A Review of Fitness Tracker Game Elements and a Novel Game Approach for the Design Space

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A Review of Fitness Tracker Game Elements and a Novel Game Approach

for the Design Space

Aatish Neupane

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

A Review of Fitness Tracker Game Elements and a Novel Game Approach for the Design Space

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Master of Science

Physical activities like walking have proven health benefits. People are adopting fitness trackers to track physical activity, but they often stop using them after a relatively short time. Many apps and games exist in the app markets that use gamification to tackle this problem of motivation. In this thesis, we examined these existing gamified fitness tracker apps from app markets and looked at the usage of different game elements within these apps. We conducted a systematic review of existing fitness Tracker Apps from Google Play Store and Apple App Store and used a mixed-method approach to identify apps, categorize them by different game elements used and found gaps in the design space using basic statistics, group clustering algorithms, and network analysis using NodeXL. We also developed a mobile game that combines step tracker data, a compelling narrative, and a strategic resource management mechanic with social cooperative-collaborative gameplay to encourage users to keep using fitness trackers and exercise more. It utilizes game elements and mechanics that haven’t been explored by previous research or games as validated by our results from the systematic review of gamified fitness tracker apps.

Keywords: game, gamification, fitness tracker, exergames, activity tracker, fitness apps, step counter game
ACKNOWLEDGMENTS

I’m deeply indebted to my advisor Dr. Derek Hansen for his guidance and supervision all along the process. I attribute the completion of this thesis and my success as a graduate student to his support and nurturing right from day one. He went above and beyond to help me reach my goal. Not only he made a researcher out of me, he also helped me become a better person by leading through examples.

I am also grateful to Dr. Jerry Alan Fails for his invaluable insights and assistance during the research process. I would also like to extend my sincere thanks to my committee members Dr. Amanda Hughes and Dr. Michael Jones for their various guidance and helping me focus in the right direction. I would also like to thank the the Eureka Trail team without which the game would not have been possible.

In addition, I would like to thank my parents and friends for supporting me in my decisions and providing emotional support during tiring times. Finally, I gratefully acknowledge the members of the IT&C Department who helped me navigate through the whole program with ease.
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CHAPTER 1. INTRODUCTION

1.1 Overview

Increasing adoption of mobile phones is a double-edged sword. On one hand, they are blamed for increasing obesity and decreasing quality of life [1]. But, on the other hand, they provide unique opportunities for creating novel interventions to encourage people to be more physically active. Paired with health tracking devices like fitness trackers, it opens up even more avenues for health and motivation related interventions. Realizing this possibility and with an ever-growing demand for fitness trackers [2], the mobile ecosystem is filled with apps and games from app developers and researchers that utilize gamification and fitness tracker data to motivate people to exercise more. Given that the benefits of physical activity are well-recognized in medical literature [3–5] and public health community [6, 7], it is imperative that a formal understanding of this emergent genre is needed. Looking at the existing apps and their usage of different game elements is an important first step in this direction.

The general public also recognizes the importance of physical activity for their personal health, and thus, in order to motivate themselves to exercise more, people buy fitness trackers, but they end up not using them after a while [8]. Some preliminary research have tracked this behavior down to some of the factors like the lack of sustained motivation and forgetting to wear it daily [9, 10]. To encourage people to keep using fitness trackers, game designers have implemented gamification (i.e., the use of game elements in non-game contexts [11]) using various game elements in their games but less is known about which game elements have been useful to help sustain motivation and tackle this behavioral issue. Existing research in this area have mostly been comparative between limited sets of game elements (like cooperative vs competitive game elements [12–15]), and lack even a taxonomy of game elements used by existing fitness tracker based apps.
Therefore, in this thesis, we characterize the design space of fitness tracker apps by conducting a thorough systematic review of existing apps for their use of different game elements. We also analyse relationships between game elements and outcome metrics (such as number of ratings and reviews) and try to identify gaps in the design space that could be filled by new apps and games. We also present a game called “Eureka Trail” that attempts to fill one of the gaps in the design space by utilizing game elements that haven’t been explored enough. The game is a culmination of work done by an interdisciplinary team of students over the past 2 years at BYU.

1.2 Purpose

There are two main goals of this thesis. They are to characterize and identify gaps in the design space by reviewing existing gamified fitness-tracker apps and to develop a novel game that attempts to fill one of the identified gaps.

The first goal can be addressed by answering the following research questions:

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?

The second goal is a research objective that builds upon the first goal and can be attained by developing a fully-functional mobile game that combines game elements that are rarely combined and utilizes step-count data to provide a compelling gameplay.

1.3 Thesis Layout

This thesis is divided into two main sections. Chapter 2 presents the results after reviewing existing gamified fitness-tracker apps from the app stores. It is a reprint of a peer-reviewed journal article which was published in Multimodal Technologies and Interaction (ISSN 2414-4088). Chapter 3 introduces the Eureka Trail game, its gameplay, and provides design justifications. Finally, Chapter 4 concludes this thesis by providing the summary and future work that can be done based on the contributions of this thesis.
CHAPTER 2. THE ROLE OF STEPS AND GAME ELEMENTS IN GAMIFIED FITNESS TRACKER APPS: A SYSTEMATIC REVIEW

2.1 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 metadata 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.

