Validating Game Design with Game Analytics in a Location-based Game

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Game analytics has grown from a trend to a norm in almost all types of games, and with the availability of tools and information, leveraging benefits has never been easier. Additionally, mobile location-based games are a great platform for applying game analytics due to location information being bound to almost every facet of such games, thus enabling developers to understand where and how their games are played.

This thesis is based on a research project at the University of Turku, of which a part was to create a pirate-themed location-based mobile game. The game was then studied in terms of how it was played with the help of telemetry data from the game. In this thesis, the player data is used to find out how the game's design can be validated in terms of healthiness and whether a game's design can have a positive influence on a player's health.

The player data was plotted as routes for each individual player, and then inspected for different kinds of behaviour. Players were found out to play in different kinds of areas, and play during or after riding a vehicle, and play the game on the same routes repeatedly. Physical activity of players can be increased by making walking between locations a requirement, but the game mechanics have to be interesting enough, as the novelty of walking in itself is not sufficient. Ultimately, players were shown to increase their physical activity by playing the game, which meant travelling between objectives.

Keywords: Game analytics, game design, physical activity, location-based game

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Chapter 1

Introduction

1.1 Thesis Motivations

The theme of this thesis is combining game analytics with game design. The subject came from a research project at the University of Turku, which researched links between snacking and gaming. A game was made for the project, which will be referenced in this thesis as the research game, which collected telemetry data from users. The telemetry data from the game proved to be an excellent source for a master's thesis. While being part of a research project can be limiting, the limitations are largely helpful in defining the research objective and the research scope.

1.2 Research Questions

The research objective of this thesis is how to validate a subset of game design with the help of game analytics, with the context being a location-based game. The focus is further narrowed down to a whether the game design can have a positive impact on a player's health.

More explicitly, the research questions are defined as

R1 How can a game design be validated in terms of healthiness with the help of game

analytics?

R2 Can a game design have a positive effect on a player's health?

1.3   Thesis Scope and Limitations

One limitation on the results of this thesis is the sample size, which becomes even smaller after filtering out players who did not   play the research game enough to provide data for meaningful analysis. This limitation can be used as a basis for discussing why most players who downloaded the game did not play past the early stages. A second limitation in the thesis is the collected player data, as the collection process can contain issues such as bugs in the game software, and inaccuracies in player locations.   A third limitation in the thesis is the fact that it is part of a larger research project, meaning that the player data gathering and game development processes were affected by multiple stakeholders.

The scope of this thesis narrows down the game design to one aspect, the healthiness aspect. And within this game design aspect,   only one method of analysis, visualisation of player movement,   is used to obtain information from the gathered player data.   A questionnaire was sent to players in the research project, but this thesis concentrates only on telemetry data, opting to leave the questionnaire out, since most players did not answer it.

1.4   Thesis Structure

The first chapter introduces the aim and research questions of the thesis.   It contains reasoning for why the subject was chosen, and an outline of all the chapters.

The second chapter introduces the concepts of game design and game analytics.   It explains what general game design is, and what issues mobile games present to game design. It also provides an insight into game analytics,   and it succinctly explores game data mining and game analytics in a spatial context. The second chapter offers a view into

related research in the form of presenting a study of a game that is similar to the research game, and dedicates a section to the physical health aspects of location-based games.

The third chapter is the chapter that contains a description of the research project the game was developed for. Furthermore, the research chapter describes how game analytics were used in the game. Finally, it contains an analysis part, where data gathered from the game are used to create actionable and human-understandable results.

The fourth chapter discusses the findings of the third chapter. It presents an evaluation of how the data gathering succeeded and how it could be improved.   Furthermore, the fourth chapter also discusses what else can be gained from the data gathered. Lastly, the chapter evaluates the game design from a health gaming perspective.

Finally, the fifth chapter provides conclusions for the whole thesis, and suggests possibilities for future work.   The fifth chapter answers the research questions presented in this chapter, and offers a summary of the entire thesis.

Chapter 2

Background

This chapter gives an outline on game design and game analytics. Along with game design, a few alternative views on gameplay are presented. Additionally, game design is viewed through the contexts of mobile games and location-based games.

The subsequent parts of the chapter focus on game analytics. The core concepts of game analytics, game telemetry and game metrics are explained. Furthermore, data mining is described in a game context. The last subchapter explores spatial data in game analytics, which ties together location-based games and game analytics.

Finally, related research is explored through a game similar to the research game. Related research is also presented by examining studies conducted on the health effects of location-based games, mainly focusing on Pokémon Go.

2.1 Game Design

Game design is a skill that combines multiple different disciplines, such as programming, map design and statistics. The process of game design can vary greatly from designer to designer and game studio to game studio. Although game design as a discipline can be sometimes very informal, the subject has attracted academic interest. Much of the research and literature focuses on creating formal frameworks and definitions.

2.1.1 General Game Design

Games have multiple different forms. In this thesis, games are understood as digital games. On a general level and higher abstraction, game design is documenting how a game is played, and what the gameplay is like. To document how a game is played, the designer (or designers) formulates the rules, mechanics, setting and interface of a game. In essence, designing a game is like an architect creating a blueprint for a building, although often people who participate in game design also participate in the implementation of the game.

An integral part in the definition of game design is the definition of gameplay. There are many definitions for gameplay, although a trait shared by most of them is that the definitions all revolve around player interactivity. One definition of gameplay is viewing a game through the perspective of game theory. The strategies that can be used to reach a goal in the game are then defined as gameplay[1]. A second definition defines gameplay as what a player does when playing a game[2]. A third definition is "The structures of player interaction with the game system and with other players in the game."[3] Additionally, game designer Sid Meier of Civilization fame said that "A game is a series of interesting choices."[1] In this thesis, the third definition will be used to refer to gameplay.

Game design is often described as a process. The process starts from having an idea that is translated to a concept[2]. This concept is then fleshed out into how the game actually plays. Then, the game is prototyped until it reaches production. The process varies from studio to studio and is also affected by studio scale. Once a game is in production, it becomes essentially a software development project[1]. During production, game design is combined together with other disciplines, such as programming, sound design and 3D-modeling to bring the game alive. One aspect of the production phase, level design, presents a strong connection between game design and game implementation. Although game design in a sense has a process with a beginning and an ending, much of it is still iterative, as the game design can change radically even during production. The reasons

for this can be a perceived lack of fun, or time and budget constraints.

After designing a set of rules and mechanics, it is important to communicate these to players. Often, games will have one or more tutorial maps, and some tutorial tooltips in the middle of the game. These are not considered to be very helpful in teaching the game, as they often separate game mechanics from the game environment[4]. Instead, game designers and level designers are encouraged to make players learn mechanics through gradually teaching game mechanics in the level and game design[4]. One classic example of teaching mechanics is the first level in Super Mario Bros., as shown in Figure 2.1, where players are taught about enemies and question mark blocks. Another well-known example is introducing new items in Zelda-games, where a dungeon will first have a simple puzzle that requires use of the new item. Later in the dungeon, the new item will be used in combination of other items to solve puzzles[5].

Figure 2.1: A screen capture of the start of World 1-1 in Super Mario Bros., which teaches the player about jumping, question mark blocks, and enemies.

One crucial aspect that affects game design is genre[2]. Although it is common for games to mix genres, genres still present design constraints and issues. For example, when a game is a variation of the First Person Shooter (FPS)-genre, players have certain expectations how the game should play and what is possible to do in the game. Genres also

Table 2.1: Crawford's Taxonomy of Computer Games

Skill and Action Games	Strategy Games
Combat Games	Adventures
Maze Games	Dungeons & Dragons Games
Sports Games	Wargames
Paddle Games	Games of Chance
Race Games	Educational and Children's Games
Miscellaneous Games	Interpersonal Games

influence the concept and setting of the game. A simple division of genres is presented by Chris Crawford, where games are either strategy-based or skill-based[6]. Figure 2.1 shows Chris Crawford's taxonomy of games. Kemppainen[7] notes that genres can define multiple aspects of a game. For example, a game labeled with the kids-genre usually describes the target audience for the game, but does not go in-depth with the gameplay content. Genres also have sub-categories: many different types of games have action as their common genre, but have a distinguishingly different setting and different gameplay.

2.1.2 Game Design in Mobile Context

Game design in a mobile context brings its own issues, starting from the mobile game market. Traditionally, consumers are reluctant to pay much, if at all, for a mobile game. Thus, mobile games are often monetised through a freemium model, where playing a game is free, but it offers various in-game transactions with real money[8]. Since getting players to pay for in-game transactions is important, mobile games often employ extensive telemetry systems to increase revenue[9]. As mobile games have usually smaller scope than console or PC games, the teams creating the games are also smaller[10]. In order to keep release cycles shorter to meet the demands of the fast-paced mobile game market, designers need to be wary of the scope of the game to avoid creating too many features that

require too much time and effort to implement.   Another important part of short release

cycles is to iterate on ideas and to get them quickly to production, as designs and ideas

have to be ultimately tried out in order to understand whether they work.

