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Article

The Role of Steps and Game Elements in Gamified Fitness Tracker Apps: A Systematic Review †

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† This article is an expanded version of a CHI Play conference paper.

Abstract: This article reviews 103 gamified fitness tracker apps (Android and iOS) that incorporate step count data into gameplay. Games are labeled with a set of 13 game elements as well as meta-data from the app stores (e.g., avg rating, number of reviews). Network clustering and visualizations are used to identify the relationship between game elements that occur in the same games. A taxonomy of how steps are used as rewards is provided, along with example games. An existing taxonomy of how games use currency is also mapped to step-based games. We show that many games use the triad of Social Influence, Competition, and Challenges, with Social Influence being the most common game element. We also identify holes in the design space, such as games that include a Plot element (e.g., Collaboration and Plot only co-occur in one game). Games that use Real-Life Incentives (e.g., allow you to translate steps into dollars or discounts) were surprisingly common, but relatively simple in their gameplay. We differentiate between task-contingent rewards (including completion-contingent and engagement-contingent) and performance-contingent rewards, illustrating the differences with fitness apps. We also demonstrate the value of treating steps as currency by mapping an existing currency-based taxonomy onto step-based games and providing illustrations of nine different categories.

Keywords: game; gamification; fitness tracker; exergames; activity tracker; fitness apps; step counter games

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1. Introduction

Fitness trackers are in high demand, and the market for them is ever-increasing. Market researchers predict that 105 million fitness tracker devices will be sold by 2022 [1]. This rising market of activity-tracking devices has given birth to a broad spectrum of games and apps that utilize data from these devices to encourage people to be more physically active. Many of these apps incorporate gamification techniques (i.e., the use of game elements in non-game contexts [2]) and game mechanics that are dependent on the physical activity data such as step count or distance travelled. Keeping pace with this development, the academic research community has also prototyped different gamified fitness tracker apps and have looked at the effects of gamification techniques and game elements on motivation. While these prototype games have shown promising results by recommending certain game elements over others (e.g., such as in [3] where they compare between collaborative and competitive game elements), there is still a need to better understand the game elements and mechanics that have made their way into commercial apps.

One common physical activity that these apps try to encourage is walking. The simple act of walking is widely recognized as having multiple physical and mental health benefits [4]. Walking is safe, for all ages, and no fees or instruments are required for it. The U.S. Department of Health and Human Services recommends that adults engage in around 150 to 300 min of moderate-intensity activity every week [5]. Chronic problems like diabetes

and hypertension pose a significant public health burden and regular walking has been shown to reduce the likelihood of developing chronic health problems and coronary heart diseases [6,7]. The use of gamification in these apps is so common that it has given rise to a whole new genre of gamified fitness tracker apps. Understanding this emergent genre of apps is not only interesting from a purely game design perspective, it is particularly important because it holds the potential of improving players' health by increasing their motivation to take more steps.

Although people recognize the health benefits of using fitness trackers to motivate themselves, research has shown that people often stop using fitness trackers after a while [8]. Researchers have tracked this down to various causes such as the lack of ongoing motivation to use it and even just forgetting about it [9,10]. Games, being intrinsically motivating [11], can help tackle this lack of ongoing motivation, and through compelling multi-day gameplay, can even remind users to wear it daily. To understand this issue of sustained use of fitness trackers, readily available app metrics such as ratings and reviews are insufficient because they only capture the perception of users towards the apps at a certain time, but do not convey whether the apps were successful in sustaining exercise habits or increasing physical activity in the long run. Thus, it is essential to look at different game elements and characterize the design space so future studies can examine which game elements and combinations of game elements lead to sustained motivation, enjoyment, and health benefits.

It is tempting to look at fitness tracker games through the lenses of mixed-reality games [12] and pervasive games [13,14], but the nature of novel affordances these games provide require a more detailed look at sub-genres within this space. Unlike many mixed-reality and pervasive games, which require sophisticated devices to play, gamified fitness tracker apps that rely on step counts can be played on the majority of smartphones which already have accelerometer sensors for multiple other purposes such as changing the orientation of the screen, and rotating maps during navigation. And, unlike resource-intensive sensors such as GPS, pedometers can be used to actively record step count throughout the day using minimal resources. Although this provides an extensive opportunity to create games that are woven into players' daily lives, these games can also intrude on player's lives if not carefully developed. Research about this design space must not only look at game elements, but also how steps are being used in the context of the games, and how they play into people's everyday lives.

Thus, the goal of this article is to characterize the design space in terms of different game elements used by existing gamified fitness apps and provide insights on how game elements are being used. More specifically, we address the following research questions (research questions 1, 2, and 4 were addressed previously in an ACM CHI Play Conference paper [15], this article expands on the analysis presented there and furthers the discussion by also addressing question 3):

1. What game elements do commercial activity fitness tracking apps utilize?
2. How do different game elements cluster and relate to one another?
3. What areas of the design space are still unexplored?
4. How are steps used within the context of the games?

2. Previous Works

Research surrounding game elements has generally been prescriptive in nature: comparing and contrasting some pairs of game elements. For example, there is a mixed consensus regarding the effectiveness of competitive vs. cooperative game elements to motivate users when implementing gamification. While some studies prescribe competitive game elements to motivate users [16,17], other studies argue that competitive game elements in gamification can be demotivating for users [18,19]. These studies recommend the use of collaborative-competitive game mechanics such as inter-team competition with intra-team collaboration rather than purely competitive game mechanics. While all of these different studies might help app developers make better decisions, it is still unclear whether

the results of academic research which is generally conducted with a small number of participants is generalizable within the broader commercial app market consisting of thousands of users. Understanding which game elements are used in existing fitness tracker apps can help to better connect research on specific game mechanics with their potential to impact players at scale. Classifying the types of fitness tracker apps can also help identify new unexplored game mechanics and techniques for integrating sensor-captured data (e.g., steps) into gameplay.

