Luleå University of Technology
Department of Computer Science, Electrical and Space Engineering
Erasmus Mundus Master's Programme in Pervasive Computing & Communications for sustainable Development PERCCOM

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Online Transportation Mode Recognition and an Application to Promote Greener Transportation

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ABSTRACT

Luleå University of Technology
Department of Computer Science, Electrical and Space Engineering
Erasmus Mundus PERCCOM Master Program

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Online Transportation Mode Recognition and an Application to Promote Greener Transportation

Master's Thesis

52 pages, 18 figures, 12 tables, 3 formulae, 12 appendixes

Examiners: *Professor Eric Rondeau* (Université de Lorraine)
Professor Jari Porras (Lappeenranta University of Technology)
Associate Professor Karl Andersson (Luleå University of Technology)

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It is now widely accepted that human behaviour accounts for a large portion of total global emissions, and thus influences climate change to a large extent [1]. Changing human behaviour when it comes to mode of transportation is one component which could make a difference in the long term. In order to achieve behavioural change, we investigate the use of a persuasive multiplayer game. Transportation mode recognition is used within the game to provide bonuses and penalties to users based on their daily choices regarding transportation. To easily identify modes of transportation, an approach to transport recognition based on accelerometer and gyroscope data is analysed and extended. Preliminary results from the machine learning tests show that the classification true-positive rate for recognizing 10 different classes can reach up to 95% when using a history set (66% without). Preliminary results from testers of the game indicate that using games may be successful in causing positive change in user behaviour.

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As this thesis also marks the end of my time in the PERCCOM program, I also like to thank all staff for their support and patience, especially Eric Rondeau. Also thanks to Jari for giving me the great idea of conducting my thesis in Leeds, which I think was a good decision in retrospect.

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LIST OF SYMBOLS AND ABBREVIATIONS

BN	Bayesian Network
CO_2e	Carbon dioxide equivalents
Evergreen	Assaults of the Evergreen (the developed game)
HSS	History set size
NB	Naïve Bayesian
RF	Random Forest
RT	Random Tree
TP	True-Positive
Weka	The Weka 3 toolkit for Machine Learning and Data mining in Java [4] [5]

1 INTRODUCTION

This work presents an approach to change human behaviour by using persuasive serious games, where the intention is to evaluate if and how we can decrease our overall carbon footprint. More specifically, the work looks at changing behaviour when it comes to selecting modes of transportation. According to Bin and Dowlatabadi [6], 22% of total emissions stem from 'personal travel', of which 68% comes from direct usage and 32% from indirect influences. Therefore, transportation accounts for a large portion of our total emissions. If we could influence our daily choices of transport it could therefore have a significant impact on the total emissions.

As an example in Sweden, the overall emissions within the country has decreased over time [7], making it seem like a good role model for change. Nevertheless, when studying the emissions generated by Swedes outside of Sweden, the total emissions have increased as shown in Figure 1. The data presented there, however, is mostly calculated on consumption and investments of households, government and companies, and is not directly related to traffic-related emissions.

If looking at emissions from transports within the same country (Sweden, see Figure 2), we can see that it has slowly increased over time [8]. The major difference is that more emissions have been generated outside of the country than inside it. This is likely attributed to increased international travel. Of the total emissions generated by households, the Swedish authorities

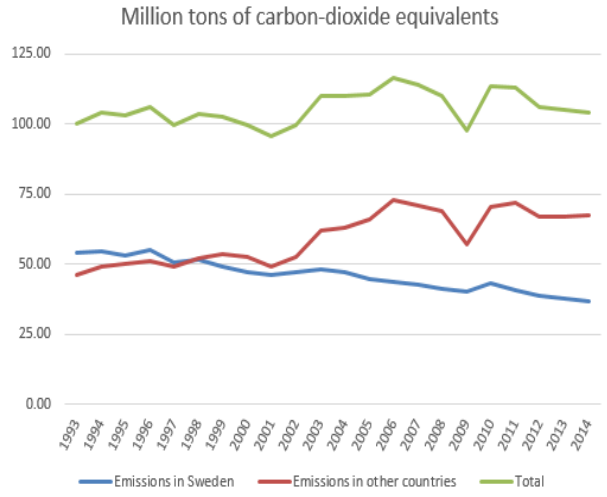

Figure 1, Emissions emitted by Swedes within and outside of Sweden in million tons of carbon-dioxide equivalents [7]. The emissions have decreased within Sweden by 30%, but increased by 50% outside of the country million.

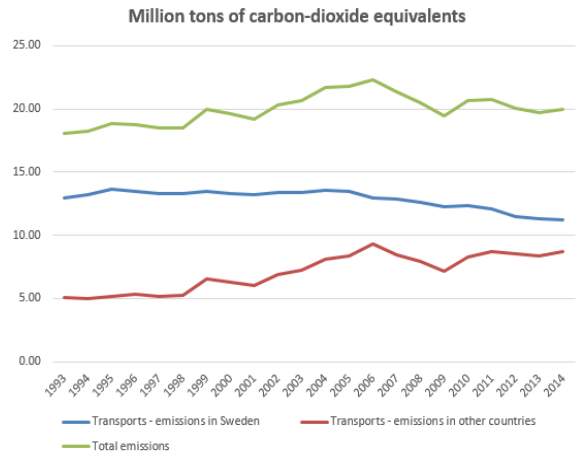

Figure 2, Emissions from transports by Swedes within and outside of Sweden, as well as the total emissions from both [8].

stated that 30% of them were emitted by transports. Another conclusion of the statistics from Sweden is that transportation has come to take a bigger role in the emissions generated, increasing from around 17% in 1990 to nearly 20% in 2014 (since the total emissions have remained rather consistent at around 100 million tons of carbon-dioxide equivalents).

One might also want to have a look at the statistics of flight journeys per inhabitant and year (see Figure 3) [9]. During the past 30-40 years travel by flight has been popularized and increased drastically. Assuming the trend continues, flight journeys may have an increasing effect on total carbon emissions.

When analysing everything in the larger context, then population growth emerges as one of the biggest – if not the biggest – environmental issue of our time [10]. This includes reproductive rights and is surrounded by numerous ethical concerns. Although it is arguably one of the most important factors contributing to the detriment of environmental sustainability, it is not a topic that will be covered further in this work.

The world population is projected to reach 9.7 billion by 2050 [11], exceeding 8.5 billion by 2030. Having these numbers in mind, there are primarily two options left to secure environmental sustainability: one is via technical solutions and new inventions, the other via other behavioural changes. Seeing as technical solutions only can help us insofar as we learn and adapt to use them, one could argue that behaviour change may be the most crucial point to achieving environmental sustainability in the future [12].