Most commonly mobile games receive input from a touch screen, and perhaps some

kind of a GPS sensor and accelerometer. This means that games are constrained by their

controls. As it is, designers have to find alternative solutions in order to make classic

game genres fit mobile platforms.   As an example, even a simple platformer game on a

console will require designers to put thought into making the controls work on a mobile

platform.

2.1.3   Game Design for Location-based Games

Location-based games usually employ the GPS-sensors in order to accurately sample

player locations. Location-based games are often mobile games as well, since most mo-

bile devices offer location tracking out of the box[11],   and, as implied by their name,

are highly mobile. Designers need to always address the relationship with their location-

based game and the real world environment. An important design issue is how and where

game content is presented in the real world.   If location-based content generation is ran-

dom, then designers have the issue of how to make players avoid dangerous or unreach-

able destinations[11].   If map content is authored by game creators,   then the team has

the issue that the game is unplayable in many parts of the world.   It is very important to

consider how to handle player data safely, as players can be tied to their location[11].

Games that use location and are played on mobile are constrained by the hardware.

Location tracking, and issues arising from it are an important concern[11].   Players also

often rely on mobile data connections,   so location-based games can be borderline un-

playable in countries with mobile connections that are either too slow or have very low

data caps[11]. This is especially a concern where mobile data plans are expensive for the

average user. Battery life is another possible issue that can make a game difficult to play

on mobile devices[12]. Although the challenges presented are technical in nature, they are best addressed in the game design.

A concrete design decision in a location-based game is having a sedentary tutorial, which is a tutorial where the player can accomplish tasks that would normally require movement without actually moving. Such tutorials can teach the players the basics quickly[12], thus lowering the bar to start playing the game in the real world. While being remarkably useful, a sedentary tutorial is not a magic trick to increase player retention and engagement, so much additional work needs to be done for the design to make it compelling.

2.2 Game Analytics and Data Gathering

Today, game analytics have almost become a requirement in game development, especially in the mobile field. Game analytics can be especially helpful for creating business metrics that can help secure funding for a new game studio. The interest towards game analytics is very likely connected with the current hype for data analytics and machine learning. It only seems natural to use such methods to improve game content and ultimately game revenue, when more traditional businesses appear to leverage them successfully.

2.2.1 Game Analytics

In contemporary times, game data collection and analytics have become the norm in productions of all sizes. Larger studios put in large amounts of effort and resources to gather and analyse data whereas game data collection has been made easier for smaller developers through the inclusion of required tools and services in commercial game engines. Often game analytics are applied in order to improve game revenue and user retention. Nevertheless, game analytics are not exclusive to mobile or multiplayer games and are used to improve single player experiences. For example, small independent game developers can use remote data gathering with remote beta testers to achieve similar results as

large AAA studios with local testing facilities.

In relation to game analytics, El-Nasr et al. [9] define three main terms: game analytics, game telemetry and game metrics. Game analytics are, as their naming suggests, analytics applied to games. Game telemetry is remote game data, such as how many tries a player needed to beat a level. Game metrics, as defined by El-Nasr et al.[9] are "interpretable measures of something related to games." An example of game metrics according to Drachen et al.[13] would be "how many daily active users a social online game has".

A single game can produce huge amounts of data, and tracking everything that happens would be unfeasible, due to having too much data to analyse. Also, data usage and network load would be serious problems for many players. Hence it is important to know what variables to track within a game[14]. Things that are quite universal include performance metrics, such as frames per second (fps) and memory usage, and monetising metrics, such as concurrent players and money spent per user. But when the goal is to make changes to game design and gameplay, it is necessary to understand what data is essential. Often the genre of the game helps with determining what information is essential[13]. For example, a multiplayer first person shooter game would want to track how much different weapons are used during a round, and which weapons yield the best score. Along with the genre, any unique and special game mechanics should be tracked, as improving the design of those is paramount to make the game differ from competitors.

So far only quantitative and measurable data has been discussed. But to better understand the quantitative data and help developers act on the results, gaining qualitative data is often useful[15]. This data can be gained through different means, but the smaller the developer, the harder it will be to attain high grade qualitative data. On the simpler end of the spectrum is getting data from different types of surveys. This is still manageable for independent developers, and a part of the overhead is set on players whose time is required to fill out survey forms with enough thought. Among more complex methods of gaining qualitative feedback, is creating a monitoring setting where players can be observed and

recorded while they play.

Combining quantitative and qualitative methods is more helpful to understand how to use game analytics to improve aspects of a game[15].   Huge amounts of telemetry data can be put   into perspective with the help of monitoring and interviews,   and vice versa; information acquired from qualitative methods after a game session can be put into context with the help of quantitative data gathered from said session.

Often game analytics are leveraged in conjunction with business metrics to improve revenue and profitability of a game.   There are already many interesting applications of game analytics published as studies,   such as using game analytics to analyze player skill[16][17], creating a player versus player recommendation system for Destiny 2[18], grouping players into player types in World of Warcraft[19], tuning difficulty in Flappy Bird[20], and researching cognitive motor capabilities with metrics from Starcraft 2[21].

2.2.2   Game Data Mining

Currently, most game studios gather telemetry data during development, and after release. Especially as the post-release game telemetry data tends to become massive,   a way to address it would be to gather very limited and specific amounts of telemetry data,   as described by Pruett[22]. While useful when knowing what to do, this makes it impossible to constantly find new things from multiple different aspects of the game and find trends by comparing with older data. As it is, a lot of different variables are tracked in telemetry data, and to help find meanings out of it, data mining is employed. Although useful, game telemetry and data mining is no silver bullet in terms of game design, as said by Pruett: "Several people told me that while they collect a lot of information,   they have trouble parsing that data into results that suggest specific design changes."[22]

Data mining is not precisely defined, and it is a combination of different methods for discovering knowledge out of data. An exhaustive description for data mining is provided

by the Gartner Group[1] : "the process of discovering meaningful new correlations, patterns and trends by sifting through large amounts of data stored in repositories,   using pattern recognition technologies as well as statistical and mathematical techniques." Data mining is also called knowledge discovery from data (KDD)[23], which is a more fitting name, as the goal is to gain information, not just data.

Databases are considered integral in data mining[23]. Relational databases can quickly help yield interesting patterns from data through the help of structured query language (SQL) queries. In larger organisations, databases from multiple sources can also be combined into a data warehouse[23],   which contain summarised data that   aim to help executive level decision making.   Although usually data used in data mining comes from databases, all kinds of data can be used, such as historical records, video streams, and text from the web.

Drachen et. al [24] suggest using the Cross-Industry Standard Process for Data Mining (CRISP-DM) [2] due to it being freely available and fitting the process of game development. It is suggested that the process is not applied religiously, as it can be slow and tedious. CRISP defines six phases: Business/research understanding, Data understanding, Data preparation, Modeling, Evaluation and Deployment. An example of systematic data mining is given by Kennerly[25] where he defines five simple steps when data mining: retrieve data from database, validate the data, contain it in its own container, remove unnecessary variables, and transform the remaining data to something that can be analysed. These steps are similar to the phases in CRISP, and it can be argued that it contains the steps three and four from CRISP. Kennerly also suggests measuring rates instead of absolute values to gain insight[25]. Also, the amount of different variables makes it harder to find relations within the data, as the dimensionality increases.

Data mining functionalities are used to find patterns in data mining tasks. According

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[1]www.thegartnergroup.com

[2]www.crisp-dm.org

to Han et al.[23], these functionalities have two different categories: descriptive and pre-
dictive. Descriptive tasks, as the name implies, are used to describe and classify data by
attributes in the main data set. For example, classifying players into different player types
from telemetry data collected in a game is a descriptive task. On the other hand, predictive
tasks use inductive methods to make predictions. An example of predictive tasks would
be to use machine learning to predict where player deaths most likely will occur in a game
using the data of the previous deaths. An important criteria to all patterns gained from
data mining functionalities is that the results need to be understandable by humans. Being
able to use the results gained from data mining is a primary interest.

2.2.3   Spatial Data in Game Analytics

A great way to analyse and visualise game data is by combining it   with spatial data.
Many games feature spatial navigation in one form or another. Most games feature planes
or spaces that are divided into maps and levels,   and combining telemetry data with a
location can prove to be very helpful with map design and overall game design. As games
are inherently visual, projecting gathered telemetry data on a game map visualisation can
be all that is needed. This is usually less complicated than trying to gain insights through
complex statistical models. An example of this would be by Pruett[22], where he created
heatmaps of player deaths to improve map design.