However, research on classifying fitness tracker games is still in the early stages. Previous research has classified fitness tracker games based on behavioural theories incorporated in the apps (e.g., [20–22]). This is useful for evaluating behavioral interventions, but not as useful for game designers to understand which game elements are currently used and how they are integrated into apps. Prior studies that evaluate existing apps are also limited due to their sample size and the comprehensiveness of their classifications [20,23]. For example, in addition to looking at behaviour change theories, Lister et al. also classified apps for the presence of different gamification elements, but the sample consisted of just iOS apps available in 2014 [23]. Based on this work, a recent study by Cotton and Patel systematically analyzed the use of different gamification elements and the presence of behavioural economics principles in mobile games [24]. They developed a classification framework for analyzing games and analyzed 50 games for use of the following game elements: Goals, Challenges, Social Influences, Leaderboards, Points, Lifelines, and Levels. Although it provided a good framework for coding game elements, the systematic survey cannot be considered comprehensive since the research only included the top 50 apps in the "Health and Fitness" category of the Apple App Store. Another limitation of the study is that it did not look into other app categories apart from the "Health and Fitness", as in an ideal world, apps related to encouraging fitness would be in this category, but, in real life, apps are often miscategorized [25]. Our previous work [15] filled some of these gaps for step-counter based apps. Specifically, we extended the work of Cotton and Patel, and performed a more thorough systematic review of all step-counter apps by adding game elements missed by this framework and including apps and games from other app store categories as well.

Our initial study [15] showed that the co-occurrences of game elements such as Competition, Challenges, and Social Influences are very common. We also observed that step-counter based apps used different types of rewards to keep users motivated but our early work did not tackle this issue of understanding different types of rewards in more detail. Since the reward system is the basis for motivation and gamification, we have added a new section that addresses this topic in this article.

Our analysis of fitness tracker games also showed that many games used steps as a form of virtual currency, which may or may not be tied to real-life incentives. We examined existing works that have dealt with the concept of in-game economy and found several frameworks that fit well with our initial analysis of how steps were used in fitness tracker games including: the European Central Bank's schema of virtual currencies [26] and the works of Asadi and Hemadi on identifying the rationale behind the virtual economy in games and game mechanics they facilitate. This study applies ideas from these frameworks to the use of steps (viewed as currency) in fitness games.

Thus, this work expands upon our preliminary analysis of game elements in fitness tracker apps by examining reward structures and steps-as-currency. The resulting analysis provides a richer description of the existing design space and helps identify game mechanics that are still unexplored.

3. Methods

We used a mixed-method approach to conduct a systematic evaluation of different game elements in existing fitness apps that use step count data from the Apple App Store and the Google Play Store. The quantitative process involved systematically identifying apps and games for review, gathering app store stats about their performance and popularity, recording the presence of different game elements using a codebook (see Table 1), and

using network analysis to identify gaps in the design space by visualizing co-occurrence and clustering patterns of game elements. We have presented part of this research previously [15]. We describe the methods used here for the sake of completeness, though some details are left to the conference paper. In addition, we describe the methods used to expand upon our prior work in this section. The qualitative process involved looking at how different game elements were used in existing games, identifying existing frameworks that mapped to our initial findings, and then translating those into the context of gamified fitness tracker apps that track steps. The following sections describe these quantitative and qualitative steps in more detail.

Table 1. Codebook of game elements and their description [15].

Game Element	Description
Goals	Measurable and well-defined target that a user has to achieve.
Challenges	They are like goals or competitions but short-lived. They are sometimes optional in the games (like a side quest) or could be a challenge that moves a story forward. Moreover, code for challenge when the app explicitly identifies something as a "challenge." [1]
Competition/Leaderboards	Compete with other members directly or through leaderboards.
Collaboration	Work together towards a common goal or objective in the game.
Social Influences	Performance is publicly displayed. Code for this if game activities can be shared or there are elements of peer pressure and social nudging.
High Scores	Tracking of best attempts over a particular timeframe.
Badges	Visual recognition earned for completing specific milestones, tasks or when player completes a goal or challenge.
Plot	Includes a pattern of events (i.e., causal chain of events) related to an unfolding narrative. Plot is a specialized narrative element. So, code for "Narrative" as well when an app is coded for "Plot".
Narrative	Includes a theme that ties to an alternate world distinct from the everyday experience of the players. If an avatar of any kind is included in an app, the app will also have the Narrative classification.
Points	Accumulates points that help progress through game and/or can be redeemed for rewards or be used in in-game economy.
Levels	Progress through parts of the game (e.g., level 1 to level 2) or gradients of status (e.g., bronze level to silver level).
Unlockable Content	Access to enhanced functionality (new levels, gameplay, etc) or content for accumulating experience or achieving a specific goal.
Real-life Incentives	Discounts, rewards, donations, or prizes in real-life.

[1] We found that apps that used challenge in their terminology aligned with our definition but adding this allowed us to more efficiently identify this game element.

3.1. Cataloguing and Coding Gamified Fitness Tracker Apps

We started by creating a list of apps and games available in the Apple App Store and Google Play Store using a systematic review framework called the Preferred Reporting Items for Systematic Reviews and Meta-Analyses [27]. However, we slightly modified the framework since we were reviewing apps instead of journal articles (which the framework is originally intended for). Figure 1 shows the summary of the process we followed and the following sections provide additional detail.

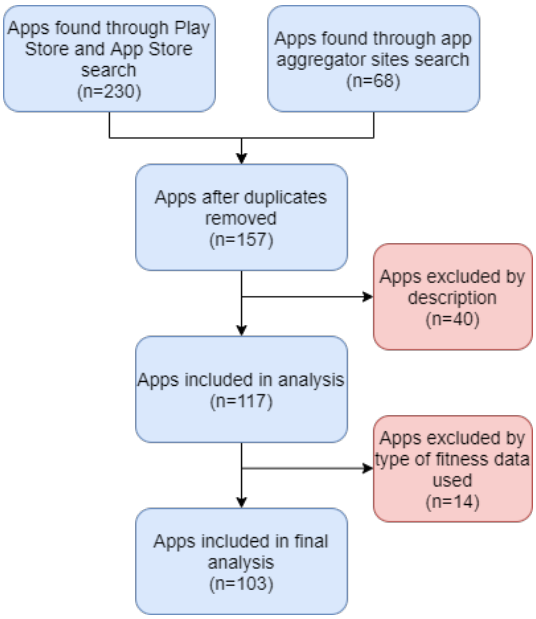

Figure 1. Selection and filtering process. Image from [15].

Initially, we identified apps for the iOS and Android platform that used step-count data either through an integration with a fitness tracker or built-in smartphone pedometer. Based on content analysis of popular fitness tracker apps, we came up with several keywords including "fitness", "fitness game", "fitbit goal", "pedometer game", "step counter game", "fitbit game", "walk gamify", "garmin game", "fitness tracker game", "exergame" to build an initial list of apps, and then we reviewed app store recommendations made when visiting the pages of our initially identified apps. Specifically, we looked at apps in the "Similar Apps," section of the Google Play Store and the "You might also like" section of the Apple App Store.