2.2 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 [2]. 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 [18]) 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 [15] 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 [3]. 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 [6]. 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 [4, 5]. 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 [19], 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 [20] and pervasive games [21, 22], 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

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?

2.3 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 re-
garding the effectiveness of competitive vs. cooperative game elements to motivate users when implementing gamification. While some studies prescribe competitive game elements to motivate users [12, 13], other studies argue that competitive game elements in gamification can be demotivating for users [14, 23]. 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., [24–26]). 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 [24, 27]. 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 [27]. 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 [28]. 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 mis-
categorized [29]. Our previous work [17] 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 [17] 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 [30] 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.

2.4 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 2.1), 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 [17]. 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 2.1: Codebook of game elements and their description.

<table>
<thead>
<tr>
<th>Game Element</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Goals</td>
<td>Measurable and well-defined target that a user has to achieve.</td>
</tr>
<tr>
<td>Challenges</td>
<td>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.”</td>
</tr>
<tr>
<td>Competition/Leaderboards</td>
<td>Compete with other members directly or through leaderboards.</td>
</tr>
<tr>
<td>Collaboration</td>
<td>Work together towards a common goal or objective in the game.</td>
</tr>
<tr>
<td>Social Influences</td>
<td>Performance is publicly displayed. Code for this if game activities can be shared or there are elements of peer pressure and social nudging.</td>
</tr>
<tr>
<td>High Scores</td>
<td>Tracking of best attempts over a particular timeframe.</td>
</tr>
<tr>
<td>Badges</td>
<td>Visual recognition earned for completing specific milestones, tasks or when player completes a goal or challenge.</td>
</tr>
<tr>
<td>Plot</td>
<td>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”.</td>
</tr>
<tr>
<td>Narrative</td>
<td>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.</td>
</tr>
<tr>
<td>Points</td>
<td>Accumulates points that help progress through game and/or can be redeemed for rewards or be used in in-game economy.</td>
</tr>
<tr>
<td>Levels</td>
<td>Progress through parts of the game (e.g., level 1 to level 2) or gradients of status (e.g., bronze level to silver level).</td>
</tr>
<tr>
<td>Unlockable Content</td>
<td>Access to enhanced functionality (new levels, gameplay, etc) or content for accumulating experience or achieving a specific goal.</td>
</tr>
<tr>
<td>Real-life Incentives</td>
<td>Discounts, rewards, donations, or prizes in real-life.</td>
</tr>
</tbody>
</table>
2.4.1 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 [31]. However, we slightly modified the framework since we were reviewing apps instead of journal articles (which the framework is originally intended for). Figure 2.1 shows the summary of the process we followed and the following sections provide additional detail.

![Figure 2.1: Selection and filtering process.](image)

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.

2.4.2 Coding for the Presence of Game Elements

In our previous work [17], we combined the works of Cotton and Patel, and Kappen et al., and came up with a taxonomy for coding game elements [28, 32]. 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 2.1. 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.

2.4.3 Network and Cluster Analysis

Using NodeXL [33], 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 [34]. Specifically, we used the python-louvain [35] 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.

### 2.4.4 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 [36] and how steps are utilized as a currency [30, 37].

### 2.5 Results

In this section we give an overview of the game data (Section 2.5.1), describe game element occurrences (Section 2.5.2) and co-occurrences (Section 2.5.3), and then discuss how steps are utilized to attain rewards (Section 2.5.4) or as currency in an economy (Section 2.5.5).

#### 2.5.1 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 2.2 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 [38, 39], 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 2.2.

![Box plots showing the distribution of average ratings and number of reviews for iOS and Android platforms](image)

**Figure 2.2:** Quality and popularity metrics in app stores.

Our final dataset has been previously published and is freely available via an open-access creative commons license [40]. 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 three apps in the store (based on number of reviews) were official apps for popular fitness tracker devices: Mi Fit [41], Fitbit [42], VeryfitPro [43]. 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 [44], Sweatcoin Pays You to Get Fit [45], and Yodo Cash for Running [46] which had real-life incentives built in. Apps like Zombies Run! [47], Walkr: Fitness Space Adventure [48], and Fit the Fat 2 [49] 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 [48] 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.

### 2.5.2 Game Element Occurrences

There was variation in the types and number of game elements in the apps we reviewed. Figure 2.3 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 [50] and Walk With Friends! [51] are standard examples using these game elements. On the other hand, almost 25% of the apps we reviewed implemented seven 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! [52] app includes features such as characters, costumes and an in-game marketplace with currency based on the steps you take. Similarly, in Pocket Plants [53], you can manage a virtual garden by growing virtual plants, evolve them, and use traditional game mechanics like powerups to enhance your plants.