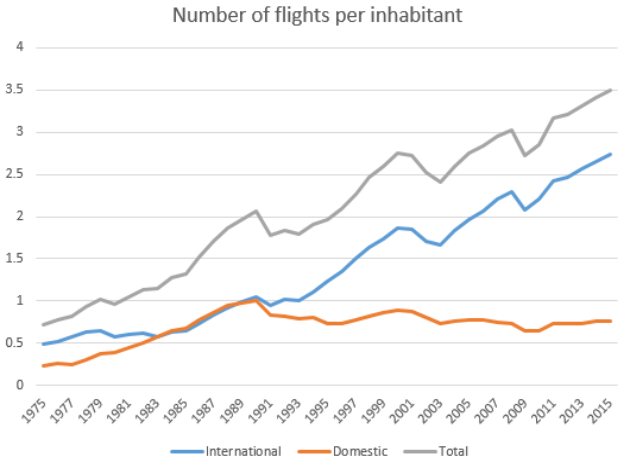

Figure 3, Number of flights per inhabitant and year, as reported by the Swedish Environmental Protection Agency [9].

One issue with technology-driven gains is that they may be undermined by lifestyle changes such as increased consumption – also known as the 'rebound effect' or Jevons paradox. One

example mentioned by the European Environment Agency concerns the car transport sector, where they state,

"*Efficiency improvements are often insufficient to guarantee a decline in environmental pressure. … This trend is apparent in the transport sector. Although fuel efficiency and emission characteristics of cars improved …, rapid growth in car ownership and in kilometres driven offset the potential improvements.*" (page 102, State and Outlook 2015, Synthesis report [13])

Taking the aforementioned statement into consideration, this thesis focuses primarily on a way to change behaviour using technology rather than a direct technical solution.

In order to achieve behavioural change, we have to consider all stages of change. Information is a key element to begin to contemplate change, and strong motivators are key elements for maintaining change. These elements are all prominent in games, making them a viable medium to persuade users for behaviour change.

In this work, a prototype persuasive game is built. Using techniques from augmented reality and transport detection via machine learning algorithms, it strives to give a personal feedback loop to users. Daily actions will give repercussions within the game world, stimulating behaviour change. The prototype game also has embedded multiplayer interactions, as this is often lacking in contemporary serious games.

1.1 Goals and delimitations

As described in the previous section, the issue of global climate change is not improving, and reductions to emissions need to be addressed.

This thesis aims to both study behaviours when it comes to mode of transportation, and try to influence or alter them. Assuming this is successful, it could be one of many steps to try and decrease our total carbon emissions and sustain the planet. If the gamification and persuasive game techniques are effective, they could also possibly be applied in other fields to decrease emissions as well.

In this thesis, a prototype persuasive game is developed and tested in order to influence or alter behavioural patterns. A feedback system is included in the prototype in order to create a bond between real-life actions and consequences within the game. The game is designed and

developed with common and popular features from the competitive game-market in order to create a persuasive game and to persuade users to change their behaviour. This includes multiplayer interactions and hints of augmented reality (via the feedback-loop). The game is tested and evaluated to see how well behavioural change could be achieved by users playing the game.

This thesis also aims to increase awareness of the environmental footprint of us all, since behaviour change on any scale may be difficult to accomplish. If information really is a key to change - and it is - then any enthusiasm into the game could potentially result in changes on the long-term that will not be visible in the results presented at the end of this thesis.

As this thesis also is technical, it studies the entire progress of developing the serious game, as well as how to efficiently use machine learning algorithms in modern smart-phone games without impacting the battery life significantly.

Some early decisions imposed delimitations such as the adherence only to Android for developing the prototype game and analysing only 4 different machine learning algorithms.

1.2 Research questions

The main research questions posed at the start of this work were as follows:

- How well can we induce greener transportation choices by persuasive games?
- What aspects of persuasive games are impactful on transportation choices?
- How can one identify specific forms of transport (car, bus, bike, walk, train, plane) without manual input and without significantly reducing battery life?

The first question is answered by qualitative studies and having volunteers play a prototype persuasive game. The second question is answered by qualitative studies from both the general public, as well as testers of the prototype game. The third question is answered both by offline analysis using the Weka 3 toolkit [5] as well as user-experience based qualitative studies.

Assuming the first and second questions are answered, persuasion via games could possibly be deployed on larger scales to achieve change. Answering the last question is vital to this specific scenario, where, without detecting transports, it is much harder to realize a convincing game.

1.3 Conduct of the experiment

This work was conducted with ethical approval from Leeds Beckett University's Ethics committee. All participants were informed how the data was to be used, and all data has been anonymized before presentation. Mainly two forms of data gathering were used: online questionnaires and data submitted automatically when playing the prototype game. Some follow-up questions and interviews were used to gather further qualitative data from the game testers.

The participants of the study were mainly recruited over social media via the author's personal account. Thus, most participants know the author either directly or in-directly (as the recruitment posts may have been shared or disseminated further), and may have introduced bias both within the transport sample gathering phase and game-testing phases.

The machine learning components were all conducted using the Weka toolkit [5]. For initial offline analysis as well as for comparison studies, the version 3.8.2-Snapshot was used. For all Android-related online and offline analysis a GUI-stripped port of the Weka 3 was used (Weka-for-Android on GitHub) [14]. A maximum difference of 1% classification true-positives difference was noticed between Weka's pre-built Explorer application and our own offline analysis software based on the Android-port.

1.4 Structure of the thesis

This report is structured as follows:

- The ***Introduction*** section provides an understanding of the reasons for and necessity of the work described in this thesis.
- The ***Related Work*** covers various aspects relevant to the project, including Behaviour change, Persuasive Design, and Transportation Mode Detection.
- The ***Theory*** section explains some of the intrinsics and details of machine learning, game design and the psychological basis for persuasion.
- The ***Methodology*** section goes into detail of all aspects of the project. It dives into details that are relevant for the design of the game, describes how the transportation mode detection is implemented and tested, and describes the process for finding volunteers to play the game and how the game is to be evaluated.

- The ***Results*** section includes descriptions, images and links for the prototype game, results for the testing of the transportation mode detection algorithms, and results from the testing of the game. For evaluation of the game, questionnaires before and after playing are analyzed and presented. Some quantitative data is also presented on what modes of transportation were used by the players throughout the test period.
- The ***Discussion*** section analyzes the presented results and discusses any short-comings as far as intended results (reduction of motorized transport use), anomalies or bias of data are concerned.
- The ***Conclusion*** presents a brief summary of what has been presented.

2 RELATED WORK

As described in the section 1.1, a persuasive game is developed and tested in order to change human behaviour when it comes to modes of transportation. Since the game is designed to be a persuasive game – wherein playing it will alter users' behaviour – a study in persuasive games and persuasive design in general is required. The first section on Persuasive Games largely covers gamification, serious games, persuasive design and some modern examples.