From the initial list, we first excluded apps based on their description. Apps that were excluded were primarily weight loss apps focused on measuring calories burned, and apps that were designed for employees of certain companies or specific insurance providers. Next, we excluded apps based on the type of fitness data they use. We purposely narrowed our search to apps that used step-count data as a primary driving factor in its in-game mechanics so that apps we look at will have that feature at minimum. Thus, we skipped apps like Strava and Pokemon Go that relied on other sensors such as GPS.

3.2. Coding for the Presence of Game Elements

In our previous work [15], we combined the works of Cotton and Patel, and Kappen et al., and came up with a taxonomy for coding game elements [24,28]. We also added two categories ("Real-life Incentives" and "Plot") as we realized the need to capture these elements as well. We used this same codebook to do several rounds of coding to ensure that discrepancies between raters due to different interpretations of definitions for game elements were minimal. The codebook used is shown in Table 1. Three raters, using this codebook, independently coded apps and interrater reliability was calculated. Discrepancies were resolved through consensus between multiple raters. This process was conducted from mid-December 2019 to mid-April 2020.

3.3. Network and Cluster Analysis

Using NodeXL [29], we performed a network analysis of game elements and their co-occurrence frequency. Each game element was treated as a node, and their co-occurrence was an edge with edge weight representing the frequency of apps containing both of the game elements connected through that edge.

We also utilized the Louvain Community Detection algorithm to identify clusters within the co-occurrence graph [30]. Specifically, we used the python-louvain [31] package together with NetworkX library to identify clusters. Once identified, we enriched the original graph from NodeXL with colours representing the community they belonged to as identified by Louvain's algorithm.

3.4. Usage of Steps within the Context of the Games

Our conference paper focused on game elements occurring in the apps and games, not necessarily those directly tied to steps. In this article we expand on our prior conference paper findings to address this issue. Specifically, to better understand the use of steps within gamified fitness tracker apps, we first assigned qualitative descriptions of how steps were used in the games identified earlier. This analysis helped us realize that steps were used in two primary ways: as a mechanism to trigger rewards, and as a currency. By currency, we mean that steps (or points based off of steps) can be used as a medium of exchange either for in-game or real-life rewards. This led us to identify existing taxonomies that could be applied to how games use steps to trigger rewards [32] and how steps are utilized as a currency [26,33].

4. Results

In this section we give an overview of the game data (Section 4.1), describe game element occurrences (Section 4.2) and co-occurrences (Section 4.3), and then discuss how steps are utilized to attain rewards (Section 4.4) or as currency in an economy (Section 4.5).

4.1. Overview of Game Data

Our resulting dataset consisted of 103 gamified fitness tracker apps of which 80% (n = 82) were available for Android phones and 76% (n = 78) were available for iOS phones. We also collected quality (from the rating in their respective app stores) and popularity (number of reviews in the app stores) parameters for these apps which is shown in Figure 2 as a box plot. The distribution of these parameters varied with ratings ranging from 1 to 5 (left part of the figure). Reviews follow a power-law distribution (right part of the figure) where a small number of apps account for a large number of reviews, while a large number of apps received only a handful of reviews. Since the range for the number of reviews was large, we used a logarithmic scale in the y-axis to aid differentiating apps in this dimension. Although apps generally tend to get better ratings on Android than in the iOS platform [34,35], gamified fitness tracker apps seemed to be breaking this trend as they were more favourably rated in the iOS platform than in the Android platform as shown in the left part of Figure 2.

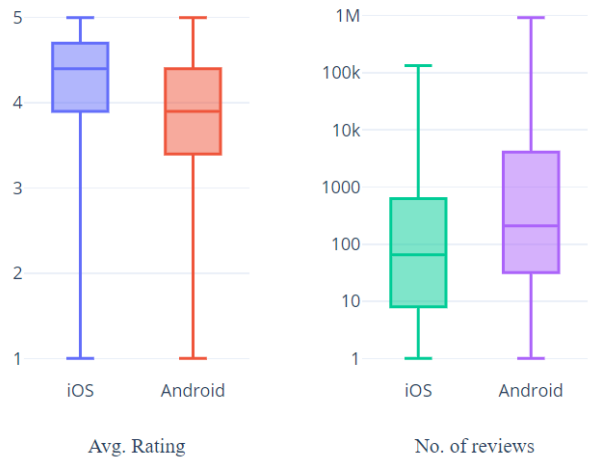

Figure 2. Quality and popularity metrics in app stores. Image from [15].

Our final dataset has been previously published and is freely available via an open-access creative commons license [36]. A quick glance at the top 20 apps with the highest number of reviews reveals several interesting insights. For example, we found that the top 3 apps in the store (based on number of reviews) were official apps for popular fitness tracker devices: Mi Fit [37], Fitbit [38], VeryfitPro [39]. While Fitbit had comprehensive gamification built in (such as Competitions, Leaderboards, Badges, Journeys), the other two apps just had basic features intended for syncing with the trackers. Then, there were apps like Charity Miles [40], Sweatcoin Pays You to Get Fit [41], and Yodo Cash for Running [42] which had real-life incentives built in. Apps like Zombies Run! [43], Walkr: Fitness Space Adventure [44], and Fit the Fat 2 [45] also made it into this top 20 list. However, these apps are more *traditional* games than *gamified* apps because they incorporate game mechanics and elements together with fitness data to provide rich and playful game experiences. For example, Walkr: Fitness Space Adventure [44] has a rich narrative and steps you take help you earn fuel for your rocket that allows you to explore the universe and play collaboratively with friends. In the following sections, we describe different game elements we encountered in our dataset and their relationship with each other. We also dig deeper into how steps are being used as currency to facilitate different game mechanics.

4.2. Game Element Occurrences

There was variation in the types and number of game elements in the apps we reviewed. Figure 3 shows the distribution of 13 game elements we coded for. About 40% of the apps we reviewed use 3 or fewer game elements. Rather than providing a full game experience, apps that utilized only a few gaming elements used game elements like Goals, Challenges, Social Influences, Competition and Real-life incentives to support gamification within them. Apps like bfit-Smart [46] and Walk With Friends! [47] are standard examples using these game elements. On the other hand, almost 25% of the apps we reviewed implemented 7 or more game elements. Unlike gamified apps, these apps provide a full-blown gaming experience consisting of game mechanics normally found only in traditional games. For example, the Garfield Fit! [48] app includes features such as characters, costumes and an in-game marketplace with currency based on the steps you take. Similarly, in Pocket Plants [49], you can manage a virtual garden by growing virtual plants, evolve them, and use traditional game mechanics like powerups to enhance your plants.