Table 2.2 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 [42] 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 2.2 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 2.2 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 2.2 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 2.4 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.

### 2.5.3 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 2.5), we identified separate clusters. The algorithm detected five clusters of game elements which are represented in the network graphs (Figures 2.5 and 2.6) as distinctly colored nodes where Figure 2.5 is an enriched NodeXL co-occurrence graph and
Figure 2.4: Game elements plotted based on occurrences and average co-occurring elements. Color indicates clusters as identified by Louvain’s algorithm as described in Section 2.5.3.

Figure 2.6 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 2.6, 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 [54] and Stroll-Walking Tracker [55] which include simple step-based challenges and competitions, and apps like Lympo [56] and Yodo-Cash for walking and running [46] (see Figure 2.7) [46] 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 2.5), 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 [57] (see Figure 2.8), a plot-based game where you manage a team of heroes, find unlockables, and collect points by taking in steps; Zombies Run! [47], where you walk to avoid Zombies from attacking you; StepGod [58], where you populate the universe by evolving game characters; and The Walk: Fitness Tracker Game [59], where you complete compelling missions based around a story through the help of steps in real-life.

Figure 2.5: 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.

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 2.5 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
Figure 2.6: Co-occurrence network pattern of game elements where edge widths represent co-occurrence weighted by their “relative strength” which is explained in Section 2.5.3.

Figure 2.7: Screenshot of Real-life Incentives in the Yodo-Cash for walking and running app where users can exchange points they earn from walking into Paypal transfers.
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 [33], and created an alternative visualization as shown in Figure 2.6 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:

\[
\text{Relative Strength} = \max\left(\frac{\text{times X and Y show up together}}{\text{times X show up in total} \times \text{times Y show up in total}}, \frac{\text{times X and Y show up together}}{\text{times Y show up in total} \times \text{times X show up in total}}\right)
\]
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 2.6 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 2.6 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.

2.5.4 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:
Task-Contingent Rewards

A task-contingent reward is a reward structure which is tied to a certain task [60]. 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 [60]:

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 [42] 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 [59] 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 [42] 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 [53] which rewards users with points regardless of goals or milestones as long as they are walking.

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 [42] 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 2.5 and Table 2.2) 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).

2.5.5 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.

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 [61], 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 [62], 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 [63] 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 [64] 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 [65] 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 [66] and RunBet-Run more, Earn more [67] 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.

**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 [68] 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 [48] 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 [69] game,
users can unlock new locations in their map by walking more. In the The Walk: Fitness Tracker Game [59] 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 [70] 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 [71] app, users can choose their “plants” based on number of steps they make and create a completely different “garden.” Similarly, in the game Hops [72], 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 [49] 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 [48], steps can reduce the virtual game time so that players can explore planets faster. In the game Space Cupcake [73], 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 [62]). For example, in the Idle Walking Tycoon [74], 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 [72] 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 [61] 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.

2.6 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 [40], 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., [75])? 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 [15], and use of social elements can raise privacy concerns to users [76]. 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 [42] (see Figure 2.9) 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! [47] have demonstrated high rankings over a significant period of time. Similarly, our dataset consisted of only one app (Space Cupcake [73]) utilizing Plot and Collaboration together which is strange considering how these game elements often coincide in many traditional and pervasive games [22]. 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 [77, 78]. 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 2.9: Screenshot of social leaderboard taken from the official Fitbit app.

Additionally, this review, although systematic, does not capture all apps that use step-tracking data. For example, the app Pokemon Go [79] 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 calo-
eries 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.

2.7 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.
CHAPTER 3. EUREKA TRAIL: A NOVEL GAME FOR EXERCISE MOTIVATION

In Chapter 2, we reviewed gamified fitness-tracker apps for the presence of different game elements. In a large proportion of the apps that we reviewed, we noticed the widespread use of common game elements (such as goals) and game mechanics (such as daily goal system and competitive leaderboards). We also identified gaps in the design space, one of which is the limited number of apps utilizing collaborative game mechanics with a rich narrative. In this chapter, we describe the development and design of a game called the “Eureka Trail” that attempts to fill this particular gap in the design space. In the following sections, we reiterate the importance of exercising, state the design goals of the game, and present the design decisions made along the way. The Eureka Trail game is a result of teamwork from an interdisciplinary team of students over the course of two years. My major contributions to the project include developing the game backend, architecturing the game state design, and implementing frontend logic and synchronization.