The prototype game that is designed and tested aims to promote greener transportation via a feedback-loop, where actions taken in the real world will affect outcomes within the game. To analyze real-world actions taken by the users, transportation mode detection is implemented in the game. Therefore, some related work in that field will be presented as well. The Transportation Mode Detection section covers various contributions in the field that make use of mobile-available sensors such as accelerometer, gyroscope and geolocational sensors.

2.1 Persuasive Games

Persuasive games, serious games and gamification are often aimed at health-related topics, such as exercise and healthy eating, or promoting education and learning in general [15]. Some other topics explored by persuasive games include smoking [16], views on homelessness [17], and greening transportation [18].

Khaled et al. [16] discuss some of the difficulties in managing player attention, balancing the game contents with reality, and questions concerning identity and target audiences, as these impact the effects of persuasive games. Orji et al. [19] analyse persuasive games and target players, and propose an approach to motivate players of certain gamer types with specific game mechanics.

Deterding [20], shows in his presentations and publications a number of ways one can work towards persuading users. Some examples include constraints (making the unwanted impossible), default settings (to use the 'path of least resistance') and facilitation (easing change somehow, e.g. by making behaviour change relevant data visible). He also argues that games are good platforms for persuasive design as they are generally voluntary (already have intrinsic motivators for players to play the games), are generally prestructured and have clear goals – while still fostering interesting interactions. Extrinsic motivators such as money and grades are

generally proven to work well only in the short-term. For social multiplayer games, there are also social motivators such as recognition, belongingness, cooperation, competition, etc.

Ferrara argues that serious games and gamification can cause real change, but highlights that inattention to the quality of the player experience threatens its success [21]. In effect, he argues that we should design games for change, rather than only applying specific gamification elements and hope that they achieve the same effect that a whole game does.

The project by Froelich et al. to promote greener transportation [18] is interesting as it is one of the few which has the same goal and setting as our work. In their work, they combined a self-reporting system with a special pedometer and a dynamic graphic design to promote greener transportation. Among the feedback participants gave, they suggested the use of negative feedback as well as positive, to include more statistical figures of transport usage, and expressed the discomfort of having to wear an extra sensor. The participants also appreciated visual stimuli, but requested diversity over time (as it only featured linear positive graphical progressions).

2.2 Transportation Mode Recognition

There are various approaches of transport recognition or classification. The relevant ones for this project are those which are readily available or compatible with Smartphone based approaches. Research conducted into distinguishing motorized transportation as one class from all other modes of transportation has been mostly successful [22] [23]. It is when different motorized transports are to be distinguished that more difficulties arise, but are usually dealt with by using specific sensors targeting the given transport [24].

Activity recognition – which is a separate branch of machine learning targeting human-centered activities – have been able to reach up to 90% classification accuracy for common classes (sitting, lying down, walking, running) [25], or even higher rates for more classes if additional sensors are used [26].

Accelerometer-only approaches have been largely successful to classify a limited amount of motorized vehicles. For example, 97% classification accuracy for 3 classes (Car, Train, Pedestrian) has been achieved using Support Vector Machines [27], and 80% classification

accuracy for classifying 6 modes of transportation (Walk, Bus, Train, Metro, Tram and Car) has been achieved using a large number of features from the gathered data (78 features) [28].

Lorintiu and Vassilev proposed a model using both Random Forest and a Discrete Hidden Markov Model for filtering for which they reached up to 94% accuracy. They used both accelerometer and magnetometer data to identify 7 classes (still, walk, run, bike, road, rail, plane, other) [29].

Jahangiri and Hesham adopted different supervised learning approaches to classify 5 transportation modes (car, bicycle, bus, walking, and running) [30]. Methods tested included K-nearest Neighbour (KNN), support vector machines (SVMs) and Tree-based models including Random Forest (RF). They used a total of 80 features extracted from four smartphone sensors (Accelerometer, Gyroscope, GPS and Rotation Vector) to train their models and managed to achieve classification accuracies of 91.2% for KNN, 94.6% for SVMs, 87.3% for Decision Trees and 95.1% for a bagging and RF model.

Bedogni et al. proposed in their first paper [31] the use of so-called ‘magnitude’ values as well as a time-based history set to filter out noise and improve classifier results. They reached an initial 97.7% accuracy for 3 classes (walking, car, train). In their second contributing paper [32], Bedogni et al. further evaluated their approach using 8 classes (standing, walking, driving, train, bike, city bus, national bus), where they reached a mean accuracy of 79% for Accelerometer-only, 87% for Accelerometer & Gyroscope, and 95% for using Accelerometer, Gyroscope and Geolocational data all together.

3 UNDERLYING THEORIES

This section presents a brief introduction into both machine learning techniques as well as game design so that the remaining sections may be better understood.

3.1 Machine Learning

Machine Learning is a subfield of computer science that tries to give computers the ability to learn that which is not explicitly programmed. Being an evolution of studies in pattern recognition and computational learning theory of artificial intelligence, machine learning studies the construction of algorithms that can learn from and make predictions on sets of data – so called data-driven analysis. It is often used where it is infeasible or difficult to create explicit algorithms for e.g. filtering of e-mails, detecting a certain state in a complex system, or computer vision. Crucial to machine learning is having enough training data available in order to achieve any meaningful pattern recognition.

Machine learning systems are generally divided into three types of learning:

- *Supervised*, where the algorithm is presented a given set of inputs and their corresponding outputs, and queried to build a model to map said inputs to the respective outputs.
- *Unsupervised*, where the algorithm is presented a set of inputs, without corresponding outputs, and tasked to find a structure within the input and divide it into some amount of new outputs.
- *Reinforced*, where an algorithm or program is given a goal in a dynamic environment and tasked to reach it, with rewards and punishments dealt out as it iteratively tries to solve the problem.

All algorithms presented and tested in this thesis are *supervised* machine learning algorithms. Before presenting the actual algorithms, introduction to some further concepts around machine learning are required. It is worth noting that many of these algorithms and names may occur in different versions. For example, Random Forest has been evolved a few times, and has several parameters. Described in the following sections are the versions as they are implemented within the Weka toolkit [5], which was used for all machine learning components of this thesis.

3.1.1 Machine Learning Definitions

An *ensemble* machine learning technique is a technique which makes use of several machine learning classifiers to improve results over using only a single classifier.

Bootstrap aggregating or *bagging*, is an ensemble meta-algorithm designed to improve stability and accuracy of machine learning techniques [33]. Given a specific training set *D*, *m* new training sets are generated by randomly sampling from *D*. The random sampling allows repetition, meaning that each new training set will hold approximately 63.2% of the unique samples of *D* (with the rest being duplicates). Using the new training sets, *m* models are generated, and their output is combined by averaging (for training) or voting (for predicting). Bagging improves stability, helps with overfitting and is usually applied to decision trees.