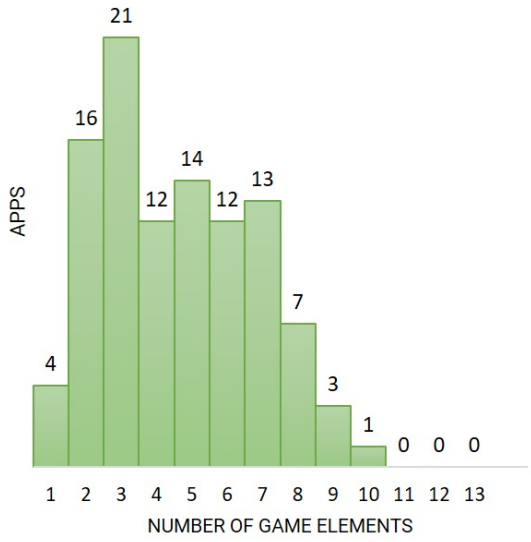

Figure 3. Frequency of apps with the specified number of game elements. Image modified from [15].

Table 2 shows the frequency of game elements in the apps we evaluated. Due to the large number of gamified apps in the app markets, game elements that facilitate the gamification of steps such as Goals (e.g., as daily step goals), Social Influence (e.g., competitive leaderboards), and Challenges (e.g., Weekend Warrior competitive challenge in the Fitbit [38] app) were unsurprisingly the most common ones. In contrast, the less common game elements were the ones often found in standalone games such as Collaboration, Unlockable Content, and Plot.

Table 2. Statistics for apps containing each game element [15].

Game Element	Count	No. of Game Elements	Rating (Avg.)	Rating (σ)	No. of Reviews (Median)	Total Reviews
Social Influences	69	5.25	3.95	0.70	202	3,772,994
Goals	63	4.89	3.98	0.64	163	3,872,679
Challenges	53	5.75	4.03	0.56	132	2,445,588
Real-life Incentives	48	4.44	3.96	0.67	332.5	510,038
Competition	48	5.90	3.97	0.70	126.5	2,436,252
Points	47	5.98	3.93	0.65	202	318,981
Narrative	34	5.94	4.00	0.65	79.5	858,347
Collaboration	29	6.24	3.85	0.69	98	119,856
Levels	22	6.86	4.08	0.51	84.5	826,489
High Scores	20	5.60	4.00	0.51	145	909,561
Unlockable Content	18	6.33	4.21	0.34	238.5	175,574
Badges	14	6.71	4.28	0.36	1713	1,537,772
Plot	8	6.63	4.26	0.16	38	38,870

Table 2 also shows average quality and popularity metrics of the apps containing each game element. We use ratings and reviews of apps as a proxy to the quality and popularity of game elements. Note that these metrics are not independent variables as reviews and ratings from a single app is included in the calculation for different game elements that the app uses. Although this limits the use of statistical comparisons based on independent variables, the metrics listed in the table still provide a general overview of users' perspective on the apps that use certain game elements.

To estimate quality, we calculated a weighted average of average ratings of apps in iOS and Android app stores using the number of reviews on each platform as the weight. We excluded apps with less than 30 reviews from this calculation as we found these apps often had all 5-star ratings (likely from self-promotion) and would only skew the results. The resulting data in Table 2 shows insignificant difference in the average ratings of apps utilizing different game elements with ratings ranging from 3.85 (Collaboration) to 4.28 (Plot). The standard deviation of ratings differed (0.16 for Plot vs. 0.70 for Social Influences); however, this may be an artifact of the small sample size of some game elements (e.g., plot).

We also present the total number of reviews and medium number of reviews in the same table. These numbers act as a proxy for popularity. Since the number of reviews followed a skewed distribution, we used the median value as it is more relevant than an average in this case. This median value highlights some interesting variations. Games that use Badges and Real-life Incentives have the highest median values (1713 and 332.5) while Plot and Collaboration have the lowest median number of reviews (38 and 98). While this might seem to indicate that both Plot and Collaboration based games are unpopular, when combined with the rating data, it points out interesting differences in how users perceive these game elements. Plot-based apps have higher average ratings than those utilizing collaboration. This suggests that plot-based apps are highly enjoyable. On the other hand, apps utilizing collaboration are not uncommon but they also seem to be

unpopular as well. We present our hypothesis on potential reasons for these differences in the Discussion section.

Finally, along with frequency, Table 2 also includes the average number of game elements in apps that have a certain game element. This number can act as a gauge for measuring gameplay complexity in the app. Figure 4 presents the relationship between this number and different game elements in a graphical format. As can be seen, Real-life Incentives and Goals occur in apps that utilize a small number of game elements. This indicates that these game elements do not normally co-occur with other game elements. They seem to be used primarily in gamified apps, not standalone games. On the other end of the spectrum are games with Levels, Badges, and Plots which generally occur in apps that incorporate many other game elements. In other words, these game elements are typically added to games that already include the more common game elements.

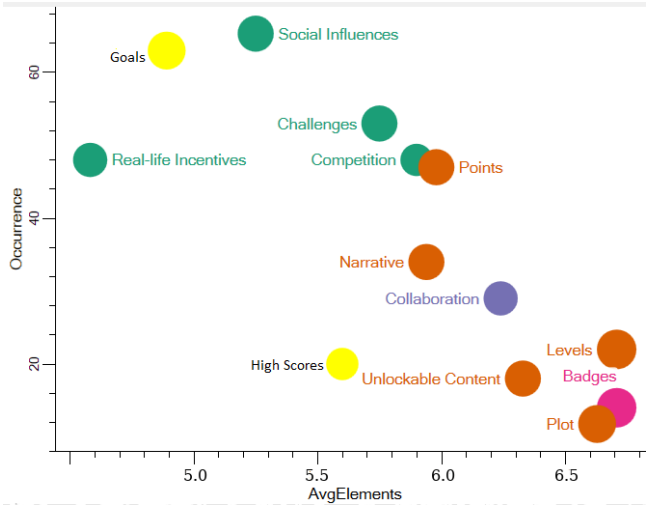

Figure 4. Game elements plotted based on occurrences and average co-occurring elements. Color indicates clusters as identified by Louvain's algorithm as described in Section 4.3. Image from [15].