3.1 Introduction

Walking is a simple, low-risk physical activity with proven health benefits [3]. The ubiquitous adoption of mobile devices and fitness trackers have opened new possibilities for novel interventions to motivate people to walk more. Although the fitness tracker market is ever expanding [11], people often stop using trackers after a few months [9,12]. To keep people motivated, researchers and app developers have tried to come up with different types of fitness games leveraging the fact that games are intrinsically motivating [7]. Unfortunately, many of these games employ simple game mechanics making them feel repetitive, and/or are not enjoyable when replayed. Social motivation is also a key factor for exercise adherence [8], but many existing games do not fully explore social game mechanics, such as cooperative play. In fact, a large portion of these games are just step-trackers with leaderboard functionality which is often the only type of social influence leveraged in these games [6]. And leaderboards can be demotivating for the ma-
ajority of people who don’t win [1]. Our game, the “Eureka Trail” is a unique genre of fitness game because it combines several key design elements including: fitness data-driven; strategic; rich narrative; cooperative collaboration; and extended, asynchronous play. This results in a fun, social, replayable, and motivational game. Furthermore, previous research on systematically identifying game elements in existing fitness tracker-based apps provides evidence that games utilizing plot and collaborative elements are rare [6].

3.2 Design Goals

The Eureka Trail is a social team-based fitness game that uses step-count data and collaborative-competitive game mechanics with a compelling narrative. It has the following design goals:

1. Motivate users to exercise more and keep using their fitness trackers.

2. Strengthen social connectedness with people they play with, including youth and older adults (e.g., extended families).

3. Combine under-utilized game mechanics to promote fun and replayable games.

4. Support research on the impacts of game mechanics on exercise, social connectedness, and integration into everyday life.

3.3 Design Justifications

The Eureka Trail game is a strategic role-playing game with a narrative representation of the historic 2000+ mile California Trail traveled by wagon caravans during the gold rush. A team in the game corresponds to a caravan of people travelling in a covered wagon across the trail. To ensure compatibility with mobile platforms and different fitness trackers available in the market, the game has been developed as a cross-platform project in Flutter and leverages consolidating fitness libraries such as Google Fit and Apple Health which work with large number of fitness trackers and provide a single API to access step-count data.

The following sections describe features we have implemented to achieve the design goals outlined earlier.
3.3.1 Fitness Data-Driven

Our game is driven by steps that users take in real life. Steps influence progress across the trail in different ways. When travelling along trail segments (which occur between destinations), a minimum number of steps is necessary to survive. Steps above the set minimum help user get to the next destination faster. When at a destination, steps help earn money, which can be used to purchase items and food that are needed to survive. Steps also influence the likelihood of earning food when hunting, which is an individual activity that can be completed once per real day. Finally, steps also help users respond to challenges within the game, such as a broken wagon wheel.

3.3.2 Strategic

Inspired by The Oregon Trail game [13], the gameplay emphasizes planning and strategic resource management. Players can choose to purchase different types of wagons, animals and items. All of these influence the speed of the wagon which, in turn, affects number of real steps necessary to travel a mile in the game. Similarly, users need to prepare for difficult segments of the journey beforehand in anticipation of different terrains on the trail. They also need to plan for certain items to respond to impromptu challenges in the game (e.g., contracting dysentery; dealing with a broken wheel). Roles of team members determine what items they start with, amount of money they bring and skills they have (e.g., hunting, negotiating). Roles are listed out in Table 3.2. Each player and animal have a health score, which when depleted incapacitates the user, making their steps ineffectual until they are revived (or the rest of the caravan members become incapacitated, in which case the game ends). Unlike The Oregon Trail, our game’s inventory includes individual items (e.g., a person’s clothes or hunting gun) and collaborative items shared by the caravan. This helps promote collaborative cooperation, as discussed later.

3.3.3 Rich Narrative

Like The Oregon Trail, the narrative writing is playful, a bit snarky, and includes historical tidbits in the game context. However, unlike The Oregon Trail, our narrative is gold rush themed and is more modern. Rather than use a highly pixelated style, like The Oregon Trail, we use an impressionistic-inspired style that captures the beauty of the trail. To create the artwork, we ran
Table 3.1: Richness of entities in the Eureka Trail game.

<table>
<thead>
<tr>
<th>Entity</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Roles</td>
<td>10</td>
</tr>
<tr>
<td>Checkpoints</td>
<td>15</td>
</tr>
<tr>
<td>Segments</td>
<td>14</td>
</tr>
<tr>
<td>Items and Collectibles</td>
<td>120</td>
</tr>
<tr>
<td>Animals</td>
<td>8</td>
</tr>
<tr>
<td>Challenges</td>
<td>50</td>
</tr>
<tr>
<td>Events</td>
<td>40</td>
</tr>
</tbody>
</table>

Gary Stone’s trail artwork found in the National Oregon/California Trail Center through a pixilation and smoothing tool. The somewhat pixelated typography, icons, and 8-bit music are meant to evoke nostalgia for The Oregon Trail. Destinations and trail segment names and properties (e.g., mountainous; muddy) are based on historical research conducted by the team. Each team member chooses to play as a certain role for the duration of the game. They receive randomly assigned custom challenges based on their role (e.g., a doctor role might have to complete a “treat dysentery” challenge) and have different items, wages, starting funds, and skills. The 10 available roles are shown in Table 3.2. Unlike games that have a single narrative experience, The Eureka Trail experience is different depending on which role you take on, which team members you have in your caravan, and which challenges are issued. This richness of roles and specialized contents (see Table 3.1) increased the replayability of the game. Unlike many existing fitness tracker-based narrative games, this approach does not get old after you experience a single story.