Overfitting is the term when a classifier has become too complex and biased towards its training set so that it will cause more classification errors during prediction on new datasets. *Pruning* and *bagging* are two ways to counter overfitting.

Pruning is a machine learning technique that reduces the size of decision trees by removing sections of the tree that hold little power to classify instances. This reduces the complexity of the classifier and should improve predictive accuracy by reduction of overfitting.

Class, within machine learning refers to a specific label which a sample or set of data may have. For example, a set of data with low activity might have the class 'Idle', and a set of data with high activity might have the class 'Walking'. The class is used for training machine learning classifiers, and when a classifier is used for predicting it will produce a class depending on its input data.

TP, or *True-positive* is a prediction that was correct.

FP or *False-positive* is a prediction which was false, and it in fact was another class.

Precision, or positive predictive rate, is a measure computed by the sum of True-positives divided by the sum of True-positives and False-positives for a given class (TP / (TP + FP)).

Recall, or sensitivity, is a measure computed by the sum of all True-positives divided by the sum of all positives for a given class (TP / all positives).

F-Measure, or the harmonic mean, is a combination of both *Precision* and *Recall*, see equation 1.

$$F = 2 \times \frac{precision \times recall}{precision + recall} \quad (1)$$

MCC, or Matthews correlation coefficient, is a measure of quality for binary classifications. It takes into account true and false positives as well as negatives. An MCC of +1 represents a perfect prediction rate, 0 random predictions, and a −1 represents 100% errors. It is sometimes also known as the phi coefficient.

ROC Area, or Area under the ROC (Receiver operating characteristic) curve, can be interpreted as a performance indicator of a classifier, and is often used to compare classifiers.

PRC Area, or Area under Precision-Recall Curve, is yet another indicator for the performance of a given classifier.

3.1.2 Random Forest

Random Forest (or RF) is an *ensemble* machine learning technique, which makes use of a group of decision trees in a specific manner to achieve better predictive performance than a lone decision tree could achieve [34]. For each tree in the forest, a random vector is generated to dictate how it should grow. Given an input x, each tree will cast a unit vote for the most popular class. Random trees also use random elements to determine the number of and which features to use for splitting each node.

Breiman [34] describes how a single tree classifier may be unable to handle a large amount of input variables (e.g. a thousand variables for medical diagnosis and document retrieval), while a forest grown on random features (a Random Forest) should improve accuracy.

Some characteristics of Random Forest include:

- Accuracy as good as contemporary classifiers, sometimes better.
- Relatively robust to outliers and noise.
- Faster than bagging or boosting.
- Gives useful internal estimates of error, strength, correlation and variable importance.
- It is simple and easily parallelized.

Since bagging is optional for Random Forests, another kind of random subset selection is used when candidate trees are to be split in the learning process, sometimes called ”feature bagging”. This is done as it should make the trees more correlated, thus increasing subsequent accuracy during prediction.

3.1.3 Random Tree

The Random Tree (or RT) as implemented and used within the Weka toolkit [5] is described as a tree that considers *K* randomly chosen attributes at each node, performs no *pruning*, and has options for allowing estimation of class probabilities. In essence, Random Tree is the base classifier or base learner used by RF within Weka.

3.1.4 Bayesian Network

A Bayesian Network (sometimes Bayes Network, abbreviated BN) is a probabilistic graphical model used to represent knowledge about an uncertain domain [35]. Each node in the graph represents a random variable, while the edges between the nodes represent probabilistic dependencies among the corresponding random variables.

The BN implementation within Weka is based on the ADtree as described by Moore and Lee [36], and uses the K2 search algorithm [37] [38]. The ADtree is a data structure intended to minimize memory usage and accelerate BN structure finding algorithms, rule learning algorithms, and feature selection algorithms while K2 is an algorithm for searching belief networks to maximize the probability metric given by a chosen equation.

3.1.5 Naive Bayes

Naive Bayes classifiers (or NB) are a set of simple probabilistic classifiers based on applying Bayes’ theorem with strong (naive) independence assumptions between the various features. The Naive Bayesian classifier as implemented in Weka is based on the work by John and Langley [39]. It uses estimator classes, where numeric estimator precision values are chosen based on analysis of the given training data.

3.2 Game Design

Game design as such is the art of applying design and aesthetics to create a game for some specific purpose – usually entertainment. Some related academic fields include gamification (which revolves around applying game-design elements in non-game contexts), game studies

(the study of games, the act of playing them and cultures surrounding them) and game theory (strategical decision-making).

Tracing back to research in the 1980s, Thomas W. Malone proposed heuristics for what makes games fun to learn [40]. In his work, he largely categorized the characteristics of good games or other enjoyable situations into three categories: challenge, fantasy and curiosity.

Another set of proposed heuristics are those presented by VandenBerghe [41] [42], named the 5 Domains of Play, or the 30 Facets of Play. These focus both on categorizing players, as well as categorizing game mechanics and games, and could possibly link the players and their game preferences. The 5 domains VandenBerghe presented are based on the Big 5 personality traits (also known as the five factor model) [43], which consist of the following factors: openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism. VandenBerghe refines these Big 5 personality traits into the following categories that can be used in the context of games, game mechanics and gamer-types:

- **Novelty**, which distinguishes open, imaginative experiences from repetitive, conventional ones
- **Challenges**, which deals with how much effort and/or self-control the player is expected to use
- **Stimulation**, which deals with the stimulation level and social engagement of play
- **Harmony**, which reflects the rules of player-to-player interactions
- **Threat**, which reflects the game's capacity to trigger negative emotions in the player.

One popular profiling system described by Bartle categorizes players into four main categories: Achievers, Explorers, Socializers and Killers [44]. Achievers are those who focus on setting and accomplishing their own goals within the game, Explorers try to find out as much as possible about the game itself, Socializers focus on role-playing or casual text interaction with other players, and Killers use actions within the game to cause distress to (or, rarely, help) other players.

VandenBerghe domain	Malone counterpart	Bartle profile counterpart
Novelty	Fantasy	-
Challenge	Challenge	Achiever
Stimulation	-	Explorer
Harmony	-	Socializer
Threat	Challenge	Killer

Table 1, Comparison between VandenBerghe and Malone's heuristics

Table 1 gives a brief overview of those elements covered by VandenBerghe and how they could be mapped onto the heuristics described by both Malone and the player types categorized by Bartle. Obviously, the *Stimulation* and *Harmony* parts – which represent the various social and player-to-player interactions are more or less lacking within Malone's initial proposal, while the *Novelty* part is not covered at all by the Bartle profiles. Note also that this is a very simplified comparison, since the work by VandenBerghe presented a total of 30 characteristics. For the sake of brevity, VandenBerghe's work is not further analysed in this work.

