gal-Oz[33] showed that offering continuous measurement of walking time, a daily goal, and real-time feedback on progress toward this goal facilitated reflection on activity and significantly increased walking time over the baseline level.

Table 2. Evaluation Stage and Evaluation Study Design of the Included Games

		Study characteristics		Sample characteristics			
Reference (year)	*Game*	*Purpose of study*	*Setting of study*	*Target group*	*Sample size*	*Age (years) [mean (range)]*	*Evaluation stage (DeChant)*
Athinen et al.[23] (2010)	"Into"	Examine participant's subjective responses toward "Into," focusing on PA as a virtual trip	Team with a team leader who sets challenges	Existing social groups	37 (31 females, 6 males)	(20–55)	Stage 1
Bielik et al.[24] (2012)	"Move2PlayKids"	User testing	Primary school	Children 10–18 years old	12	(12–13)	Stage 1
Fujiki et al.[25] (2008)	"Neat-o-games"	To investigate trends in behavioral change	Daily life	Colleagues in the same organizational unit	10 (8 females, 2 males)	37.9	Stage 1
Jensen et al.[26] (2010)	"PH.A.N.T.O.M."	To evaluate the user experience and persuasiveness of the game	In the field	Students of the campus	9 (all men)	—	Stage 1
Lin et al.[27] (2006)	"Fish'n'Steps"	To evaluate the effect of "Fish'n Steps" on behavioral change	Daily life	Staff of Siemens corporate research	19	(23–63)	Stage 2
Munson and Consolvo[28] (2012)	"GoalPost/ GoalLine"	To investigate how people respond to the four strategies	Daily life	General public with active Facebook account and iPhone, who were in the contemplation, preparation or action phase (TTM)	23	(20–50)	Stage 1
Rodríguez et al.[29] (2013)	"CAMMInA"	To evaluate the persuasive strategies used in "CAMMInA"	Senior center	Elderly	15	(63–86)	Stage 1
Stanley et al.[30] (2008)	"RealTime Chess"	Investigate how to effectively integrate accumulated context into play environments	Daily round-robin tournament. Paired with a different teammate for each session. Interview after each play	Local university	8 males	23 (19–34)	Stage 1
Walsh and Golbeck[31] (2014)	"StepCity"	To investigate whether (1) a social game and (2) simple interaction experience encourage users to take more steps than otherwise	Daily life	Not stated	74	37.7 (23–63)	Stage 2
Xu et al.[32] (2012)	"American Horsepower Challenge"	To study how pervasive AVGs are adopted in the real-world context	Inside and outside school	Middle-school students	1743	(10–13)	Stage 2
Zuckerman and Gal-Oz[33] (2014)	"StepByStep"	Systematically evaluate the effectiveness of several gamification elements	Daily life	Undergraduate communications students	59 (44 females, 15 males)	23.4 (20–27)	Stage 2

AVG, active videogame; TTM, Transtheoretical Model.

Such examples also show the evident overlap between game characteristics and behavior change techniques. As this is both theory-founded and has been shown to be an effective component of interventions to promote physical activity, self-monitoring, goal setting, and encouraging feedback should preferably be combined in mobile gaming applications that aim to promote physical activity. We would expect that by including behavioral aspects into the game of an individual player, adapted to, for example, self-efficacy, this could probably create a game that is more effective.

To increase the motivation of the user to engage with the game, the reviewed studies included two to nine game elements. Metaphors or avatars are commonly used to represent the monitored activity to the user. The use of metaphors and avatars is common and reasonable in game design, but also in persuasive design: showing physical activity levels as, for example, a flower,[43] a garden,[44,45] or art.[46] Such metaphorical displays are in general well accepted and positively received.[43–47] Lin et al.[27] specifically showed that exhibiting activity through the growth and emotional state of virtual fish indeed increased users' awareness of their levels of physical activity and increased their motivation to exercise. As abstract presentations of activity (e.g., by a graph) have shown a decreasing adherence after a few weeks of use,[12] such metaphors seem a promising tool for motivation in mobile gaming applications.

The review shows that virtual rewards and social comparison (competition) were the two most commonly implemented elements. Zuckerman and Gal-Oz[33] investigated the added value of these two gamification elements in their application but did not find a significant contribution of the game elements. Reeves and Read[19] distinguished 10 game elements, but this does not mean a great game should contain all elements; this could even be an overload. To our knowledge, clear recommendations on what game elements are most suitable to increase engagement with a mobile game are not yet available. As mentioned elsewhere,[33] most systems are evaluated as a whole, and different elements of the applications then confound. Systematic evaluation of the effectiveness and added value of game elements for better understanding their motivational contributions should be an important field of research.