3.3.4 Cooperative Collaboration

The main goal in the game is to get the caravan successfully across the plains as a group. A secondary goal is to do so as fast as possible. It is collaborative within a team because the game ends only when all caravan members arrive at Eureka (the final destination) or die by running out of food or are stranded on the trail because they did not make it to the next destination. The caravan’s speed is dependent on everyone’s steps, as well as the weight of everyone’s items, wagon type, and number of pack animals. When traveling between destinations in the trail, steps taken by all team members are averaged to get the team to the next destination. We also show total step count for each player, so they can help motivate each other if someone is slacking. Food and most
Table 3.2: Different roles in the Eureka Trail game.

<table>
<thead>
<tr>
<th>Role Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wagon Master</td>
<td>As the dauntless Wagon Master, you will safely guide your company to untold riches and lighten their spirits with tales of prior adventures.</td>
</tr>
<tr>
<td>Caretaker</td>
<td>As an experienced caretaker of children, the elderly, animals, and idlers, you will use your creative skills to keep the company well-fed, clothed, and happy during their treacherous journey.</td>
</tr>
<tr>
<td>Horse Thief</td>
<td>As a reforming horse thief, you will put your natural good looks, stealth, and riding skills to more productive use to not only protect from thieves, but also steal them back if necessary, while hopefully avoiding hefty fines from the Anti-Horse Thief Association if caught.</td>
</tr>
<tr>
<td>Doctor</td>
<td>As the team doctor, you will treat broken bones, snake bites, and dysentery through bloodletting and other modern medical practices.</td>
</tr>
<tr>
<td>Preacher</td>
<td>As a devout, God-fearing missionary, you will take responsibility for the spiritual well-being of your caravan and bring religion to the &quot;Godless heathens.&quot;</td>
</tr>
<tr>
<td>Merchant</td>
<td>As a former shopkeeper and savvy negotiator, you plan to make your millions extracting gold from gold diggers.</td>
</tr>
<tr>
<td>Blacksmith</td>
<td>As an experienced blacksmith, you are ready to put your unique skills to use by fixing wagon wheels, shoeing oxen, and hammering in the heads of anyone that might stand in your caravan’s way.</td>
</tr>
<tr>
<td>Carpenter</td>
<td>As a talented woodworker, you will be ready to put your skills to good use repairing wagons, fixing barrels, and building caskets.</td>
</tr>
<tr>
<td>Soldier</td>
<td>As a veteran of both the Texas-Indian wars and the Mexican-American War, you’re finally ready for your toughest fight yet: the Outside World. You are well equipped to fearlessly protect the caravan against thieves and coyotes.</td>
</tr>
<tr>
<td>Hunter</td>
<td>A skilled hunter and adventurer, you are ready for a new challenge. You have complete confidence that your skills will help feed and protect your caravan.</td>
</tr>
</tbody>
</table>
other items are shared within the caravan and players can help other members who need personal items (e.g., clothes) by giving them money. The narrative requires players to make group decisions which can possibly help build better social connections. For instance, whenever a player gets a challenge, all team members are notified, and they can chime in and help that member decide what to do. Furthermore, if someone buys a pipe organ, it will slow down the entire caravan due to its extra weight. The game is competitive across teams in the sense that teams who get to Eureka first show up on a team leaderboard. This can help build a sense of comradery within groups, since they have a “common enemy” they are competing against.

3.3.5 Extended Asynchronous Play

The standard game is played over a fixed duration of 14 days. We designed the game to be asynchronous, so it is easier to fit into people’s everyday lives. This allows each player to play when it is convenient to them, though steps they take throughout the day contribute to trail progress. Activities such as buying items or responding to challenges can be completed at any time during the day, so as to not disrupt players (e.g., give an advantage to those who are not busy at work or school). Each 24-hour period in the real-world alternates maps to a trail destination or a trail segment. When players are at a destination, their steps earn them money, which they can use to purchase items and food at any time. When players are traveling on a trail segment, each player responds to a challenge whenever is convenient for them. If they do not respond during the day, challenges have a natural consequence (e.g., health or speed may be reduced). After the minimum number of aggregated team steps for a trail segment are met, additional steps start to reduce the number of “trail days” for the journey. This approach to dealing with time is different than our original prototype, which interrupted people’s lives too much (see Section 3.4).