3.2.1 Challenge

A goal is almost required for a game to be called as such. Some recommendations on goals are as follows:

- For simple games, a goal should be obvious and compelling. This can be done via visual effects (Breakout) or fantasy (Hangman).
- A game can also be without goals, but then the game needs to be well-designed so that users can generate their own goals (that should be appropriate to their skill or difficulty level).
- The best goals are often practical or fantasy goals (e.g. reaching the moon in a rocket).
- The players must be able to tell if they are getting closer to the goal. This could be done via some visual or aural stimuli.

One topic relating to the Challenge-aspect of game design is self-esteem, since it is highly correlated with the players' successes and failures within the game. It is thus best to consider this when designing the level of challenge within games. If failures are sufficiently severe to lower a person's self-esteem, it will also decrease their desire to play the game. Two implications from this are that games are recommended to use variable difficulty levels, and

that perhaps the performance feedback should be presented in a way that minimizes possible damage to the player's self-esteem.

3.2.2 Uncertainty

Another typical requirement for good games is uncertainty. If the player knows they will win or lose, the gaming experience will be boring. Some steps to ensure uncertainty are as follows:

- Variable difficulty levels
- Hidden information – which increases difficulty and provokes curiosity
- Randomness – which can be used to increase uncertainty in almost any game
- Multiplayer interactions – including multiplayer interaction will likely add more uncertainty to a game.

3.2.3 Fantasy

> "It is very difficult to know what emotional needs people have and how these needs might be partially met by computer games. It seems fair to say, however, that computer games that embody emotionally-involving fantasies like war, destruction, and competition are likely to be more popular than those with less emotional fantasies." – T. W. Malone [40]

Fantasy often makes games more interesting, and involves objects, environments and situations which are impossible from a realistic point of view.

Fantasy may be described in two versions: extrinsic and intrinsic. The extrinsic fantasies are those where real-world actions (e.g. solving arithmetic problems) which progress the game, while intrinsic fantasies are those actions which occur within the game itself that progress the game. Intrinsic fantasies may be more interesting, immersive and instructional than extrinsic fantasies, since they better incorporate the sense of realism within the game (in-game actions affecting the in-game world).

Consider, for example, the logic where solving an arithmetic problem in the real world would yield a change within the game world. This could work, but possibly only for a narrow range of scenarios (e.g. inventing or crafting something within a game) without breaking the immersion of the game.

When studying the modern-day emerging augmented reality games and apps, perhaps the extrinsic fantasies will appropriate larger use in digital games. Take for example Pokémon Go, where moving about in the real world is required to progress the game [45].

3.2.4 Curiosity

Curiosity is another important component of game design. It may be independent of goals and fantasies, but may also be stimulated by the game environments, or the complexity of the game. Just like in movies, you may be given clues as to where the story will end up, or what will be revealed, and you may have your curiosity satiated once it is finally revealed. These kind of storytelling scenarios are present in games as well.

Curiosity can be divided into two types: sensory and cognitive curiosity.

Sensory curiosity

Sensory curiosity basically entails changes in sound or graphics, and can be measured in 'technical events per minute', such as changing camera angles, playing a sound effect, displaying a graphical reward, etc. Sensory events can be used as a decorative piece (background animation or music), to *enhance fantasy* (by evoking some certain thoughts or feelings), as rewards ("Good job!", "Congratulations!", etc.), or as representation systems (e.g. audio feedback on event occurrences, using graphical elements instead of text). Using sensory events as rewards can increase the sense of completion, but can also become tedious or undermine people's interest if used incessantly.

Cognitive curiosity & Informative feedback

Cognitive curiosity can be thought of as wanting to improve, solidify or verify one’s own knowledge about some knowledge structure. In games, this could be verifying your own skill level, recalling if you can traverse some game area without the help of a map, or testing your own limits to what you can achieve within the game in order to better understand the game itself.

Malone claims that people are motivated to achieve *completeness*, *consistency* and *parsimony* for to all their cognitive structures [40]. He continues to argue that the way to engage in players’ curiosity is to present them just enough information to render their current knowledge seem incomplete, inconsistent or unparsimonious. The learners (or players) are then motivated to try and learn more and improve their cognitive structures accordingly. For example, reading a

crime novel’s last chapter and figuring out who the murderer was brings completeness to the knowledge structure you had of that specific story.

4 METHODOLOGY

The methodology is largely split into three parts. The design, testing and implementation of a persuasive game, methods for evaluation of the promotion of green transportation when deploying the developed game, and the design and testing of an approach for transportation mode detection to be used within the game.

4.1 Persuasive Game Development

In order to develop a persuasive game, the full procedure of developing a digital game has to be considered. The first few subsections (4.1.1 to 4.1.3) present the system architecture for the game and its peripheral systems, the persuasive-related requirements of the game, and a list of applications that were developed as part of the project. The remaining subsections (4.1.4 to 4.1.8) discuss some aspects of the game and some decisions that were taken during game development, as well as rationale to justify decisions made.

4.1.1 System Architecture

For this project, a series of applications were developed, with an accelerometer sampler application and a persuasive game being the two applications used or tested by volunteers. The sampler application was named Transportation Mode Sampler, as it included categorization of sampling data to the target transport modes and was used by volunteers to help gather data for transportation classification tests. The serious persuasive game *Evergreen* was named as such since it refers to the evergreen-trees as a symbol of sustainability, and it also gives a good picture of what the game is about – surviving out in the wilderness against forest beasts.

Figure 4 gives a glimpse into how the system was laid out code-wise within the scope of this thesis. Section 4.1.3 lists all applications developed as part of this thesis.