     Geographic Information System(GIS) tools are very usable in analysing spatial game
data, according to Drachen and Canossa[26].   GIS tools provide lots of flexibility due
to them having multiple uses across different industries. Game studios will often create
their own tools, but they are usually limited to the game or game engine they are designed
for. Drachen and Canossa describe two spatial game analytics case studies, where in one
game, Kane and Lynch 2, they use an in-studio tool for analysis,   and in another game,
Tomb Raider Underworld, they analyse the spatial data with ArcGIS, a publicly available
commercial GIS tool. Both case studies show simple,   yet effective ways how to gain

actionable knowledge in how players play a game.[26]

Collecting and analysing spatial metrics are of utmost importance in location-based games. It is not enough to just collect the location of gameplay actors, the temporal dimension should also be stored along with the location. The most basic location-based metric is the point-based metric, which is usually represented as geocoordinates in location-based games. But only using point metrics can be limiting, and trajectories and areas can be used in addition. Trajectories can convey information about movement and projectile behaviour. Area metrics are useful for clustering and containing player behaviour, for example, understanding which parts of a city players use in a location-based game.[27]

2.3 Related Research

The game Pirates! and the study[28] about it are similar to the research game and this thesis. Both games share a similar theme, and have comparable gameplay. Like this thesis, the study analyses game data collected from players. A difference between the games can be found on a technological level, as the study is from 2001. Creating a mobile location-based game in the real world was not as feasible then as it is now.

Games are often viewed purely from an entertainment perspective, yet they have been used for other purposes for years. Although many games have been specifically made for exercising, location-based games are often developed with entertainment in mind, with the exercise aspect being a plus. The effects on health of location-based games are presented through studies on Pokémon Go.

2.3.1 Case Pirates!

Pirates! was a mobile location-based multiplayer game developed for a study conducted by Björk et al.[28] It featured a pirate theme and it was played indoors, which is a bit different from modern location-based games, as they tend to be played outdoors. The

game consists of sailing a pirate ship to different islands by moving physically.   Within
the game, players are able to solve missions, trade goods, upgrade their ship, and explore
islands. The game has a scoreboard that shows the current standing of each player. Players
are also able to attack other players, which leaves the losing player eliminated. Eliminated
players are permanently removed from a game session.

The game featured a server-client architecture with a centralised server. The client was
developed for handheld computers with a 640x240-pixel screen. The handheld computers
were equipped with WLAN cards and proximity sensors, and all game input was handled
with a touch screen using a stylus.   Player locations are determined with the help of
proximity sensors attached to the handheld devices and to physical locations that represent
points of interest in the game.

The game was tested at the Handheld and Ubiquitous Computing conference in 2000,
and it had 31 test users. During the test, player logins, logouts, islands explored, and en-
counter types were logged on the game server. Out of the 31 players in the test, 13 were
interviewed after their game session. The interviewed players also filled out a question-
naire. The player data showed that few of the players battled eachother, although most of
the player eliminations were caused by battles between players, as just three players were
eliminated by non-player enemies.   Most players liked the game and setting,   although
many felt like the penalty of losing a battle between players was too harsh.   A few play-
ers would have also wanted more multiplayer gameplay, such as trading with players and
co-operating against monsters.

2.3.2   Health and Location-based Games

Often games are thought of as having an adverse effect on health by encouraging a seden-
tary lifestyle. Unhealthy snacks and sweetened beverages play an integral part in gaming
culture[29]. As gaming is a very common hobby among children and adolescents, they
are the group[30] threatened by the potential health risks. Research and development on

healthy gaming is an attempt to combat these negative effects. Healthy games often belong to the serious gaming category, which is not the category of games most gamers play on their spare time.

Serious games are games that are designed to train, educate or help players in some way[31]. Common applications for such games include job training, military simulations and education. While serious games have a clear objective of what they are supposed to achieve, it is still helpful for them to be entertaining, as it separates games from normal applications. As a matter of fact, some conventional games have been developed into serious versions. An example of this is Minecraft: Education Edition[3], which is an educational version of Minecraft[4].

Pokémon Go is a location-based mobile game, where players are encouraged to move physically. While it is not a serious game itself, but made for entertainment, the game has benefits similar to a serious game. Players have to move to nearby Pokémon to catch them, and to also walk a certain distance in order to hatch eggs that they are carrying. Since the game has been hugely popular, it has sparked numerous studies on its effects on players' physical activity and health.

In their study, Broom and Flint[32] note that many studies conducted on Pokémon Go only observe the short term effects. Thus the study adopted a three month follow-up questionnaire after the initial one in order to gather results on the longer term. Along with measuring physical activity, the study was interested in whether playing the game reduced the time spent sitting. The results of the study suggest that playing the game does not increase vigorous physical activity among players, but it still increases moderate physical activity. While playing the game was associated with increased physical activity, it was not found to reduce sitting time.

A similar study, conducted by Barkley et al.[33], assessed whether Pokémon Go had

[3]education.minecraft.net

[4]minecraft.net

an impact on walking and sitting for a sample of college students. The method of the study was that participants estimated their levels of activity one week before downloading the game, one week after playing it, and during the week of answering the survey. The results showed an association with playing the game and increased walking and reduced sitting.

While many studies focus on the positive aspects of playing Pok émon Go, the study by Barbero et al.[34] also examines risks associated with playing the game.   Reviewing healthcare encounters within medical   records, the study found that   most Pokémon Go related encounters were positive,   with 1/3 of the encounters being adverse.   Out of the adverse encounters, 10% were the result of severe injuries, such as head trauma. Still, the low overall number of severe injuries suggests that playing the game is safe.

Chapter 3

Research

This chapter gives details on the research project on which this thesis is based on. A quick outline is given on how players were recruited and how data was collected. The research project is also discussed from the perspective of other studies that were based on it. Next, the game that was implemented within the research project is described to give a clearer context for the data in this thesis.

Player data and how it was used are an important part of the chapter. The data gathering system and how it worked is explained, along with a brief description of what the data was like. The last part of the chapter explains how the data was analysed and what was found from it. The data was used to create map figures out of event locations. Interesting patterns and behaviour were then collected from the figures as findings.

3.1 Research Project

The game that is referred to in this thesis was created for the needs of a research project. The research project studied links between snacks and gaming, and whether snacks could be better marketed through games. Stakeholders in the project included several food companies and four research groups from two different universities. Creating a game was only one part of the project, and the project overall included multiple surveys, LAN event

monitoring and online group discussions.

The research project produced multiple publications.   Only one currently published study is based on player data gathered from the research game in this project[12].   It explains the effects of improving the tutorial   between testing periods.   Other research conducted within the research project mostly deals with food and snacking, such as the 2017 paper by Syrjälä et. al[35], which attempts to find out where and how snacking takes place.

Over the course of the research project,   there were multiple game prototypes and ideas. Most ideas included ways to exercise while gaming. Ultimately, the final idea was strongly influenced by Pokémon Go, which suited the goal of making snacking healthier. The game idea and design were iterated on with the help of a consumer community, which was a part of the research project.   The members of the community had to complete 30 weekly tasks over half a year, of which three were related to the research game.   Along with the consumer community, marketing professionals from the stakeholder companies offered their input.

The game development process had roughly four stages.   In the first stage,   several game ideas were presented to the marketing professionals, from which a location-based game was agreed on, due to the healthiness aspect. After conceptualising the game idea, feedback was gathered from the consumer community. In the second stage, the core walking and island interaction mechanics were implemented along with placeholder graphics. Again, the consumer community gave feedback on the game. In the third stage, a tutorial was added along with other smaller improvements gathered from the feedback.   This is also the stage where the combat mechanics were added. Feedback was also collected after this stage. In the fourth stage, the graphics were finalised and the game was polished for release.

The actual data gathering for the research project took place over two periods of time. These periods lasted for two weeks each and players were provided an incentive by of-

fering one gift card to the leader of the scoreboard and another to a randomly selected
player between players who had played enough to be eligible for the draw. Other motiva-
tors provided to players were the leaderboard where players could see their standing, and
actual snacks that could be earned through playing the game. A questionnaire was sent to
players after each data gathering period, but the data from the questionnaires are not used
in this thesis.

Players were recruited for the research project through university mailing lists, flyers,
recruitment posters and face-to-face interaction.   Most recruited players were university
students and university personnel.

Player data was gathered between June 2017 and March 2018.   Along with the data
that was gathered during the two research periods,   player data in this thesis has also
been gathered from other sources. In March 2018, a university course on Mixed Reality
recommended that students play the research game. Additionally, the game was promoted
to be played during an event for children in the same month. The resulting sample size in
this thesis is 99 after filtering out test accounts and players with zero events.

3.2   Game Description

The game that is the target for data gathering and analysis in this thesis is a location-
based mobile game targeted for Android phones. The game is called Aarrejahti and it was
downloadable from the Google Play store throughout the testing phase.   In the game, as
shown in Figure 3.1, players assume the role of a captain of their ship.   The aim of the
game is to complete stages, which are represented by treasure maps. A map is completed
by following directions to specific islands which eventually lead to a treasure island. Each
marked island on the route contains a fortress that players have to defeat in battle in order
to progress.