3.4 Dealing with Time

One of the major changes we made from our early prototypes had to do with how we mapped game-time to real-world time. Designing a socially adaptive game which fits into people’s everyday lives is one of the key design challenges in pervasive games [2,5]. Initially, we linearly mapped step counts to trail miles, which then triggered events such as challenges or arriving at a
destination (e.g., city). This way, teams could progress through multiple destinations and segments even on a same real-world day and complete multiple challenges throughout the day. Our play-through as a group made it clear that this style of gameplay required too much attention at specific times (e.g., when we were in class while one of the members was on a holiday and getting in more steps), especially given the collaborative nature of the game. For example, if the team arrived at a destination, but others did not check their phones while there, they could miss the opportunity to purchase items. To not overwhelm users each day while still keeping them engaged, we came up with a solution to map each real day to either a single destination or a single trail segment. This allowed the game to be more predictable and flexible within a given day (i.e., people can respond to challenges at any time during a day). However, to still reward extra steps when traveling along a trail segment, steps beyond the minimum needed to arrive at the next destination will decrease the total “trail days” it takes to complete the trail. This allows teams to still “race” other teams across the plains virtually, even though the duration of gameplay is set ahead of time (e.g., 14 days for a standard game). Formally, time in this game is fixed-scaled, synchronized between teams, and activity-driven [10].

3.5 Converting Steps into In-Game Resources

In the Eureka Trail game, steps play a central role in the gameplay. At any given day, a caravan can either be in a checkpoint or in a segment (going towards a next checkpoint). In a segment, steps translate to the speed of the caravan (as discussed in earlier in Section 3.4). In a checkpoint, steps translate to wages earned by the players. After crossing the daily goal of 12,000 steps, the steps “overage” is still utilized in the game so as to incentivize players who wish to take more steps than required. So the minimum number of required steps translate to base caravan speed but any more steps increase the caravan speed positively, albeit with diminishing returns. Similarly, in the case of wages, up until the minimum number of steps, wage rate remains constant but once players start making more steps than the minimum, they still earn wages but the wage rate keeps decreasing. These diminishing returns are implemented using the following logistic function:
\[ f(x) = \frac{L}{1+e^{-k(x-x_0)}} \]

where \( L \) = maximum value the curve can take i.e., the maximum trail speed or maximum wage,

\( k \) = Logistic Growth Rate,

\( x \) = Step overage,

\( x_0 = \ln \left( \frac{(\text{Maximum Allowable Value}/\text{Base Value} - 1)}{k} \right) \)

In case of caravan speed, \( x_0 \) becomes:

\[ x_0 = \ln \left( \frac{(\text{Maximum Caravan Speed}/\text{Base Caravan Speed} - 1)}{k} \right) \]

and for the wage, it becomes:

\[ x = -\text{Step overage}, \]

\[ x_0 = \ln \left( \frac{(\text{Max Numeric Value}/\text{Base Character Wage} - 1)}{k} \right) \]

The maximum numeric value (which determines the maximum value the curve can take) in the case of wage calculation does not matter because the wage rate decreases as steps increase (note the minus sign for \( x \) in case of wage) so only the negative x-axis values for logistic function is taken into consideration which tends towards zero as \( x \) decreases.

These diminishing return functions ensure that enthusiastic players who walk more than the bare minimum are rewarded but prevent their step counts from skewing the balance of the game. For example, the caravan speed cannot reach unrealistic values with high step counts even if a player hiked all day, thereby making it impossible to arrive at Eureka in an unrealistic number of days (e.g., 2 days). Likewise, in the same scenario, the player cannot earn large amount of wages, because if they could, that would then allow them to complete the rest of the game effortlessly.
3.6 Gameplay

The following sections describe the different gameplay features of the Eureka Trail game along with how they relate to the design goals. Table 3.3 provides an overview of all the pages and design goals related to the functionality provided by those pages.

Table 3.3: Game pages as it relates to design goals.

<table>
<thead>
<tr>
<th>Page(s)</th>
<th>Design Goals</th>
</tr>
</thead>
<tbody>
<tr>
<td>Role Selection Page</td>
<td>Replayability</td>
</tr>
<tr>
<td>Notice Board Page</td>
<td>Collaborative, Rich Narrative</td>
</tr>
<tr>
<td>Location Pages</td>
<td>Rich Narrative</td>
</tr>
<tr>
<td>Caravan Pages</td>
<td>Collaborative, Fitness data-driven, Rich Narrative</td>
</tr>
<tr>
<td>Inventory Management Pages</td>
<td>Strategic, Replayability</td>
</tr>
<tr>
<td>Food and Trip Planner Pages</td>
<td>Fitness data-driven, Strategic</td>
</tr>
<tr>
<td>Settings Page</td>
<td>Asynchronous play</td>
</tr>
</tbody>
</table>

3.6.1 Login and Registration

The game requires authentication to play. Since it is a cross-platform game, we have implemented multiple authentication mechanisms such as Apple ID, Google Login, and plain Email-based authentication as shown in Figure 3.1.

3.6.2 Onboarding a Caravan

Once logged in, players have three options to onboard a caravan (see Figure 3.2). They can do one of the following:

1. **Create Caravan** A user can create their own caravan by providing a caravan name, the visibility of the caravan (i.e., public or private), maximum occupancy, and the start date of the caravan. The start date determines how many days the caravan will wait until the game starts.