4.3. Game Element Co-Occurrences

To identify gaps in the design space, we looked at different clusters formed by combinations of game elements. Using the Louvian community detection algorithm on the initial co-occurrence graph obtained using NodeXL (Figure 5), we identified separate clusters. The algorithm detected five clusters of game elements which are represented in the network graphs (Figures 5 and 6) as distinctly colored nodes where Figure 5 is an enriched NodeXL co-occurrence graph and Figure 6 is an alternate visualization of the same graph focusing on "relative strength" which is described in the upcoming paragraphs. Although it is important to note that these clusters are not formed by games but by game elements that occur frequently together, we can still find archetypical examples of games that illustrate these clusters well because they tend to use the same set of key game elements defined by the cluster. Thus, in the following sections, we dive deeper into each of these multi-node clusters (i.e., except for Badges and Collaboration which are single-node clusters) and illustrate each with some games that represent the cluster well.

As shown in Figure 6, a major cluster is formed by Social Influences, Challenges, Competitions, and Real-Life Incentives. This cluster represents the most common types of apps currently found in the app markets. These are often apps that include Social Influences, Challenges, and Competitions (n=32) and allow users to compete with their friends or other players based on the number of steps they can take during a particular time period (most often a day). Less common than these three game elements is the Real-life Incentives where people are rewarded in real-life for steps they take. Some prototypical examples of these kinds of apps are Challenges—Compete, Get Fit [50] and Stroll-Walking Tracker [51] which include simple step-based challenges and competitions, and apps like

Lympo [52] and Yodo-Cash for walking and running [42] (see Figure 7) [42] which provide real-life rewards on top of challenges and social elements they incorporate. Although Goals occur frequently with game elements in this cluster (as evident by the edge thickness between Goals and elements of this cluster in Figure 5), the clustering algorithm created a separate cluster together with High Score because the element High Score hardly ever co-occurs with game elements other than Goals.

Another important cluster is formed by Narrative, Plot, Unlockable Content, Points, and Levels. Apps using these game elements represent significant deviation from standard gamified apps. These apps are more like stand-alone games, and have complex gameplay with rich narratives. Some examples include the Fitness RPG [53] (see Figure 8) , a plot-based game where you manage a team of heroes, find unlockables, and collect points by taking in steps; Zombies Run! [43], where you walk to avoid Zombies from attacking you; StepGod [54], where you populate the universe by evolving game characters; and The Walk: Fitness Tracker Game [55], where you complete compelling missions based around a story through the help of steps in real-life.

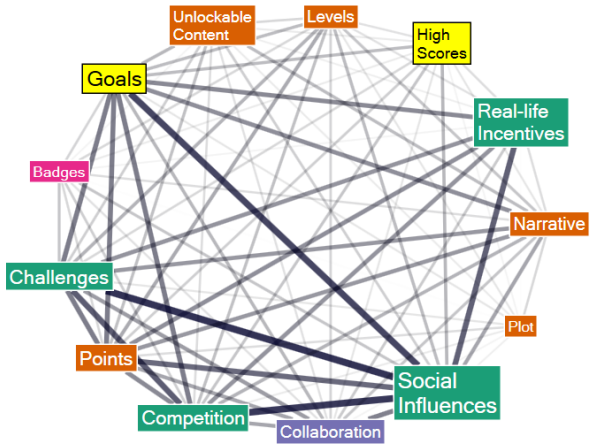

Figure 5. Network Diagram of Game Elements. Size of vertices represent frequency of game elements and edge widths represent co-occurrence between game elements. Color indicates cluster. Image from [15].

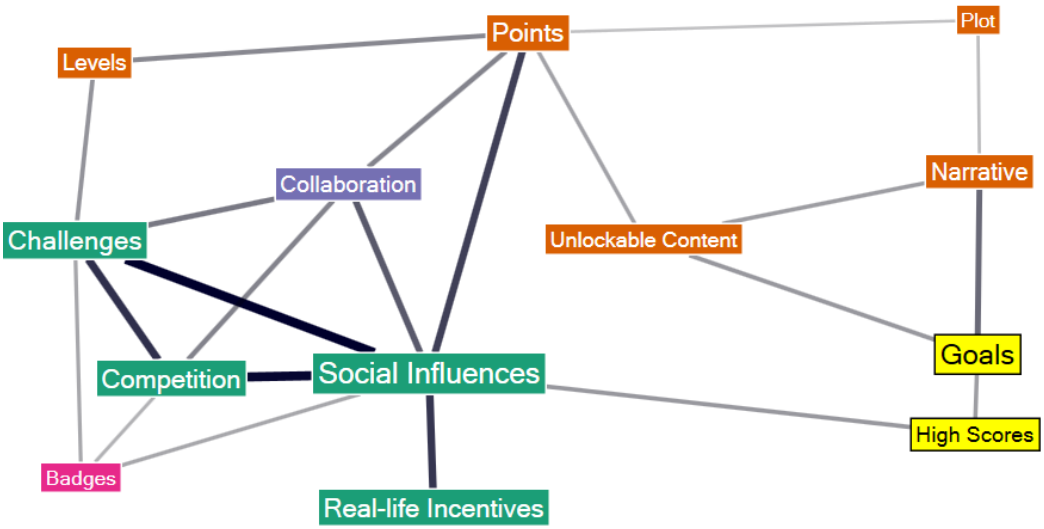

Figure 6. Co-occurrence network pattern of game elements. Edge width represent co-occurrence weighted by their "relative strength" which is explained in Section 4.3. Image from [15].

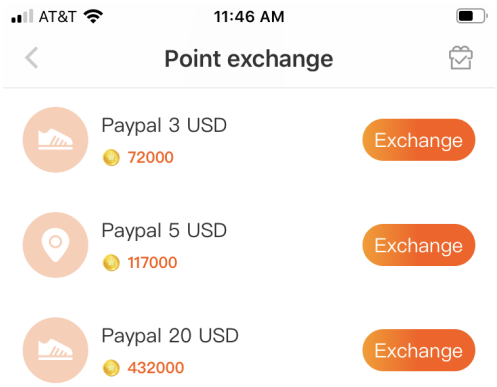

Figure 7. Screenshot of Real-life Incentives in the Yodo-Cash for walking and running app [42] where users can exchange points they earn from walking into Paypal transfers. Image ©Yodo Apps.