An integral part of the game was the island creation algorithm. The algorithm worked

by dividing areas through the use of geographical coordinates. Then, a seed for the random generator was created for each area from said coordinates. Islands were then placed pseudo-randomly with the initiated seed. This way island placement looked somewhat random, but each player had a similar experience. Island types would still vary between players and sessions.

Game environment safety is a concern in location-based games[12][11], and the research game addresses it by limiting game interaction in high velocities. When a player moves faster than 30 $\frac{km}{h}$, they are unable to conquer islands, thus reducing the possible actions a player can perform while using a vehicle. The game will also generate islands next to roads, and avoid creating them in large bodies of water, graveyards and military areas. Additionally, players will also not gain any points from moving while being over the speed limit. These limitations also help enforce the physical movement goal of the game.

The game has a customisation feature, which enables players to edit the look of their pirate avatar. More customisation items for the avatar could be unlocked by reading codes located in two grocery stores during the testing phase. The game also has an in-game store, which is shown in Figure 3.2, where players can transform the loot they have found into game currency, and buy upgrades. Upgrades include upgrading the ship's cannon and a compass to follow the treasure route more easily.

The game has an in-game tutorial to teach new players how to play the game. Every player has to complete the tutorial, as it is the first treasure map in the game. The tutorial was played in the same way as the rest of the game in the first testing period, except it included helpful messages about game functionality, and explained what the player should be doing next. The tutorial was slightly revamped in the second testing period by making it sedentary. This means that the new tutorial required less effort, as in not having to move physically, to complete than the old one.

The game also has a few social elements in it. The first social element is the leader-

Figure 3.1: Screen capture of the game

board, which ranks players by their score.   The second social element is the hunting of trade ships, where a trade ship can randomly spawn in an area that players are roaming in. These ships can require multiple players to attack them in order for the battle to start.

The game has multiple design goals in alignment with the research project.   Firstly, the game needed to promote healthy gaming in some manner, in contrast to the gaming stereotype of unhealthy snacks and sedentary lifestyle. Secondly, the game had to be able to establish a link between snacks and gaming,   as it was part of the research question. Thirdly, the game had to combine real life and gaming in some way. Fourthly, the game needed to give players a sense of progress to keep players more engaged.   Fifthly and lastly, the game had to present an interesting core loop to give players a feeling of doing something, to keep players interested for the research period of two weeks.

Figure 3.2: The game's in-game store

3.3   Data Gathering

Data gathering in the game was designed in a fairly ad hoc manner after reading a report about current data gathering methods, which was based on[9] and [13].   There are three different game telemetry systems.   The first system stores player information such as experience and money. It was devised from the need of storing game data on the server to mitigate cheating behaviour and display leaderboards. Although not designed to be a game telemetry system, it can still provide useful information about players. For example, user data required for authentication is closely coupled with other game data,   and the authentication system provides information on when a player logs in.

Table 3.1: List of events and their targets

Event actions	Event targets
Battle won	Battle type
Battle lost	Battle type
Level up	None
Treasure found	None
Item transaction	Upgrades purchased, loot sold
Island conquered	Island type
Avatar saved	Not used
Code scanned	Scanned code
Coupon used	Store name

The second system tracks separate sessions. It is the first actual attempt to create a system for recording telemetry data in the game. The system attempts to create logical sessions out of chunks of playtime, where a session starts when the application starts and the session ends when the application is closed or paused. Each session recorded changes to variables without any associated timestamps or such. Sessions contained information such as changes to player money, amount of items bought or times engaged in battle. The first iterations worked rather poorly, as some sessions could span even a day. Implementation issues stemmed mostly from not handling and reading Android application events properly. Ultimately, the system was found to be too unreliable from a technical point of view and not very usable from a data gathering point of view. Thus, a third system for game telemetry gathering was devised.

The third system keeps a record of most actions players do during their game, and combines them with time and location information. The system records events such as conquering an island or game item transactions. These events can then have targets, such as buying a new cannon in the case of an item transaction. The need for this system came from the requirement that data gathered for a location-based game should include location

data. Most of the data used for research came from this third system, and it will be the main focus when discussing game telemetry systems in this thesis.

The technical design of the event tracking system is quite straightforward. Each event has an associated action, which is hardcoded and an optional target, if the action has one. Then a timestamp is created and latitude and longitude is recorded. Everything is then put into a record-type data structure and the record is stored in a buffer. Once the buffer is full, the game client will attempt to empty the buffer to the server. The game will also attempt to empty the buffer when exiting the application. After several failed attempts, the buffer will be stored on disk, and the client will attempt to resend the buffer each time the game starts. The game server receives the buffer as a regular HTTP POST request. The request's data is then subjected to validation, and saved to the server's database afterwards.

Viewing and analysing the event data is done through requesting it from the server from an Application Programming Interface (API) endpoint. The API endpoint serves the event data in the JavaScript Object Notation (JSON) format. No visualisation or analysis tools were created on the server's web client side, so all data manipulation has to be done locally, unless done in the database software itself, which should be avoided in order to avoid making the data unusable. A Python script was created for easy data access. The script transforms the data into a Comma Separated Values (CSV) file that is easily imported into spreadsheet software for further analysis and visualisation. Another script imports the data in JSON format, without transforming it into CSV.

3.4   Data Preparation

As the first step, event data was retrieved from the database in JSON format. Next, the data was cleaned by removing event data that clearly originated from test and developer accounts. In the following step, a Python script was written to plot geographic data with the help of the GeoPandas geospatial library. The script used map data downloaded from

Table 3.2: Maximum event count and size per quartile

Quartile	Maximum event count	Sample size
First	13	25
Second	32	25
Third	134	24
Fourth	4935	25

the National Land Survey of Finland as a base map for visualisation. Event coordinates where then translated from WGS84 to the ETRS-TM35FIN coordinate system. Thus, event locations and their distances could be viewed in meters in the plot, instead of geographical coordinates. Then, event data was plotted on the base map using individual colours for each player. Players were grouped into quartiles by their total event count. A total of eight different plots were created: One for the players in the 0% to 50% (shown in Figure A.6) percentiles, two for the players in the 50% to 75% percentiles (shown in Figures A.7 and A.8), and five for the players in the 75% to 100% quartiles, which are depicted in Figures A.1 to A.5.

3.5 Data Analysis and Findings

The total sample size is 99 players. This means that each quartile contains 25 players, except for one 24 sized quartile, as shown in Table 3.2. Most findings come from the most played quartile, the 75% to 100% percentile, since the lower percentiles do not have enough data samples per player to make many meaningful assumptions. Table 3.3 shows findings from the fourth quartile. The event total limits for each quartile, displayed in Table 3.2, showing a high disparity within the last quartile.

Figures A.1 through A.8 show route visualisations for the highest quartile players. A path is drawn between recorded event locations until there is a waiting period longer than 10 minutes between events, after which a new path is started. Each colour represents a

Table 3.3: Findings from event plots in the fourth quartile

Variable	Out of 25 players
Repeated routes	12
Played in or on a vehicle	14
Moved around to play the game	23
Played in different areas	8

different player in a figure.   Dots are starting and ending points of a path.   Stars signify locations of found treasures.

Players are required to move around at least a few hundred meters to move between in-game islands. The overall assessment of Figures A.6, A.7 and A.8 from the first to third quartiles is that not very much movement was recorded,   but players still clearly moved around to play the game.   Because of this, it can be validated from route visualisations between events that lower quartile players indeed moved around several hundred meters and also clearly took turns that would imply them following objectives in the game.

As shown in Table 3.3, half of the highest quartile players showed repeated behaviour, meaning that they performed the same actions in the same location repeatedly,   when analysing their route visualisations.   This can be deduced from very similar path lines that overlap. This can mean that the players fit the game into their routines, such as their commute, walking their dog or trips to the store. Another meaning to the repeat routes is that players found a route that was effective to obtain in-game resources.

Above half of the highest quartile players also played either from a vehicle or before and after moving a longer distance with a vehicle,   as shown in Table 3.3.   This can be counted from event route visualisations in Figures A.1 through A.5. It can be concluded that to travel distances longer than 3.3 km,   players must have had a velocity of 20 $\frac{km}{h}$ or higher, thus being on a vehicle of sorts.   Since the game disallows interactions with islands on high velocities, players can only do store-related actions while driving or riding a vehicle. Islands can then be accessed during traffic stops. For example, while riding a

bus, a player can try to find and conquer any islands found nearby when the bus stops.

It is evident from the movement patterns in Figures A.1 to A.5 of the highest quartile players that they moved between locations in order to accomplish tasks in the game. This is further confirmed by treasure events on the map,   as players must move to multiple different locations before being able to find a treasure chest.   Thus it can be said that 23 out of 25 players in the highest   quartile "moved around to play the game",   while the remaining 2 players performed their actions within a small area.   This confirms the exercise aspect of the game design goal of making healthy games.