2. **Join Private Caravan** A user can also join a private caravan using a join that they receive from friends or families. Join codes are auto-generated but uses dictionary words to make it more human-friendly (e.g., wicked-gecko-59).
3. **Join Public Caravan** Finally, users can also join from one of the public caravans that hasn’t started yet. This option provides opportunity for players to play with complete strangers.

![Different login options](image)

**Figure 3.1: Different login options.**

### 3.6.3 Role Selection

The player can choose from one of the 10 roles (see Table 3.2). When choosing a role, they also specify their in-game name and the pronoun they prefer to use (see Figure 3.3). Since in-game challenges, events, skills, and items are dependent on roles, this adds replay value to the game by allowing users to play this game again as a different role and get fresh content that they wouldn’t have seen before. To ensure the game can support groups larger than the number of roles, multiple players can select the same role.

### 3.6.4 Notice Board

Once into a caravan either by creating a new one or joining an existing one, the player sees the Notice Board page (see Figure 3.4a). The Notice Board Page displays progress towards
(a) Create a caravan.  
(b) Join a private caravan.  
(c) Join a public caravan.

Figure 3.2: Different ways to join a caravan.

Figure 3.3: Choosing a role and specifying in-game name and pronoun.
the final destination, caravan notifications, and new challenges. The user can then respond to new challenges (Figure 3.4b) and also see challenges that have been assigned to other players.

### 3.6.5 Location Pages

From the notice board page, players can go to the Location page (Figure 3.5a) which displays information about the location they are in and different actions they can do while they are there. If in a checkpoint, users can also talk with locals which often provide them with helpful tips about the upcoming journey (see Figure 3.5b).

### 3.6.6 Caravan Page

As a collaborative game, the Caravan page (see Figure 3.6) provides a way to look at the members of the caravan and their step count statistics. The page also provides information about when the steps were last synced. This can be useful to facilitate social accountability by nudging other players to use the app and sync their steps if they are falling behind. To encourage
collaboration, players also have an opportunity to gift money to other players which they can use in case of emergencies like food shortage or buying certain items for personal challenges.

The second tab of the same page allows players to look at animals they have purchased. Some animals like Ox and Horse contribute to the pulling capacity of the caravan which is displayed in their detail pages (Figure 3.6b). In the same page, players can also give them a personalized name or even kill them for food during food shortage.

### 3.6.7 Inventory Management Pages

The Inventory page (Figure 3.7b) displays all the items and collectibles grouped by their ownership. Some items are personal to players but some are shared between members in the caravan. Managing items is a strategic process because the weights and types of items (such as wagons or horse shoes) determine the speed of the caravan. Some items are also essential for challenges and events that occur throughout the game. Finally, on checkpoints, players can buy and sell items through the Buy/Sell page (Figure 3.7). They have to be strategic about what things to buy and sell by thinking ahead of what might be required in the upcoming segments.
(a) List of animals.  
(b) Animal detail page.  

Figure 3.6: Members and animals pages.

(a) Buy/Sell page.  
(b) Inventory page.  

Figure 3.7: Inventory management pages.
3.6.8 Food and Trip Planner Pages

The Food Page (Figure 3.8a) and the Trip Planner Page (Figure 3.8b) are one of the most important pages that players use to ensure they can complete the game and win. The food page is essential to plan the food supply and plan ahead so that the caravan does not run out of food (which reduces health of the players). The Trip Planner page provides information about number of steps required to reach the next destination and the weight efficiency (pulling capacity vs weight of items). If they find that they are inefficient, they can use inventory management features to drop or sell items and reduce the inefficiency.

3.6.9 Settings Page

Notifications about in-game events are pushed to users’ devices as instant notifications. This allows users to be updated with the caravan progress without having to load the app and check for updates. This facilitates asynchronous play but can be intruding depending on users’ preferences. So, the Settings page (Figure 3.9) provides users with an option to disable notifications.
if they are too frequent for them. In future updates, we plan to add granular controls to enable or disable specific types of notifications (such as personal vs caravan notifications).

![Figure 3.9: Settings page.](image)

### 3.7 Technical Implementation

The game utilizes Node.JS for the backend and Flutter for the frontend. The following sections describe some technical implementation details and reasoning behind it.

#### 3.7.1 Authoritative Server and Dumb Clients

The Eureka Trail game utilizes the concept of “authoritative server and dumb clients” [80]. The game backend is written in Node.JS. Most of the game logic and calculations are made on the server and only the current state of the game is passed to clients through the real-time Socket.IO protocol. For example, caravan parameters like weight, pulling capacity, current speed, etc are all calculated in the backend rather than in the mobile game. Following are the advantages of keeping the game state centralized as opposed to letting the clients calculate caravan parameters locally:
1. Even if we had put game logic in the client app, we would still have to implement that in the server anyway so a centralized game logic reduces the need to maintain game states in two different places.

2. By allowing clients to manipulate game state directly, it makes it easy to implement cheating. Keeping state centrally eliminates this problem.

3. Publishing new updates through the mobile app stores normally takes days due to app review processes implemented by iOS App Store and Google Play Store. However, fixing logical errors in calculations on the backend is much easier and can be instantly deployed without having to update client apps.