The majority of the evaluations of the reviewed studies are still in their infancy, showing as mainly Stage 1/2 evaluations, and no large clinical trials on clinical or cost-effectiveness are really available. This review did not report on evaluation outcomes, and meta-analysis is by far not possible in this new field of research. Therefore it is difficult to say whether these mobile games/applications can contribute to actual behavior change, also because the majority of studies were short term, with a lack of power or low methodological quality. Furthermore, from this review it also became apparent that the games were developed for and evaluated with healthy individuals. Only one has been developed for the elderly[29] and none for persons with a (chronic) disease, although these are the groups that would benefit the most from a physically active lifestyle. Clearly, we need more substantial research on the effects on mobile gaming applications, and future reviews should focus on the potential effect of gaming applications on physical activity in daily life, preferably following a structured reporting method (e.g., PRISMA).

Strengths and limitations

In this review, we chose several definitions, selection criteria, and methodologies for the analysis of the studies, as to our knowledge no standard framework is yet available. For example, we chose the ''10 ingredients of great games'' for scoring game elements in the included studies, despite the possible incompleteness of this list. Our choices could have influenced the reported results: for example, we excluded applications that did not include a game goal, rules, and feedback, thereby excluding studies evaluating persuasive applications like Flowie.[43] Especially in this field of research, authors have defined design guidelines for motivating applications to change daily activity, where goal setting, awareness, and ubiquity seem important elements.[28,42,48]

The application of gaming in mobile interventions to change daily activity behavior is new and upcoming. This review provides an overview of mobile games, regardless the technology readiness level (e.g., proof of concept or complete), as we did not limit the review to randomized controlled trials. We executed the search in different fields of expertise (i.e., health, psychology, and computer science). It has to be noted that many game developments arise outside the scientific world, from which we could learn motivating gaming aspects. For example, ''Zombies, Run!'' is a very popular mobile game, in which you can walk, run, or jog in the real world while you are on a story mission in the mobile game, chased by zombies and collecting supplies to rebuild your town.[49]

Conclusions

This review provides a first overview of a new research area: mobile activity games to promote physical activity in daily life. The reviewed studies show that there is limited theoretical foundation for the game development, and most studies used goal setting as a motivation strategy to engage people in playing the game. Metaphors were used to visualize the monitored activity, whereas feedback was mostly provided in relation to the goal. Rewards and competition were the most commonly incorporated game elements. However, substantial evaluations of the mobile games are not yet available, and additional efficacy trials are needed to establish the impact of mobile gaming application on daily physical activity.

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References

1. Kohl HW, Craig CL, Lambert EV, et al. The pandemic of physical inactivity: Global action for public health. Lancet 2012; 380:294–305.
2. Lee IM, Shiroma EJ, Lobelo F, et al. Effect of physical inactivity on major non-communicable diseases worldwide:

An analysis of burden of disease and life expectancy. Lancet 2012; 380:219–229.