It was found that   some players also played the game in different   areas.   This was indicated after noticing that players had game activity in areas over 10 kilometers apart from each other. Out of the 25 players in the quartile, 8 belong in this category.   Thus it can be said that some players played in different areas.

Chapter 4

Discussion

The data samples could be manipulated in multiple different ways. This thesis presents one way at finding meaning from the data. There is a lot of collected data to analyse, but the most difficult part is interpreting the findings. Data analysis puts emphasis on getting actionable and understandable results, so often simpler findings and methods can be used instead of more complex models.

This chapter discusses the data collection system and the data itself. It presents some thoughts on how the data gathering succeeded, and how the data from the game can be used. The findings are also discussed, and answers for the research questions are presented. Improvement suggestions are then presented in the last part of the chapter.

4.1   Evaluating the Data

On a general level, the data that was gathered represents a good amount of the players' actions, and makes it possible, to at least some extent, to follow what players have been doing and how they have played the game. The variables that were tracked and what they can yield are as follows:

Store codes scanned and coupons used. Scannable codes could be found in two different real world grocery stores and could be used to gain cosmetic items in the game.

Players could earn coupons that could be exchanged for free snacks at the same two gro-
cery stores. The coupons lasted a certain duration and had a set prize. The game records
each use of a coupon and each time a player scanned a unique code. The tracked variables
can be used to find out if, when and where the features were used.   The results can then
lead to further speculation. For example, with a large enough sample size, coupons used
can be utilised to create a profile of players who gravitate towards these types of rewards.

Battles won and battles lost. Events are recorded for each won and lost battle. The
variables can tell how people understood the battle functionality,   and how well it was
communicated to players. Battle event records have an important role in understanding
game balance and the game loop itself, since battling is an important part of the game.

Treasures found. Treasures are found in treasure chests on treasure islands. An event
is recorded each time a player finds a treasure. Recorded treasure events can give insight
into treasure and game economy balancing. They can also help understand how and where
players find their treasures. For example, how far is a player willing to travel to find a new
treasure.

Item transaction. Item transaction events are recorded every time a player sells loot
or buys an item. The variable tells if people understood the functionality, and is helpful
with balancing of the game economy.   The events help understand how much in-game
currency players are spending and gaining, and how the game should be balanced between
spending and gaining.

Islands conquered. Any time an island is conquered, an event gets recorded along
with the type of the island. The type of island can have very different effects on gameplay.
The variable helps with understanding how and where people moved, and how it impacted
their gameplay, as conquering islands is a core part of the gameplay.

4.2   Evaluating Data Collection

Although not flawless, the technical implementation of the data gathering succeeded quite well. The goal of the gathering system was to capture data with enough granularity to enable conduction of scientific studies.   The data gathering system works mostly and accomplishes the goal it was set to do.

One flaw was that recording level up events did not work at the time of testing. As an improvement, there could have been some kind of server side improvements that would have made it possible to tune the data gathering process during testing, such as enabling or disabling whether to collect certain data.

In the end, not all data could be collected and there was some data loss. The data loss was confirmed through testing the research game and then inspecting the event data. First signs of data loss were found after a coupon was marked as used in the database, but the coupon event was missing from the player who used it. One reason for data loss could be that the data gathering systems were not tested and designed enough, as the schedule for everything was very tight. Another reason could be connectivity issues, such as lacking mobile connectivity or poor Wi-Fi. A third possible reason is the interaction between the game and the operating system and the interaction between the game and the hardware. To combat data loss, the data gathering systems could have been tested more thoroughly. To better understand the data loss rate,   a sequential numbering system could have been put in place, where a number is included and incremented with every message for a player, so the server would know if a message has been missed. Such a system could have been used to estimate the data loss rate and to find bugs in the data transfer process.

4.3   Validating the Game Design

When approaching game design from a validation perspective, a fundamental question is whether game design even can be validated.   Instead of pondering deeper philosophical

questions, the scope of this thesis is limited to whether validation of some degree can be achieved. For more formal validation, a framework should be either created or chosen. Here, a more ad hoc method will be used instead. The findings of Chapter 3 will be used to validate the design. The specific game design aspect to validate is whether the game encourages players to improve their health through physical activity.

One of the most popular recent games made purely for entertainment with a positive effect on health, is Pokémon Go. Pokémon Go, like the research game covered in this thesis, makes players move around physically. A few reasons why it has been so successful in what many serious games have attempted are that the game contains novelty value, has an engaging game loop and has the help of a very famous brand.

The research game does not have the same novelty value as Pokémon Go, nor does it have the same kind of brand recognition. So in essence, validating the game in terms of improving health is also linked to validating the core gameplay. For example, the game's core gameplay can be considered interesting if all players who tried the game would have played for tens of hours and walked several kilometers daily. Interestingly, while the studies by Broom and Flint[32], and Barkley et al.[33] use a self-reporting questionnaire as the research method, a more quantitative approach is presented in this thesis. Also, while the study by Björk et al. [28] depicts a very similar game to the research game, the study itself is less focused on researching the users and more focused on presenting the game.

There were different levels of activity among the players. It can be validated that the game encouraged physical activity in 23 out of the 25 players in the fourth quartile, since the remaining 2 in the fourth quartile moved considerable less than the rest. However, the reasons that kept the players playing are not completely clear. Possible reasons range from enjoying the game to hoping to win prizes that were promised to top players. For further validation, the profiles of the players who played the most could be linked to the qualitative survey that was sent to the players during the research project. This would

help understand player motivations and gain feedback to improve the game.   Another, more statistical method to improve comprehension of player motivations could be finding connections between distance walked and game variables.   This could help identify gameplay aspects that increase activity among players.

Most of the 99 players who tried the game at   least once did not continue playing either after their fist try or after the tutorial. On one hand, asking about the game from the players who played the most helps gain insight in gameplay balance and improvements. On the other hand, the opinions of those who did not play are also valuable,   because it is highly important to know what were the reasons that kept most players from playing longer. The difference between not having time or interest to properly even try the game and not enjoying the game is immense.

The data gathered enables evaluating the game design.   Many of the players moved a lot, although over half did not   move much at   all.   While the studies on Pok émon Go[32][33] found most users to walk more,   the users studied were already playing the game voluntarily, whereas the users in this thesis were all specifically recruited to try the game. Although there is no control group used in this thesis, the results point to a similar direction as in the studies on Pokémon Go.

The research game would need more improvements to its gameplay to better engage players, which would lead to increased physical   activity. Still, Pokémon Go and the research game affirm that people can be motivated to increase their physical activity with a game that is interesting enough.

4.4   Improvements and Issues

4.4.1   Game Design Improvements and Issues

The game had two versions of the tutorial, as mentioned in 3.2. Könnölä et al.[12] studied the effects on the differing tutorials in the game, and found that tutorial completion rate

increased, but the ratio of players who continued past the tutorial was negligible. Creating some kinds of metrics to benchmark the tutorial would have been an interesting task and would have made the study on the effects of the tutorial easier, although it was not in the focus of this study.

Player safety is an important consideration in location-based games. While the game took some measures to ensure player safety, there is still room for improvements. A way to further improve player safety would be to better limit the play area according to the available map data. For example, no islands should be created within closed-off private buildings. Safety could be also improved by even going so far as to disable all actions in the game when the player is considered to be in danger.

4.4.2   Data Improvements and Issues

It is much easier to understand in retrospect what data could and should have been collected on top of the existing data. Tracking in-game currency and experience points was not done very well. An improvement would be to include information about them in every event. Less in terms of data gathering, and more in terms of an application of it, there could have been more server side systems in place to prevent cheating behaviour. As it stands, the game validates almost everything in the game client, and not the server.

An improvement to the data collection process would be to turn tracked variables on or off. This would have been be especially helpful during the development stage for pinpointing issues in specific areas of the game. Additionally, the game's multiplayer component could have been tracked. Neither the multiplayer trade ship battle nor the leaderboard feature had any sort of associated event data.

Chapter 5

Conclusions and Future Work

This thesis provided an overview into game analytics both from a theoretical level and a practical one. Game design as a skill is a collection of other disciplines, and it is difficult to define exactly when, for example, concept art becomes game design and vice versa. In the same way, game research as a field is a combination of different research areas, as work has been done in such diverse areas as formalising game design and healthy gaming. There also exists a division between academia and game designers, as most successful game designers are still employed in the industry, keeping a lot of game design knowledge within game development circles. Instead of research literature, game developers and game designers tend to write grey literature about the process of designing and creating a game.

Analytics are often catered more to the business side of game development than the design side in order to increase revenue and player retention. Regardless of the ultimate goal, game analytics are quite useful for finding flaws and figuring out ways to make a game more enjoyable. While the term game analytics is strongly associated with large mobile game companies with huge datasets and big multiplayer online games, game analytics are still perfectly usable on a smaller scale. Even solo game developers have the resources to gain insight into how their game is played and understood by recording some well selected game events. In the end, useful results come from understandable data pre-

sentations and models.