3.7.2 Cross-Platform

To ensure maximum compatibility between mobile phones of “friends and families”, we created this game in Flutter. Flutter is a cross-platform mobile development platform based on the Dart programming language. Once written in Flutter, the app can be built for both iOS and Android platforms.

Even with Flutter, gathering step-count data through native APIs proved to be difficult. The iOS platform provides Apple Health Data APIs to query for step-count values and the Android platform provides Google Fit APIs for the same. After evaluating many wrappers around these APIs, we chose the “health” library developed by the Copenhagen Center for Health Technology (CACHET) at The Technical University of Denmark.

3.8 Testing

We have been iteratively testing and improving the app on various devices (iPhone 12, iPhone SE, Pixel 3), and have confirmed that UI functionalities and flows (e.g., login, registration, caravan creation, joining, ending conditions etc.) are working as intended. We have also confirmed that the step counts are correctly being sent to the server. To ensure that the team can check multi-day functionalities without having to wait a full day, we also added a “Debug Page” which lets testers add fake step data and advance inside the game. The game backend also features
a set of integration tests written in NodeJS which simulates caravans through different possible
game scenarios like step-count variations (inadequate, minimum, or high step counts), and checks
whether it leads to completion or not. The beta version of the game has been published to Apple’s
TestFlight system which lets iOS users test the app before publishing it into the App Store. It will
soon be released to the Google Play Store as well.

3.9 Future Research

The overarching goal of the Eureka Trail game is to integrate novel game mechanics into
fitness games to increase exercise motivation and social connectedness. Although a user study is
out of scope of this thesis, the fully developed game can be used for future research to study the
following types of questions:

1. Which interactions with the mobile application lead to increased activity?
2. Which interactions with the mobile application are most enjoyable to participants, and why?
3. How does the use of the mobile application affect social connectedness?
4. How does group composition influence game play? (e.g., groups of family members com-
   pared to groups of friends or strangers)

We hypothesize that the Eureka Trail will lead to increased physical activity as a result of
different interactions and mechanics that are present in the game. Specifically, we believe that by
using average step counts from everyone within a team, players will feel more motivated to make
their share of steps due to the feelings of accountability towards the goal [81] and not wanting to
let the team down. Aside from this collaborative nature of motivation, we also believe that the
concept of trail days (time it takes a caravan to complete the game) will further motivate players by
introducing an element of competition between caravans and provides caravan members with yet
another goal that they can “brag about”. Finally, the rich narrative consisting of unique challenges
and events that are released every day should encourage users to continue playing the game in
order to see how the narrative unfolds.

We also hypothesize that the use of the Eureka Trail will lead to increased social connect-
edness among members of the team. The game does not have any form of in-game communication.
This is deliberate because we believe that the happenings inside the game will give players something to talk about through social media means. Some examples include calling other players up to remind them to make an adequate number of steps and talking about challenges that they received. The game also requires a lot of strategic group-based decision making such as talking about what to purchase for the next segment of the journey and gifting money so someone has enough to purchase a wagon. We believe these kinds of strategic decision-making and collaborative nature of goal achievement will help players stay connected during the process.
CHAPTER 4. SUMMARY

4.1 Summary and Future Work

In the first part of the thesis, we reviewed existing gamified fitness tracker apps and analysed their usage of different game elements and their relationships in games. This helped identify different emerging sub-genres within gamified fitness tracker apps and identified possible new areas for development. Specifically, this part of thesis contributes to the research space in the following ways:

1. Our research contributes to the taxonomy for identifying game elements in gamified fitness tracker apps and canonical fitness tracker based games.

2. Knowing the distribution of game elements in fitness tracker games helps to define the space, so it can be tracked over time. It can also be used by designers to help justify claims that their game is innovative in its use of game mechanics (e.g., game X combines game elements that aren’t typically combined), or to help identify unexplored sections of the design space.

3. Game designers and researchers can use our dataset to take inspirations by looking at how existing apps handle similar design problems. For example, designers and researchers can perform a detailed analysis of all games that use Social influences (or all games that combine Narrative with Competition), using our published dataset as a starting point for identifying those games.

In addition to these contributions, the second part introduced the Eureka Trail Game. The game attempts to fill a void of collaborative plot-driven apps in the gamified fitness tracker app ecosystem. Specically, our systematic review identified that although plot-based apps are available in the app markets (e.g., Zombies Run! [47]), they rarely use social elements like collaboration. In fact, most plot-based apps that utilize social elements do so by implementing simple leaderboards
(see Fitness RPG - Walking Games, Fitness Games [57] for an example) which are not part of their core game mechanics. The Eureka Trail is novel in the sense that it not only provides a rich narrative gameplay, but also includes a strong social game mechanics that requires collaboration between players in order to win the game. As a fully functional game, this can now be used for future research to study the novel combinations of game elements like Plot and Collaboration on sustained exercise habits and feelings of social connectedness among players.
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