3. Sjöström M, Oja P, Hagströmer M, et al. Health-enhancing physical activity across European Union countries: The Eurobarometer study. J Public Health 2006; 14:291–300.
4. Hillsdon M, Foster C, Thorogood M. Interventions for promoting physical activity. Cochrane Database Syst Rev 2005; (1):CD003180.
5. Conn VS, Hafdahl AR, Mehr DR. Interventions to increase physical activity among healthy adults: Meta-analysis of outcomes. Am J Public Health 2011; 101:751–758.
6. Prochaska JO, diClemente CC. Toward a comprehensive model of change. Appl Clinical Psychol 1986; 13:3–27.
7. Fanning J, Mullen SP, McAuley E. Increasing physical activity with mobile devices: A meta-analysis. J Med Internet Res 2012; 14:e161.
8. Free C, Phillips G, Galli L, et al. The effectiveness of mobile-health technology-based health behaviour change or disease management interventions for health care consumers: A systematic review. PLoS Med 2013; 10:e1001362.
9. van Weering MG, Vollenbroek-Hutten MM, Hermens HJ. Do personalized feedback messages about activity patterns stimulate patients with chronic low back pain to change their activity behavior on a short term notice? Appl Psychophysiol Biofeedback 2012; 37:81–89.
10. Evering RMH. Ambulatory feedback at daily physical activity patterns—A treatment for the chronic fatigue syndrome in the home environment? [PhD thesis Number 30]. Enschede, The Netherlands: Roessingh Research and Development; 2013.
11. Tabak M, op den Akker H, Hermens H. Motivational cues as real-time feedback for changing daily activity behavior of patients with COPD. Patient Educ Couns 2014; 94:372–378.
12. Tabak M, Vollenbroek-Hutten MMR, Van der Valk PDLPM, et al. A telerehabilitation intervention for patients with COPD: A randomized controlled pilot trial. Clin Rehabil 2014; 28:582–591.
13. Huis in 't Veld RM, Kosterink SM, Barbe T, et al. Relation between patient satisfaction, compliance and the clinical benefit of a teletreatment application for chronic pain. J Telemed Telecare 2010; 16:322–328.
14. Lange B, Flynn SM, Rizzo AA. Game-based telerehabilitation. Eur J Phys Rehabil Med 2009; 45:143–151.
15. Taylor MJ, McCormick D, Shawis T, et al. Activity-promoting gaming systems in exercise and rehabilitation. J Rehabil Res Dev 2011; 48:1171–1186.
16. Harjumaa M, Segerståhl K, Oinas-Kukkonen H. Understanding persuasive software functionality in practice: A field trial of polar FT60. Presented at the 4th International Conference on Persuasive Technology (Persuasive '09), Claremont, CA, April 26–29, 2009.
17. Consolvo S, Everitt K, Smith I, Landay JA. Design requirements for technologies that encourage physical activity. Presented at the SIGCHI Conference on Human Factors in Computing Systems (CHI '06), Montréal, QC, Canada, April 22–27, 2006.
18. McGonigal J. *Reality Is Broken: Why Games Make Us Better and How They Can Change the World.* New York: Penguin Press; 2011.
19. Reeves B, Read JL. *Total Engagement: Using Games and Virtual Worlds to Change the Way People Work and Business Compete*. Boston: Harvard Business School Press; 2009.
20. Dunwell I, de Freitas S, Jarvis S. Four-dimensional consideration of feedback in serious games. In: de Freitas S, Maharg P, eds. *Digital Games and Learning*. London: Continuum Publishing; 2011: pp. 42–62.
21. Rogers C. *Client-Centered Therapy: Its Current Practice, Implications and Theory.* London: Constable; 1951.
22. DeChant HK, Tohme WG, Mun SK, et al. Health systems evaluation of telemedicine: A staged approach. Telemed J 1996; 2:303–312.
23. Ahtinen A, Huuskonen P, Häkkilä J. Let's all get up and walk to the North Pole: Design and evaluation of a mobile wellness application. In: *Proceedings of the 6th Nordic Conference on Human-Computer Interaction: Extending Boundaries (NordiCHI '10).* Reykjavik, Iceland: ACM; 2010: pp. 3–12.
24. Bielik P, Tomlein M, Krátky P, et al. Move2Play: An innovative approach to encouraging people to be more physically active. Presented at the 2nd ACM SIGHIT International Health Informatics Symposium (IHI '12), Miami, FL, January 28–30, 2012.
25. Fujiki Y, Kazakos K, Puri C, et al. NEAT-o-games: Blending physical activity and fun in the daily routine. ACM Comput Entertain 2008; 6:21.
26. Jensen KL, Krishnasamy R, Selvadurai V. Studying PH.A.N.T.O.M. in the wild: A pervasive persuasive game for daily physical activity. Presented at OzCHI 2010, Brisbane, Australia, November 22–26, 2010.
27. Lin J, Mamykina L, Lindtner S, et al. Fish'n'Steps: Encouraging physical activity with an interactive computer game. Presented at UbiComp 2006: The Eighth International Conference on Ubiquitous Computing, Newport Beach, Orange County, CA, September 17–21, 2006.
28. Munson SA, Consolvo S. Exploring goal-setting, rewards, self-monitoring, and sharing to motivate physical activity. Presented at the 6th International Conference on Pervasive Computing Technologies for Healthcare (PervasiveHealth), San Diego, CA, May 21–24, 2012.
29. Rodríguez MD, Roa JR, Morán AL, Nava-Muñoz S. CAMMInA: A mobile ambient information system to motivate elders to exercise. Pers Ubiquit Comput 2013; 17:1127–1134.
30. Stanley KG, Pinelle D, Bandurka A, et al. Integrating cumulative context into computer games. Presented at FuturePlay 2008, Toronto, ON, Canada, November 3–5, 2008.
31. Walsh G, Golbeck J. StepCity: A preliminary investigation of a personal informatics-based social game on behavior change. In: *CHI '14 Extended Abstracts on Human Factors in Computing Systems*. Toronto: ACM; 2014: pp. 2371–2376.
32. Xu Y, Shehan Poole E, Miller AD, et al. Designing pervasive health games for sustainability, adaptability and sociability. Presented at the International Conference on the Foundations of Digital Games (FDG '12), Raleigh, NC, May 29–June 1, 2012.
33. Zuckerman O, Gal-Oz A. Deconstructing gamification: Evaluating the effectiveness of continuous measurement, virtual rewards, and social comparison for promoting physical activity. Pers Ubiquit Comput 2014; 18:1705–1719.
34. Sallis JF, Owen N, Fisher EB. Ecological models of health behavior. In: Glanz K, Rimer BK, Viswanath K, eds. *Health Behavior and Health Education: Theory, Research, and Practice*, 4th ed. San Francisco, Jossey-Bass; 2008: pp. 465–486.