The practical part of this thesis was implementation of game analytics in a location-based game that was developed in a research project.   Data was gathered from players while they were playing, and the data was then analysed. There are several existing game analytics services that are easy to integrate with popular game engines and frameworks. While this being the case, a custom data gathering system was built for the research game, which has the benefit of addressing the required data gathering needs. Disadvantages of implementing custom systems include the amount of work required and that an existing system contains a multitude of features out   of the box.   With the custom system,   all analysis has to then be manually performed with the collected data.

The research questions for this thesis were:

R1 How can a game design be validated in terms of healthiness with the help of game analytics?

R2 Can a game design have a positive effect on a player's health?

Answering **R1**, the chosen method for analysis in this thesis was visually showing how players moved while playing the game. Players were split into quartiles by the amount of their total events. Out of the entire sample size of 99, the fourth quartile, consisting of 25 players was selected for analysis. This was due to the visualisations in the lower quartiles having very little movement recorded, which makes assessing patterns in the movement difficult or even impossible. All tracked events are visualised similarly except for treasure events, which were chosen as special events because players are required to move from objective to objective in order to find a treasure when a player is playing a map.   This means that those events cause player movement due to players having to move to several different locations in order to get to a treasure island.   Since players were observed to physically chase objectives, it can be said that the game design can be validated in terms of healthiness with the chosen method of game analytics.

Answering **R2**, the player movement visualisations showed different types of be-

haviour. The types of behaviour were repeating routes, playing while on a vehicle and playing in more than just one area. It could be argued that repeating routes and playing on vehicles would not result in increased physical activity, since repeating routes could just mean that playing the game was fit into the normal routines of the player, and playing on vehicles could stand for a player following game objectives without increasing their physical activity levels. A counter-argument for the previous statements comes from the event data, which suggests that players walked to treasure islands. Since following the game objectives forces players to increase their physical activity, which is especially evident in the fourth quartile, it can be concluded that playing the game can be healthy.

When discussing **R2**, in a game with location-based objectives, the health of players can be positively impacted by increasing their physical activity. This, however, does not work if a game does not offer a rewarding play experience. Thus, in order to improve a game's effects on health, it is important to make the game design interesting enough for players to care about following real life objectives. Hence it can be said that a game design can have a positive impact on health, when the game itself requires players to be physically active, and doing so feels rewarding.

The event data from the research project offers possibilities for future work. One avenue of future research would be to apply data mining methods to the event data to, for example, create different categories of the players. Another potential direction would be to focus on using the event data to balance more traditional elements, such as the economy system, in the research game. Some of the limitations of this thesis still apply to further research, and it should be assessed whether following the aforementioned directions is viable.

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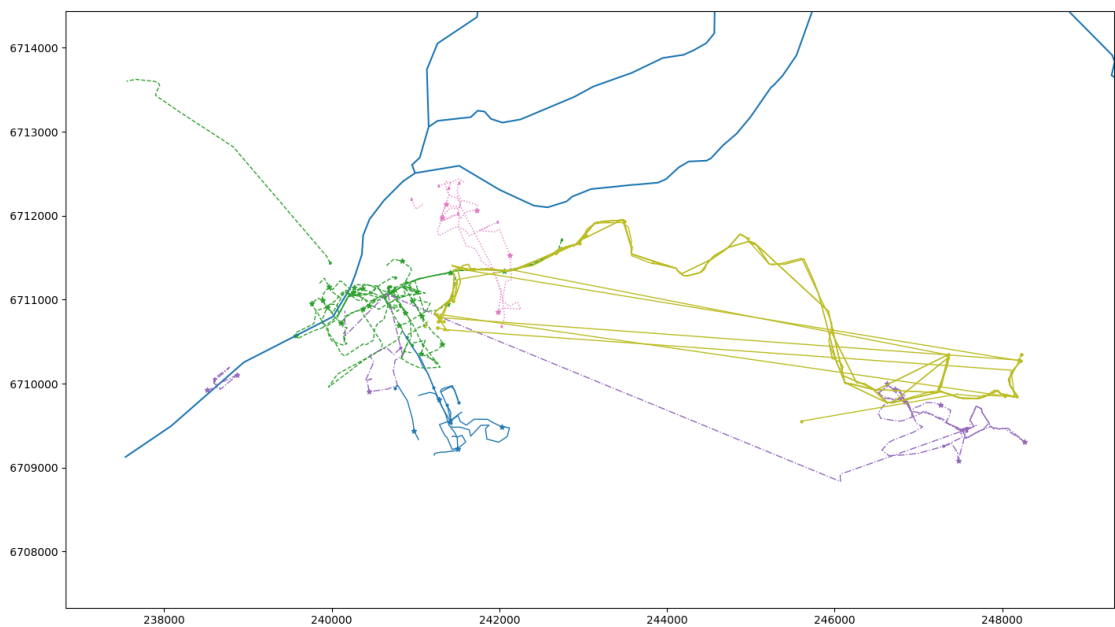
Appendix A