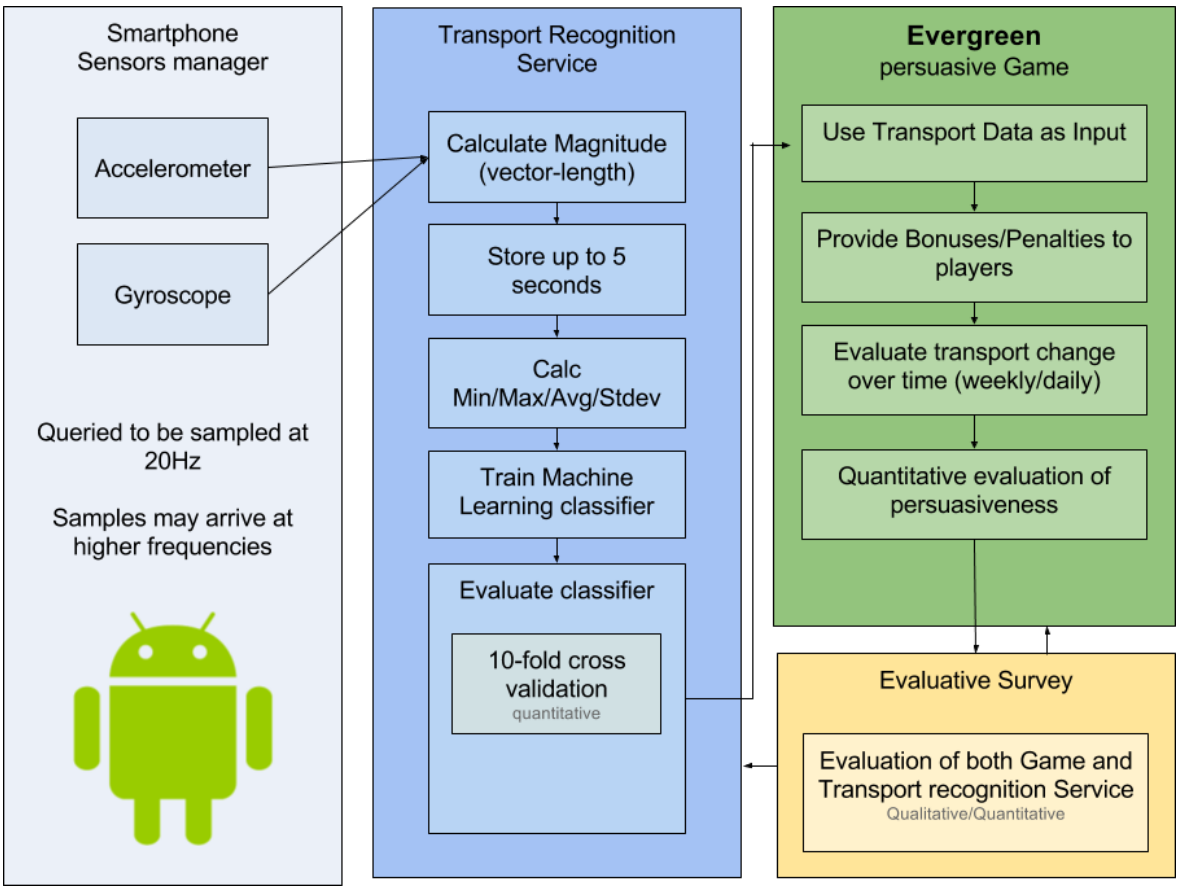

Figure 4, System architecture overview

4.1.2 Persuasive Game Requirements

Initial requirements for the project highlighted that players of the persuasive game should be motivated to change their current behaviour. For a game to be successful it also requires good game design. The initial game design requirements could thus be listed as follows:

- Iterative game design so it can be played for longer periods of time
- Include multiplayer interactions to make it more appealing
- Feedback-loop based on user data to incentivise behaviour change

Additional requirements were derived from the inclusion of a feedback loop, since Machine Learning was chosen as a method to accomplish it:

- Samples gathering to train and test classifiers for usage
- Classifier testing to evaluate which one to use, and in what way

Requirements	Rationale	Behaviour intervention categorization
Iterative game design	Allows for longer periods of play – should foster greater behavioural change	Incentivisation
Multiplayer interactions	Make change more likely by increasing the game's appeal	Environmental Restructuring, Modelling
Feedback-loop to incentivise behaviour	Giving consequences for real-life actions in the game should incentivise change	Persuasion, Incentivisation, Coercion

Table 2, Requirements, their rationale and categorization.

According to the characterization method proposed by Michie et al [46] the game design requirements related to persuasiveness could be categorized into categories shown in Table 2. The iterative game design and character-development typically used in role-playing games could be considered as Incentivisation where the game creates an expectation of grander rewards which increases with play. The multiplayer interactions could both alter the environment (in the form of social context of players within the game) and could also – according to the modelling intervention – create models of people or teams within the game world to which players can imitate or be inspired (either via player-player interaction or via public green transportation activity leader boards). The feedback-loop could be categorized as persuasion in the sense that it could induce positive and/or negative feelings, and thus could also be considered Incentivisation (expectation of reward) as well as Coercion (expectation of punishment or cost) depending on mode of transportation.

4.1.3 Applications developed

In terms of separate applications developed, the following were planned and then implemented:

- Persuasive game, entitled *Evergreen*
- *Transportation Mode Sampler* – an application for gathering data samples
- *Transport Detection Service* – an Android service to detect mode of transportation used
- *Evergreen* game server – Java-based back-end for co-ordinating the multiplayer game mode
- Java-classes for training, testing and evaluating preliminary data and classifier accuracies (*WekaManager*, *WClassifier*, etc) based on the Weka API [5].

4.1.4 Game Genre

For game genre, a turn-based strategy and role-playing game hybrid was chosen. There are several reasons for this. Firstly, it enables an iterative approach to try and persuade players for each turn or day that they are playing the game. Secondly, players of role-playing games tend to play them for a long time, as long as they are well-designed. In the game, each turn would correspond to one real-life day. Actions in the real life (transports taken) would affect, to some extent, results in the game, and thus, give an incentive for players to subsequently choose greener modes of transportation. Using a turn-based approach also makes it available to a larger audience, as less time is required to play it (a few minutes per turn or day), whereas a real-time game may distract and interfere with daily life. Pokémon Go is a great comparison as it is also in the same genre, gathered a large popularity, caused a distinct change in behavioural patterns of players, but also has its disadvantages and hazards inherent in the game design [45].

4.1.5 Game Goals

Since a goal of this work was the design of a *persuasive game* – a game whose goal is not primarily (or *exclusively*) for entertainment – several goals would be present within it concurrently:

- Reduce emissions by choosing greener forms of transportation.
- Promoting awareness of each person's environmental footprint.
- Defeating other players or surviving the longest.

To keep the game compelling, the first and second goals are embedded in the game and are not explicit goals for the players. They are instead tools and parameters in the game which players can try and use to achieve the third goal. Within the resulting game, these goals are mainly integrated into a generation of random events which are spawned depending on which transportation mode players use, as well as one of the main game statistics called "*Emissions*". The third goal is a typical game-goal that resonates well with general and contemporary game designs in that it is likely to provoke emotions and is more likely to entice game players. Within the game, the players may also set their own goals – such as helping others, building the largest shelter, etc. Due to the complexity of the resulting game (and role-playing games in general), players tend to set up different own goals based on what they enjoy in games.

4.1.6 Game Fantasy

Through intrinsic fantasy, the player can choose a wide array of actions within a conflict-ridden fantasy-world. Through extrinsic fantasy, players' real-life actions will be used in a feedback-loop manner back into the game, stimulating transportation choice. This way, the game will permeate players' everyday lives, possibly generating a larger behavioural change – which is the aim of this game.