35. Fogg B. A behavior model for persuasive design. In: *Proceedings of the 4th International Conference on Persuasive Technology*. Claremont, CA: ACM; 2009: pp. 1–7.
36. Locke EA, Latham GP. Building a practically useful theory of goal setting and task motivation. A 35-year odyssey. Am Psychol 2002; 57:705–717.
37. Festinger L. A theory of social comparison processes. Hum Relat 1954; 108:117–140.
38. Shegog R. Application of behavioral theory in computer game design for health behavior change. In: Cannon-Bowers J, Bowers C, eds. *Serious Game Design and Development*. New York: IGI Global; 2010; pp. 196–232.
39. Noar SM, Benac CN, Harris MS. Does tailoring matter? Meta-analytic review of tailored print health behavior change interventions. Psychol Bull 2007; 133:673–693.
40. Baranowski T, Buday R, Thompson D, et al. Developing games for health behavior change: Getting started. Games Health J 2013; 2:183–190.
41. Achterkamp R, Dekker-Van Weering MGH, Evering RMH, et al. Strategies to improve adherence to coaching systems in telemedicine: Development of personas for providing tailored feedback. Manuscript submitted for publication, Informatics for Health and Social Care, 2015.
42. Consolvo S, Klasnja P, McDonald DW, Landay JA. Goal-setting considerations for persuasive technologies that encourage physical activity. In: *Proceedings of the 4th International Conference on Persuasive Technology*. Claremont, CA: ACM; 2009: pp. 1–8.
43. Albaina IM, Visser T, van der Mast CAPG, Vastenburg MH. Flowie: A persuasive virtual coach to motivate elderly individuals to walk. Presented at Pervasive Health2009, London, United Kingdom, April 1–3, 2009.
44. Consolvo S, McDonald DW, Toscos T, et al. Activity sensing in the wild: A field trial of UbiFit garden. Paper presented at CHI 2008, Florence, Italy, April 5–10, 2008.
45. McMahon S, Vankipuram M, Fleury J. Mobile computer application for promoting physical activity. J Gerontol Nurs 2013; 39:15–20.
46. Fan C, Forlizzi J, Dey A. Considerations for technology that support physical activity by older adults. In: *Proceedings of the 14th International ACM SIGACCESS Conference on Computers and Accessibility*. Boulder, CO: ACM; 2012: pp. 33–40.
47. Anderson I, Maitland J, Sherwood S, et al. Shakra: Tracking and sharing daily activity levels with unaugmented mobile phones. Mob Netw Appl 2007; 12:185–199.
48. Consolvo S, Everitt K, Smith I, Landay JA. Design requirements for technologies that encourage physical activity. Presented at the SIGCHI Conference on Human Factors in Computing Systems (CHI 2006), April 24–27, 2006.
49. Zombies Run! 2015. zombiesrungame.com (accessed July 20, 2015).

Address correspondence to:
Monique Tabak, PhD
Telemedicine Group
Faculty of Electrical Engineering, Mathematics and Computer Science
University of Twente
Drienerlolaan 5
P.O. Box 217
7500 AE Enschede, The Netherlands

E-mail: m.tabak@utwente.nl