Player movement figures

Figure A.1: Player movement and events in the fourth quartile, 1/5. Each player has their own colour and line type. Stars represent treasure events, dots represent the rest of the events. The movements represented by the yellow colour are a good example of a player using a vehicle while playing.
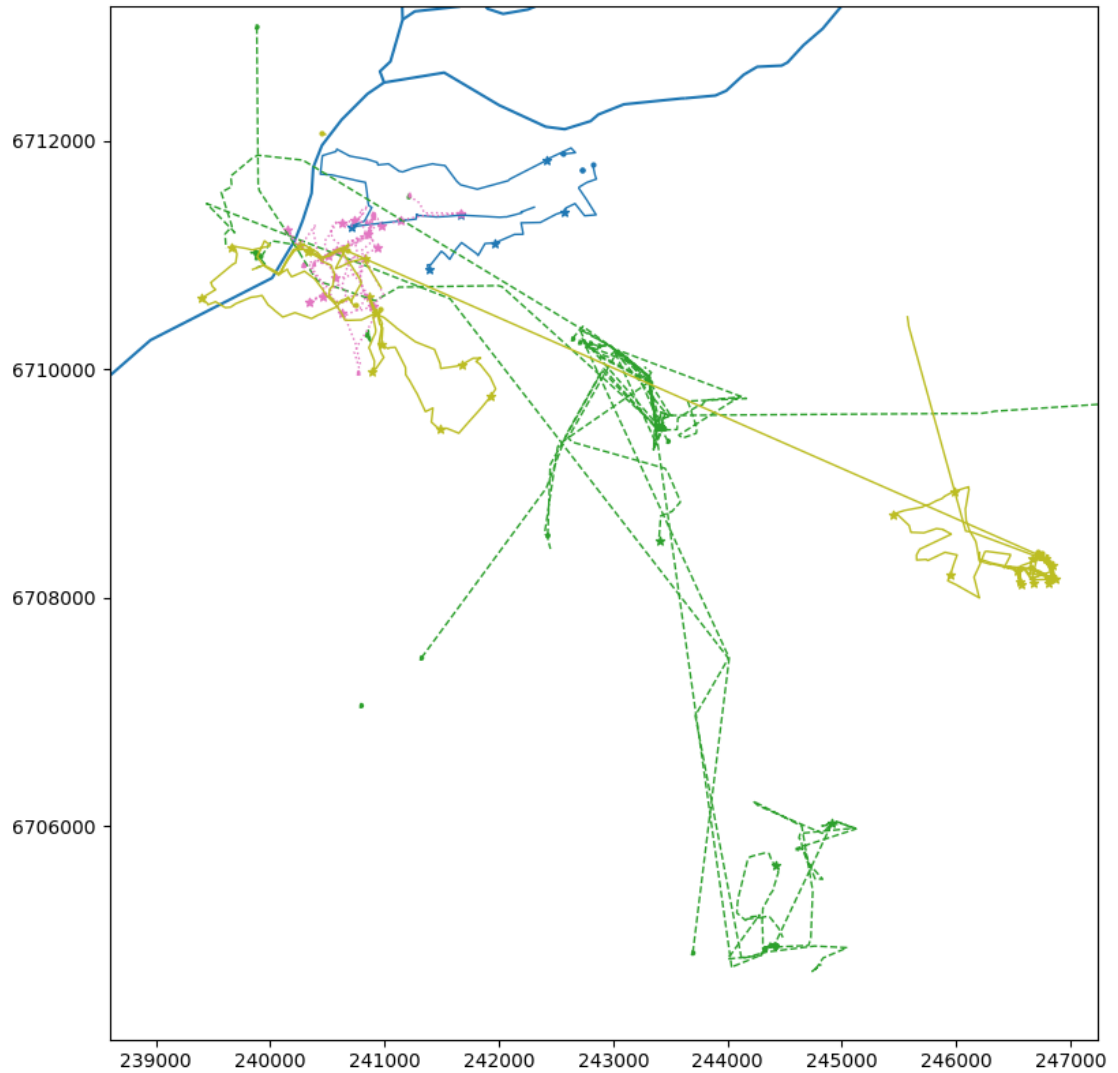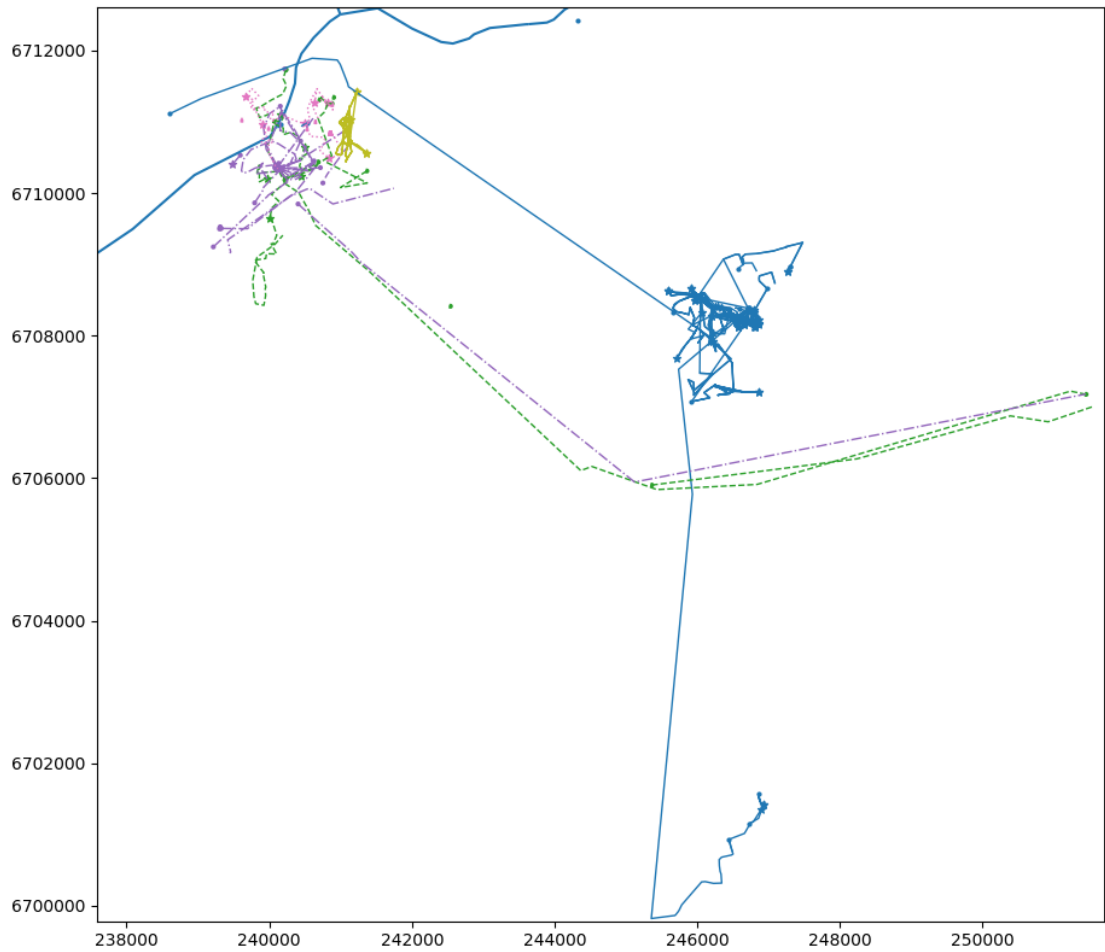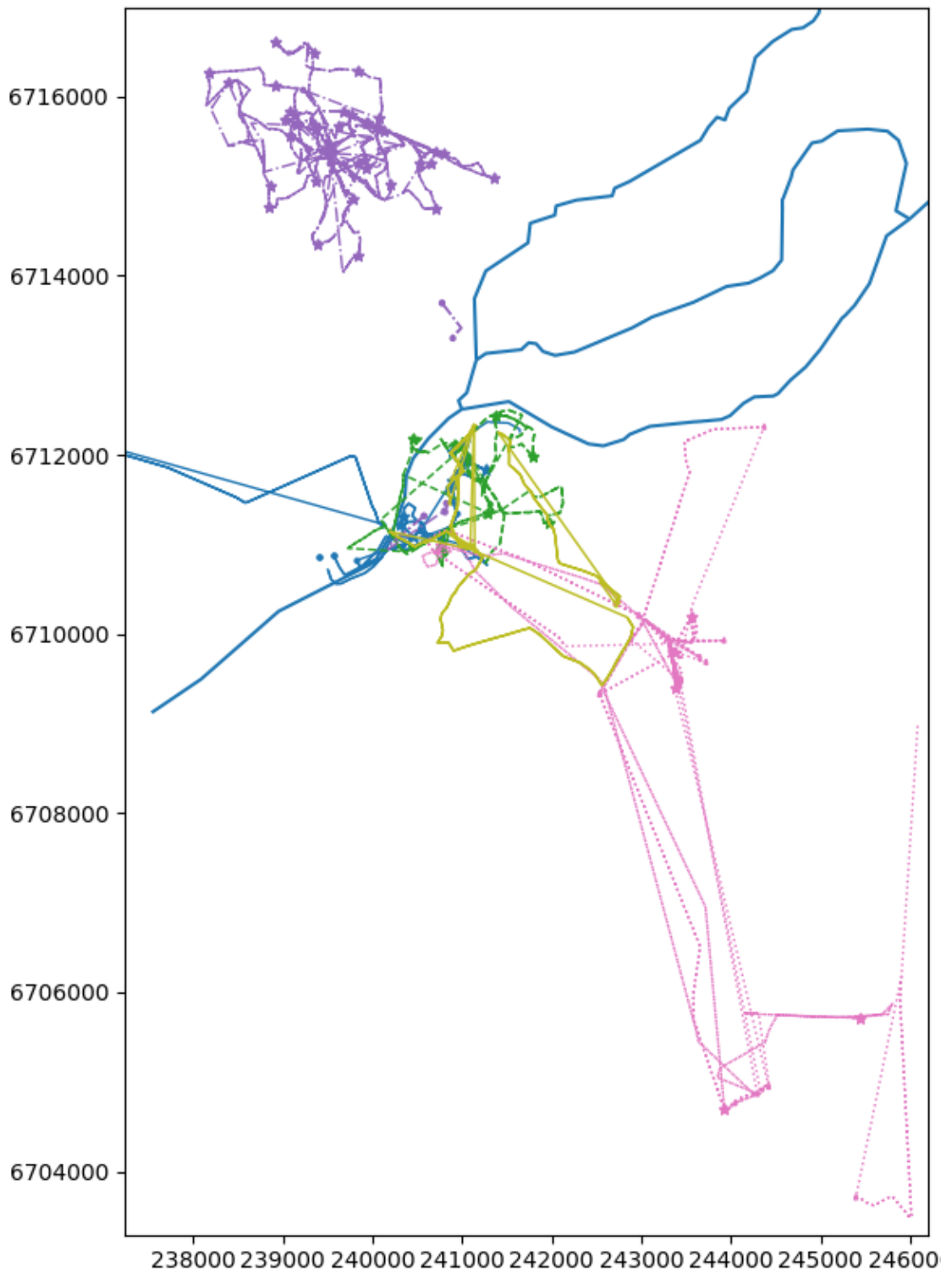
Figure A.2: Player movement and events in the fourth quartile, 2/5. Each player has their own colour and line type. Stars represe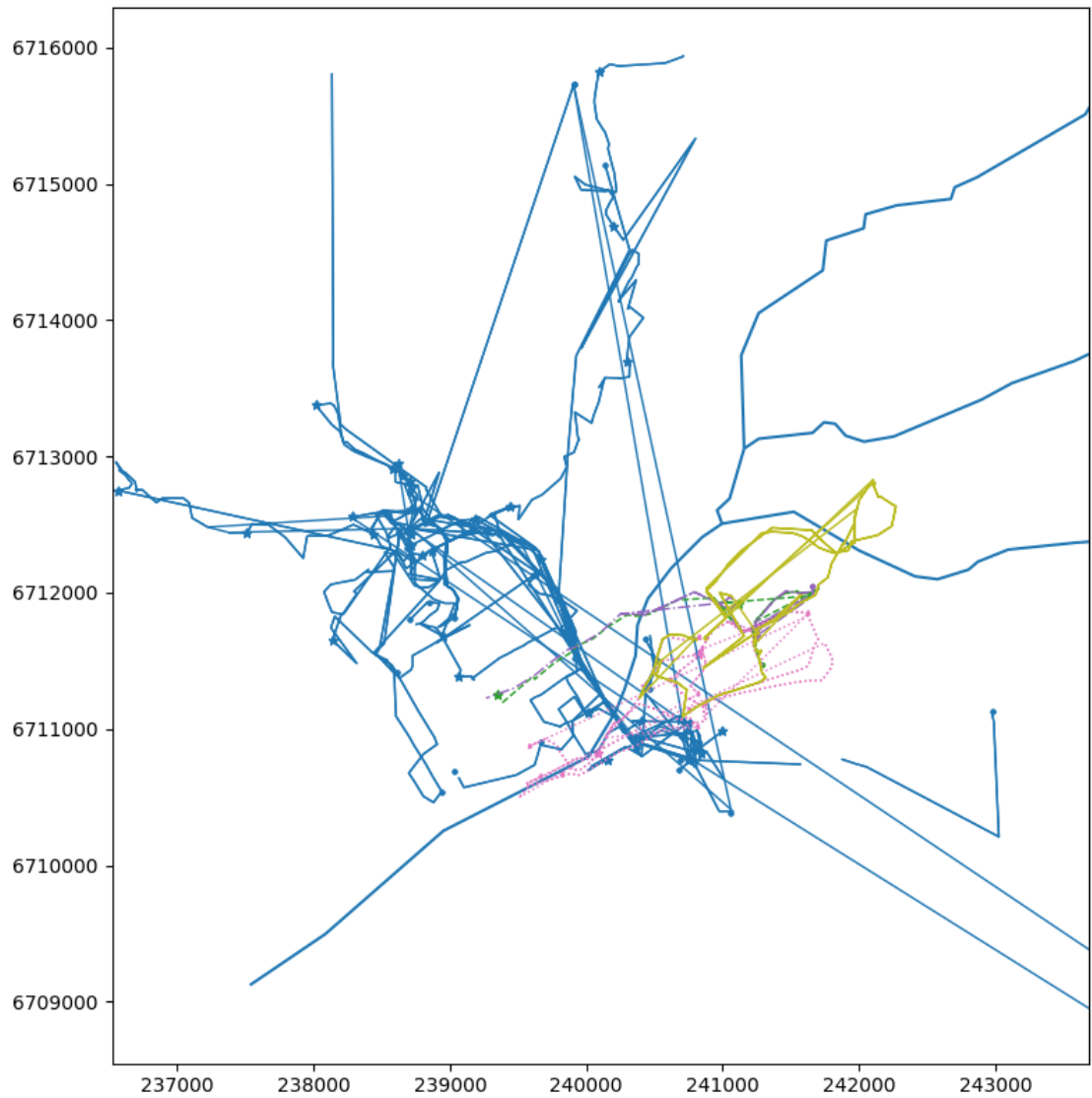nt treasure events, dots represent the rest of the events. The movements represented by the green colour are a prime example of playing in different areas.