As discussed in section 3.2.3, people have different emotional demands, and may thus find different forms of fantasies appealing. In order to appeal to at least one group of players, the genre of the game and most of the mechanics have already been decided: post-apocalypse where nature is out to get you. Common game mechanics from turn-based strategy and role-playing games were chosen, as they best fit in with the designed player experience and projected playing time required for behavioural change. The required estimated time for signs of change is at least 7 to 14 days. One earlier hypothesis was that some groups of people enjoy this genre, and may thus enjoy the game, while others may reject it.

4.1.7 Game Curiosity

As described in section 3.2.4, the game should be novel with an element of surprise to some extent, but should not be too complex so as to deter players. Some expectations should also be met (adhering to certain common game mechanics and interactions), while some parts should be novel coupled with uncertainty (new game mechanics or new interpretations of existing ones) in order to appeal to a wider audience.

Based on the above, the game abides by some common rules and game mechanics found in modern turn-based role-playing games (RPGs) and strategy games. The game also features new game mechanics to make it novel and invoke curiosity as well as fulfil the requirements for being a persuasive game (here defined as stimulating behaviour change regarding vehicle use).

As for sensory curiosity, the game is designed to give more extensive sensory events as rewards when noteworthy events happen within the game. For example, the player's dwelling graphics updates as it is upgraded, and the background picture is tinted into different shades based on how points of emissions the player has emitted. In the beginning of the game, the player has 0 emissions and has a nice and soft green background. As emissions increase beyond a certain threshold, yellow tints at the bottom appear. At the later stages, the tints gradually change to orange, red, and lastly, black. At each progression, the "decaying" colours also gradually move

upwards, so that the entire screen at the end of the game may be a dark red and black gradient. Figure 5 shows the progression as it was implemented in the Android prototype game.

Daily events occurring in the game would not get any special sensory events besides presentation in a summarized form, while there were plans to give some further sensor feedback for more notable events (such as surviving a harsh encounter with dangerous foes). Unfortunately, further sensor events were not added, but may be incorporated in a later version.

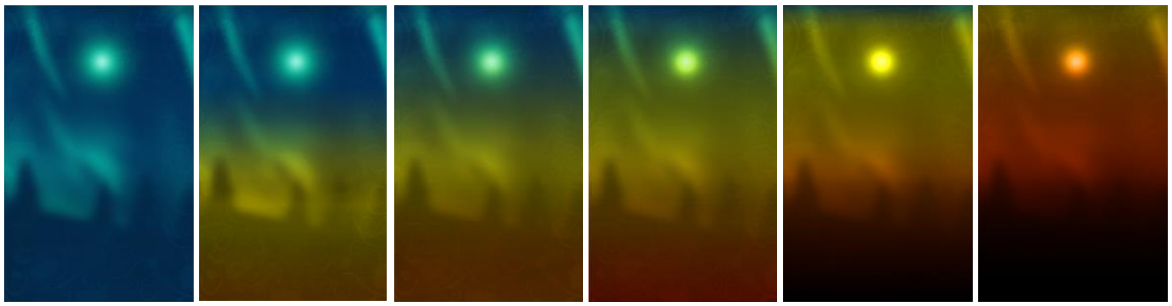

Figure 5, Sequence of background images as emissions increase

4.1.8 Game Design details

In the developed game, *daily actions* are chosen, such as gathering food or resources, inventing and crafting weapons, armour and tools, building defences, scouting, interacting with other players, etc. The *daily actions* are then used as inputs for the game once each new day or turn is simulated. *Skills* are also chosen by players to be trained so that they may specialize and become better in one trade or another, to try and motivate cooperation. Some actions and skills were also competitive, such as stealing from or being able to attack other players. *Active actions* such as sending resources, items or messages between players could be performed on demand to allow some flexibility.

Within the game, there are some relevant statistics, with *emissions* being the next-most important one (affecting overall game difficulty) besides *hit points* (the standard statistic used to represent a character's vitality in many role-playing games). Different modes of transport give varying amounts of bonuses to the in-game *Daily actions*, as well as generate various amounts of *emissions*. Choosing specific actions within the game which consume resources (crafting, inventing, building defences) also increase the *emissions* statistics, while some actions and skills actively reduce or indirectly reduce current or future *emissions* generation.

To adhere to good game-development and software development practices, the development lifecycle was preceded with the development and evaluation of a paper prototype (see appendix 1) [47]. Volunteers were recruited and the game was tested in group sizes between one and three. Four separate groups tested the game for initial feedback and iterations. Testers of the paper prototype found the game interesting, after which a digital graphical prototype was designed (see Figure 6 or Appendix 2).

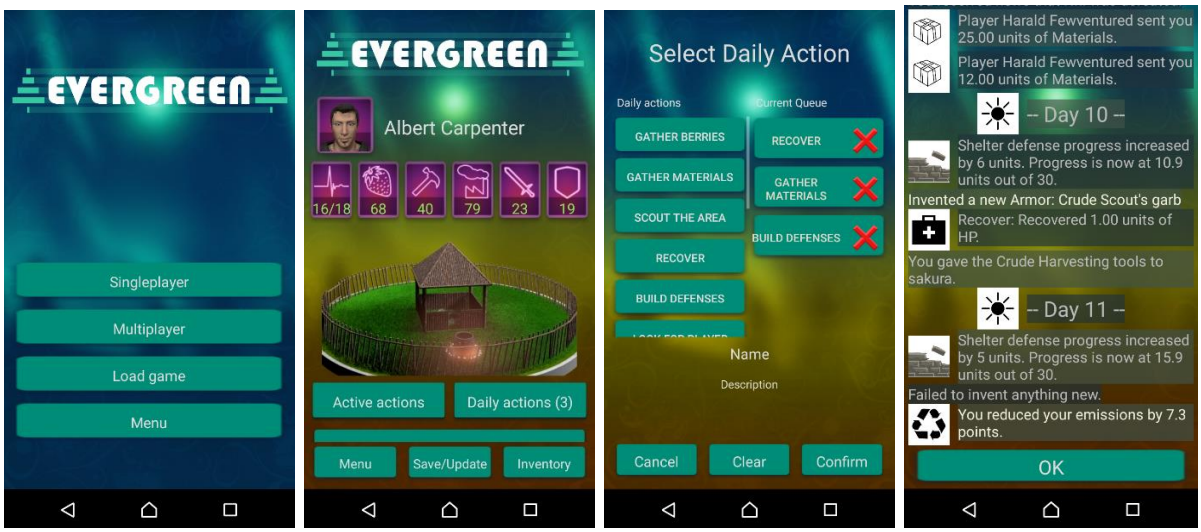

Figure 7. Screenshots from the Android version of the game Evergreen. Far left: splash-screen. Middle-left: Main screen, showing statistics in the top 6 icons. The background changes colour as emissions increase, and the representation of the shelter changes as it is being upgraded. Middle-right: 'Daily Actions' selection screen. Far-right: the results-screen showing what has happened the most recent days/turns.