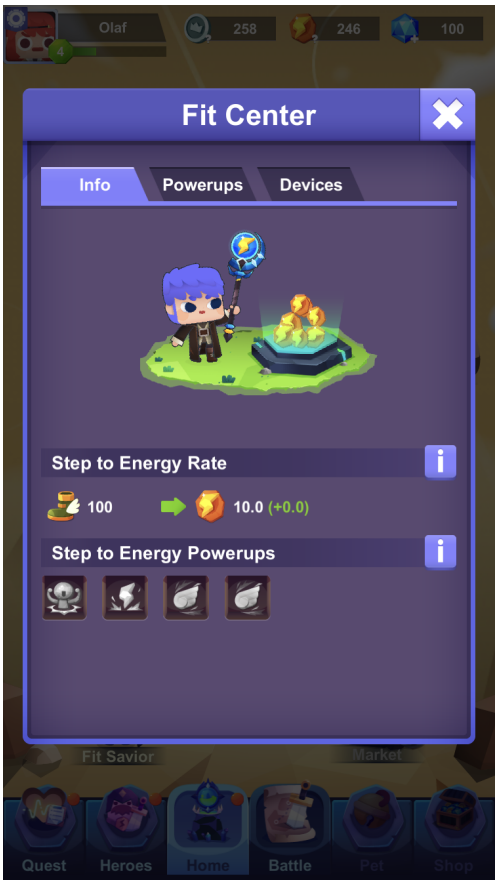

Figure 8. Screenshot from the Fitness RPG app [53] showing canonical game elements found in traditional RPG games. Image ©Shikudo.

The Louvian Clustering algorithm put game elements Collaboration and Badges into single-node clusters. Since these elements co-occur equally with all other identified clusters, it was not possible to associate these game elements to a specific multi-node cluster. This indicates that these game elements serve multiple purposes in different styles of gameplay (i.e., sub-genres of gamified fitness tracker apps).

Although Figure 5 did a good job of showing co-occurrences between different game elements based on the popularity of a pair of game elements, it does not account for the importance of edges to particular game elements. For example, since the pair Social Influence and High Scores elements occur less frequently, the edge between them is comparatively

thin (with weight = 15). This makes sense as a thin edge for Social Influences as it occurs more frequently with other game elements than High Scores, but when looked through the outlook of High Score, it is one of the strongest relationships between any of the other game elements. To better visualize this "relative strength" of relationship, we took inspirations from a similar analysis in [29], and created an alternative visualization as shown in Figure 6 which better highlights the "relative strength" of edges. Say, for game element X and Y, this new edge weight (i.e., the strength) is calculated using the following formula:

$$relativestrength = Max\left(\frac{\text{times X and Y show up together}}{\text{times X show up in total}}, \frac{\text{times X and Y show up together}}{\text{times Y show up in total}}\right)$$

where the first fraction is the fraction of X based games that also include Y and the second fraction is the fraction of Y games that also include X. For the calculation of strength, we take the maximum of these two fractions as the maximum value will make the edge prominent if it is important for any of the either game elements. To ensure we only show important edges, we filtered out edges with strength less than 65%. Thus edges between any two nodes in Figure 6 mean that at least 65% of the occurrences of these two nodes co-occur with the other element.

The resulting enriched strength diagram in Figure 6 highlights some interesting connections. It spotlights the central role played by Social Influences in all types of gamified fitness tracker apps as evident by its connections to all other identified clusters. It also highlights common game elements used to facilitate gamification, such as Challenges, Collaboration, and Competition which is seen in the graph to be connected with many other game elements. On the contrary, the only edge that Real-Life Incentives has is one that connects it with the Social Influences node indicating they are a sub-genre of their own. The strength-based connections also seem to support the findings from the Louvian clustering algorithm as many edges like the ones between "green" nodes seem to be strongly connected as well. The loosely-connected cluster of Levels, Points, Plot, Narrative, and Unlockable Content signify that these elements often co-occur together but they are diverse in terms of which game elements co-occur within that cluster.

4.4. Steps as Rewards

Rewards are a universal motivator in real-life playful contexts. In this section, we present our results from looking at different types of reward structures implemented by existing gamified fitness tracker apps. We only considered rewards that are facilitated by or contingent upon physical activity performed by users. For example, we do not consider rewards that users get just by logging into the app everyday or connecting their social accounts. Specifically, we looked at conditions that trigger rewards within the apps. The following sub-sections describe these reward structures in more detail:

4.4.1. Task-Contingent Rewards

A task-contingent reward is a reward structure which is tied to a certain task [56]. When referring to tasks in the context of gamified fitness tracker apps, we consider "task" to be a physical activity. Deci et al. have divided this reward structure into two specific types [56]:

1. Completion-contingent reward: A completion-contingent reward structure rewards users when they complete a task. In the context of gamified fitness tracker apps, these tasks often include requirements such as completing a daily step goal (e.g., 10,000 steps). For example, the Fitbit [38] app provides users with a badge when they complete their daily step goal. While many apps use standard reward elements like badges, some apps use alternative rewards. For example, in The Walk: Fitness Tracker Game [55] users unlock new story bits as they complete their goals.
2. Engagement-contingent reward: An engagement-contingent reward is a reward system that uses engagement as a condition to trigger rewards. These rewards are often represented as streaks in games. For example, the Fitbit [38] app rewards players if they continuously achieve their daily step goal for a streak of 23 days. The engagement-

contingent reward may or may not be connected with a completion-contingent reward. In the same Fitbit example, although the streak represents an engagement-contingent reward, it also requires users to complete the daily goal which is a completion-contingent reward. A counterexample can be seen in Pocket Plants [49] which rewards users with points regardless of goals or milestones as long as they are walking.

4.4.2. Performance-Contingent Reward

Performance-contingent rewards require users to exceed their performance beyond a certain measure. This reward structure is often employed as a comparison with previous performance of the same user or between different users. High scores and Leaderboards often facilitate this type of reward structure. "Weekend Warrior" in Fitbit [38] is an example of a performance-contingent reward where users compete with each other over the weekend, and the user with the highest number of steps is rewarded. Unlike completion-contingent rewards, which are all or nothing, performance-contingent rewards are continuous in nature. These rewards are often used in combination with completion-contingent rewards, since they motivate players to do more than just hit a minimum threshold.

Applying the lens of this framework on the previously presented data (e.g., Figure 5 and Table 2) allows us to see that many of the current fitness games reside in the area of task-contingent, completion-condition rewards (e.g., Goals, Badges, and Challenges) and performance-contingent rewards (e.g., Competition and High scores)

4.5. Steps as Currency

In addition to the lens of steps as rewards, it is helpful to understand how steps are used as currency within the economy of the games. Our initial analysis led us to look at steps as currency since they could be used to purchase real or virtual items. In the following sections, we discuss the types of step-facilitated in-game economies, as well as how steps are used as currency within those economies.