Figure A.3: Player movement and events in the fourth quartile, 3/5. Each player has their own colour and line type. Stars represent treasure events, dots represent the rest of the events.

Figure A.4: Player movement and events in the fourth quartile, 4/5. Each player has their own colour and line type. Stars represent treasure events, dots represent the rest of the events.

Figure A.5: Player movement and events in the fourth quartile, 5/5. Each player has their own colour and line type. Stars represent treasure events, dots represent the rest of the events. The movements represented by the yellow colour show a player repeating their previous routes.
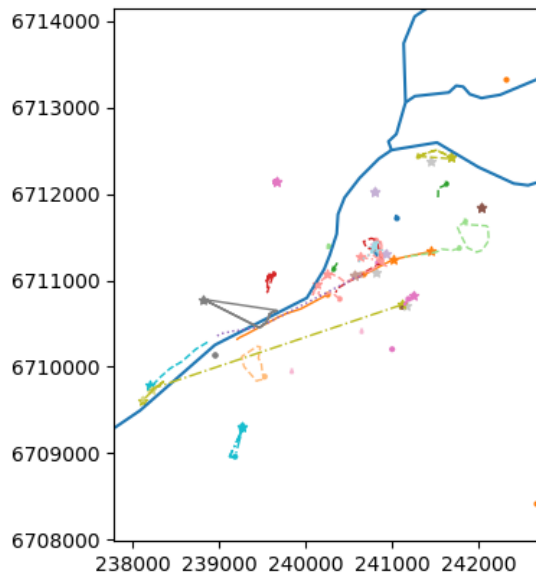
Figure A.6: Player movement and events in the first and second quartiles. Each player has their own colour and line type. Stars represent treasure events, dots represent the rest of the events.
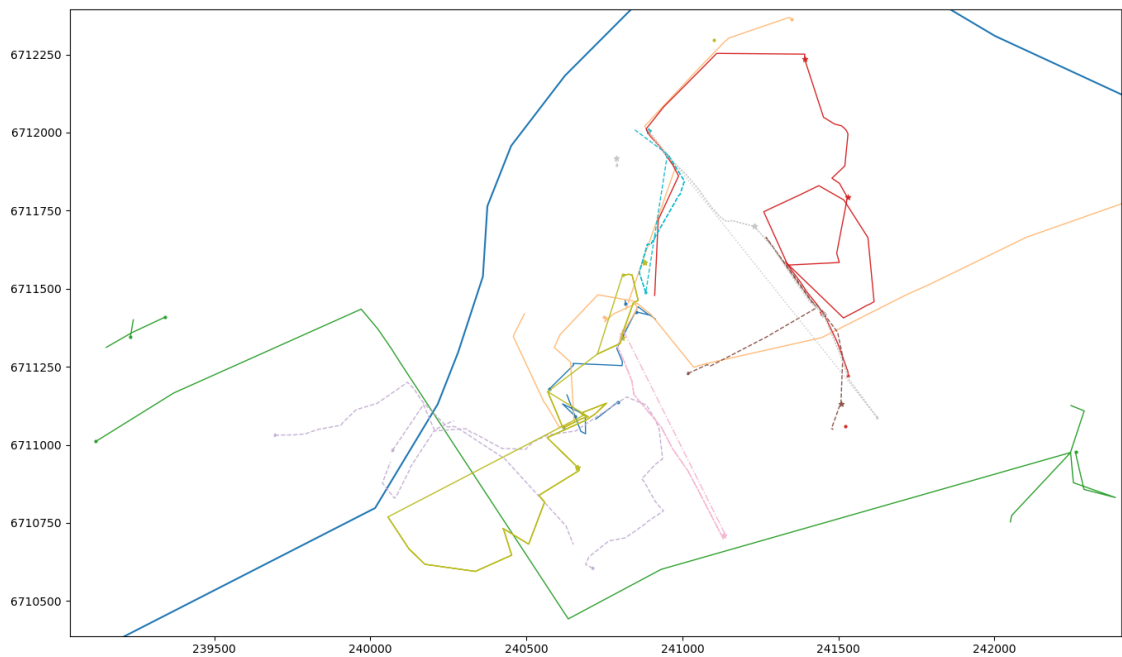

Figure A.7: Player movement and events in the third quartile, 1/2. Each player has their own colour and line type. Stars represent treasure events, dots represent the rest of the events.
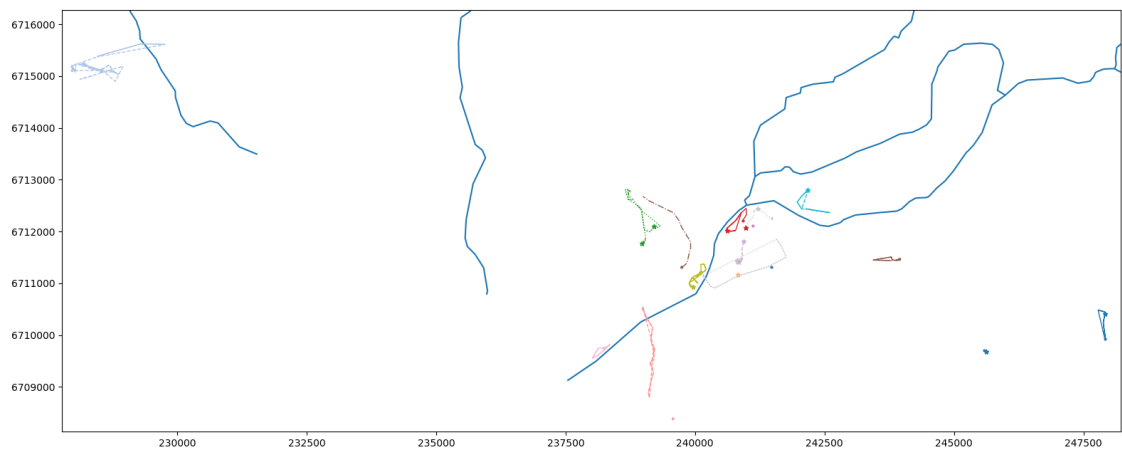
Figure A.8: Player movement and events in the third quartile, 2/2. Each player has their own colour and line type. Stars represent treasure events, dots represent the rest of the events.