4.5.1. Where Is the Currency Used?

In this subsection, we define the types of currency that steps are mapped to in the game-related economies. We propose the following types of economy, which map well to our context:

1. Virtual economy: In many games, steps are used as a closed virtual economy. Typically, steps are mapped to an in-game currency such as "energy," "points," or "coins." Walking allows users to spend this currency to obtain resources that only exist inside the game world. For example, in Wokamon [57], users can upgrade their "Woka-monsters" by spending points that are obtained from walking.
2. Virtual and real-world economy: In some games, the economy can include real currency, as well as virtual currency (based on steps). The conversion of virtual and real-world currency can occur in multiple directions:
    (a) *Virtual currency* (derived from taking steps) can be converted into real-world incentives such as gift cards, discounts, merchandise, or even conventional money. For example, in LifeCoin [58], you can earn "lifecoins" which can redeemed as gift cards for services like Amazon and Uber.
    (b) *Real-world currency* can be converted into virtual currency and rewards, such as occurs in games with in-app purchases. An example app that implements this type of flow is the Walk The Distance [59] game where users can make in-app purchases to unlock additional virtual trails that they can walk on. Games with unidirectional flow allow for only one of these options (i.e., steps can be used for real-world rewards OR real money can be used for virtual rewards), not both. Yes.Fit [60] is an example where steps earn progress towards your goals—completing certain long-term badges can earn you a physical medal or badge that is sent to you in the mail. atlasGO Charity [61] allows the in-game currency of steps to be translated to money for charities.

(c) Some games allow currency to be exchanged in both directions. Step-based betting apps like StepBet: Get Active & Stay Fit [62] and RunBet-Run more, Earn more [63] are canonical examples implementing this kind of flow where you can spend real money for competitions and get it back (or even more) if you win them.

4.5.2. How Is Currency Used?

With steps as currency, it is also useful to know the types of game mechanics they facilitate. In the following list, we list game mechanics facilitated by having an in-game economy from Asadi and Hemadi and provide examples of how they map to fitness tracker games:

1. Complementing physics: In some games, steps can complement the in-game physics to change how the game is played. A common implementation is a conversion of real steps into in-game time. For example, in the PuzzleWalk [64] game, taking more steps can change the scale of in-game time by reducing the time it takes to reach different places. Similarly, in the Walkr: Fitness Space Adventure [44] game, taking more steps reduces the time it takes to "explore" new planets and increases food production rate.
2. Influencing the progression: Unlocking new levels and narratives is a common theme found in many apps that utilize steps for in-game economy. In the Idle Fitness Orchard [65] game, users can unlock new locations in their map by walking more. In the The Walk: Fitness Tracker Game [55] app, steps can help unlock audio story bits for the game narrative.
3. Adding strategic dimension: Some games use the in-game economy as a way to enable a strategic dimension in the game. These are often found in narrative-based games which use steps as a way for users to choose a strategy in the gameplay. For example, in The Outbreak [66] game, users are presented with obstacles which require them to strategically spend steps or save them for future events.
4. Creating large probability spaces: Similar to adding a strategic dimension, steps can facilitate large probability spaces when implemented in games. In the Sprint Garden [67] app, users can choose their "plants" based on number of steps they make and create a completely different "garden." Similarly, in the game Hops [68], players can purchase items that can be crafted together to make new items.
5. Item Degradation: In some games, items degrade either gradually with time or some other measures. In these games, steps are required to replenish this deterioration. In the Fit the Fat 2 [45] game, the character's health decreases and it loses health over time unless users complete their step goals, only then is the character's health restored.
6. Inconvenient Gameplay: Often, when game designers add inconvenient gameplay to a gamified fitness tracker app, an inconvenience of time is added which can be mitigated using steps. For example, in the Walkr: Fitness Space Adventure [44], steps can reduce the virtual game time so that players can explore planets faster. In the game Space Cupcake [69], steps can change the rate of ticket (an in-game resource) regeneration which is slow to regenerate by itself.
7. Medium of exchange: In games that implement an exchange economy, steps act as a commodity that has a value or it can be traded. This mechanic can be seen in games implementing real-life incentives (e.g., Lifecoin [58]). For example, in the Idle Walking Tycoon [70], you can spend steps to hire virtual workers in the game.
8. Inventory mechanic: In this type of game mechanic, the inventory itself is part of the gameplay. Steps can increase or decrease inventory properties such as number of items it can hold or its capacity in general. The game Hops [68] allows players to increase the size of their burlap sack, which contains items. However, the current version only allows you to do so by an in-app purchase, not by taking a certain amount of steps.

9. Artificial Scarcity: In this game mechanic, an artificial scarcity is created which can be mitigated by more steps. Games where users can use steps to unlock more levels and merchandise can be considered to have implemented this type of economy. For example, in the Wokamon—Monster Walk Quest [57] game, energy is a scarce resource used for feeding, growing, and collecting "Wokamons", and it can be obtained by walking more.

As illustrated by these examples, viewing steps as a currency can greatly enrich the game potential in gamified fitness tracker apps. While early games seemed to have stressed using steps in direct competitions and for rewards, a growing number of games treat steps as currency, which has dramatically expanded the design space for gamified fitness tracker apps and allows for the use of existing game mechanics found in traditional games genres such as RPGs, strategy, and sandbox games.

5. Discussion

When new technologies become mainstream, they are often exploited as a new platform for playful experiences. This article helps characterize the growing number of games and gamified apps that leverage the fitness trackers, which have become increasingly ubiquitous via smartphones, smartwatches, and standalone fitness tracker devices such as Fitbit. It establishes a foundation to understand fitness tracker games by classifying, quantifying, and characterizing game elements used by existing gamified fitness tracker apps, as well as their relationship with each other. Furthermore, this paper identifies ways in which physical activity data (i.e., steps) are incorporated and blended with traditional gameplay techniques such as using the data for rewards or as a currency. A key meta-level insight from our analysis is that app developers can relatively easily map physical activity data, such as steps, to traditional gameplay mechanics. While many gamified apps use standard techniques such as social leaderboards based on steps taken, a smaller but growing number of standalone games integrate steps into existing game genres such as role-playing games, puzzle games, sandbox games, gambling, etc. As fitness trackers become even more ubiquitous, we expect to see even more games that incorporate fitness data, as well as techniques for mapping that data onto gameplay.

This study presents a snapshot of emerging fitness tracker game genres supported by fitness data. For example, for the first time we have drawn attention to the large number of games, including several highly rated games, that allow people to convert their steps into Real-Life Incentives. This indicates a trend of utilizing extrinsic rewards as a way to motivate users. Future work could explore this trend in related contexts. For example, do apps that track things other than steps also provide Real-Life Incentives? To what extent? What economic models do they use?

A significant contribution of this work is also the dataset that we compiled in order to perform the analysis, which we believe others can build off of. The fully-coded dataset is available online [36], and can serve as a starting point to support different types of future studies. For example, in this study, we only looked at the visual game elements included in these apps; however, future work could look into other modalities such as haptic and sound feedback, and label the dataset as such. Our dataset can also help researchers sample a particular subset of apps they find interesting. For example, a future study could perform a qualitative examination of apps that use the Collaboration game element (29 apps). Why were there not more Collaboration games? Why did they have lower ratings and fewer reviews? Was it due to technical problems like synchronization issues, or just difficulties associated with collaboration due to factors like schedule conflicts (e.g., [71])? Whatever the specific research questions, we hope that our systematically collected and tagged list of apps can help reduce the "transaction cost" of future research in this space.

Our resulting dataset can also help game developers tackle difficult design challenges. For example, although we found out that Social Influences play a central role in many fitness tracker apps, and are what make many games fun and tempting, managing the

right amount of Social Influences is a challenging task as social comparisons can sometimes demotivate users [3], and use of social elements can raise privacy concerns to users [72]. We hope that they can use our dataset to take inspirations by looking at how existing apps handle similar design problems.

Other insights come from examining the entire design space of fitness tracker apps. Some of the areas in the design space already seem over-saturated with large number of games utilizing similar gameplay elements. One such over-use is the common triad of game elements Goals, Social Influences, and Competition. Apps using these game elements often provide a repetitive gamified experience which just relies on users making the required number of steps, and/or comparing it against other users. Some apps, such as Fitbit [38] (see Figure 9) started with the commonly used triad, but have added additional game elements over time. In contrast, some areas of the design space, such as apps that incorporate a plot are under-explored. In our dataset, only 7.7% of the apps were plot-driven; however, they seem to be highly-rated, suggesting the need to explore the development of more plot-based apps. The success of games like Zombies, Run! [43] have demonstrated high rankings over a significant period of time. Similarly, our dataset consisted of only one app (Space Cupcake [69]) utilizing Plot and Collaboration together which is strange considering how these game elements often coincide in many traditional and pervasive games [14]. Novel designs that explore this gap in the design space might allow multiple players to work towards a plot-driven story goal such as completing a journey around the world or to a destination. Designers may identify other gaps in the design space to create novel games and further push the design space boundaries.

We also believe that our research can prove useful in other fields apart from game design. For example, our dataset could be useful to medical researchers who can conduct comparative studies of different game elements on physical health parameters and test the effectiveness of various game elements as health interventions. Even though we focus on steps, the game elements identified by our codebook may be useful for implementing gamification on other data types such as heart rate and blood glucose levels.

Although this article performs an extensive review of gamified fitness tracker apps, it does have several limitations. Our results on game elements are based on a taxonomy we developed by combining game elements from previous research and things we saw lacking. However, different taxonomies from other game research areas could be used, and the level of detail captured by these game elements could be different. For example, while we generalized social game elements into Social Influences, it could be disaggregated into sub-categories such as a chat system, nudging other players, etc. Since this study only looks at game elements and not at behavioral principles, this study does not provide insights into how different game elements support motivation and self-reflection needs of users, which is an essential component for quantified self and adherence to long-term activity tracking [73,74]. Similarly, although this study presents app store parameters such as ratings and reviews, it does not relate them to sustained use of apps and subsequently to exercise adherence. Future research could look at these parameters and perform factor analysis with various game elements to understand which game elements are more preferred by users. Furthermore, thematic analysis of reviews of apps identified by our dataset could help uncover user perceptions of the elements. In general, we hope this study will serve as a foundation for future work on gamified fitness tracker apps.

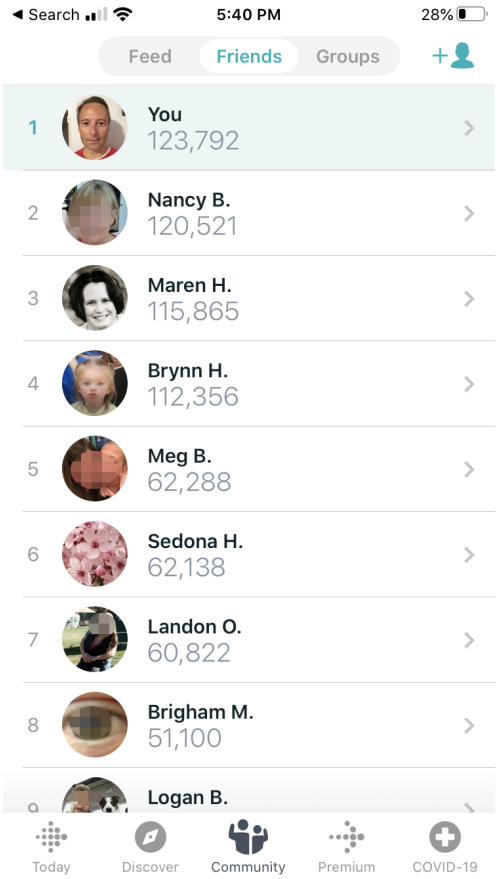

Figure 9. Screenshot of social leaderboard taken from the official Fitbit app [38]. Image ©Fitbit Inc.

Additionally, this review, although systematic, does not capture all apps that use step-tracking data. For example, the app Pokemon Go [75] is not included in our dataset even though it uses walking distance data because our study was focused on apps that solely rely on step-count rather than other sensors such as GPS. Adding to that, future work could look at apps utilizing other sensor data such as heart rate; miles biked and even non-exercise related data such as calories consumed, time spent reading, and sleep time. We think it is likely that many of the same game elements will be feasible for different types of data, though that remains to be seen. Finally, apps are evolving fast, and this study only captures the game elements that were used in the version of the apps we reviewed, and it is possible that new game elements and gameplay techniques will be added to these apps making this dataset outdated. The research community is welcome to contact the authors to update the dataset in the future.

6. Conclusions

The advent of fitness trackers has created a new class of games that utilize activity-tracking data such as step-count to motivate users to be more active. This article provides a snapshot of these apps and games that utilize step-tracking data. By conducting a systematic review of 103 gamified fitness tracker apps, we list out different game elements that are being used in apps currently available in different app markets. Using network analysis and clustering techniques, we visualize the current design space and suggest fruitful new areas ripe for innovation. We also identify how steps are used to trigger different in-game and out-of-game rewards and give examples of ways that steps are used as currency in games. We hope our findings (and the published dataset) will help future researchers further analyze existing gamified fitness tracker apps and help inspire designers to explore novel game mechanics and unique combinations of game elements apart from these standard gamification techniques.

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