Using volunteer testers and the help of a graphics artist, an Android-based version of the game was developed. Figure 7 shows some screenshots of the game as it was published in social media (Appendix 3 shows more screenshots from the tested game version).

To readers who intend to analyse the game in further detail, we suggest reading Appendix 1 (since the paper prototype game design largely corresponds to the design used within the developed Android prototype).

4.2 Evaluating Behaviour Change

To evaluate potential behaviour change, one *expectations* questionnaire, as well as pre- and post-intervention questionnaires were given out to volunteers. The *expectations* questionnaire was distributed before any serious development of the game began, the pre-intervention questionnaire was distributed before testing began, and the post-intervention questionnaire was given to players after they had played the game for 10 days or more. Both quantitative and

qualitative answers for each respondent was recorded, and participating game testers were also asked follow-up questions based on their playing experience. Volunteers and participants for testing the game were mainly recruited over social media with no extra incentive added to play the game.

4.3 Gathering sensor samples

Volunteers were sought out to assist in providing training data. A small app was developed where users could observe current data, see the preliminary window feature values and export the data into other applications (see Figure 8). Volunteers were sought out in the vicinity both locally and online, and for each transport the aim was to include an equivalent amount of samples, comprising at least 30 minutes' worth of sampling. If classification errors were found early during testing, further samples were gathered to improve classification for that specific transport scenario. In order to make the final trained transport-classifier user independent, samples were requested from at least 2 volunteers per transport whenever possible.

4.4 Transportation Mode Detection

The transportation mode detection work that is presented and analysed in this work is based primarily on the work presented by L. Bedogni et al [31] [32]. Accelerometer- and Gyroscope data was queried at 20Hz, and saved in intervals of non-overlapping 5 second duration windows. Depending on what applications were running in the background, the number of samples that were gathered have been higher, as this is how the Android OS handles sensor requests. If the system supplied samples at higher rates, no data would be discarded, so some intervals could differ in their actual sampling rate.

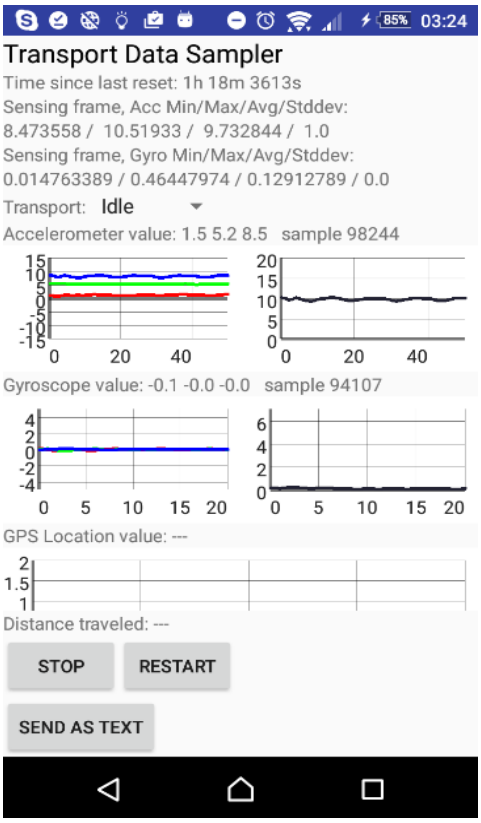

Figure 8, Screenshot of the Transport Data Sampler application volunteers used to submit data for the project.

Each sample within the time window was recalculated into a magnitude value to make the sample data user orientation- and position-independent (see equation 2).

Based on a set of magnitude values, each interval, minimum, maximum, average and standard deviation values were calculated. These 4 values per sensor (8 in total) made up the time window features that were later used for machine learning classifier training and prediction tests.

$$magnitude = \sqrt{sample_x^2 + sample_y^2 + sample_z^2} \qquad (2)$$

To train the classifiers, data was gathered with the help of volunteers for 9 transportation modes (10 including *Idle*): *Bus*, *Foot*, *Car*, *Bike*, *Train*, *Tram*, *Subway*, *Boat*, and *Plane*.

Each instance fed to the classifiers for training consisted of the 8 time window features mentioned above, along with a pre-labelled transport (that was used to gather and calculate the

previously mentioned features). During prediction, the classifier would then be fed 8 other window features and queried to predict which transport was currently being used.

4.4.1 Noise reduction by using a History set

To improve prediction, a history set is used to filter out noise in the classifier predictions. As an example, consider the following prediction sequence: *Bike*, *Bike*, *Bus*, *Bike*, *Bike*. It is unlikely that a user would take a bus for a few seconds while all other predictions, before and after, indicate that the user is riding a bike. Figure 9 visualizes how the history set would work be used.

The usage of the history set of size N is as follows: when a new prediction is made, it is added to the history set. If the set has more than N predictions, the oldest prediction is discarded. The transport of highest frequency within the set is returned and used instead of the initial prediction.

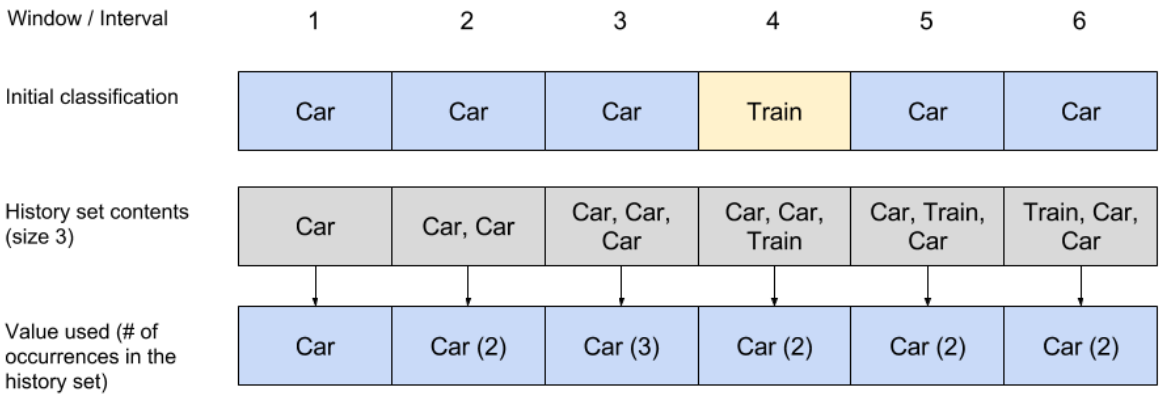

Figure 9, How the History set can remove noise. It is improbable that the user switches transport for only 5 seconds (1 interval)

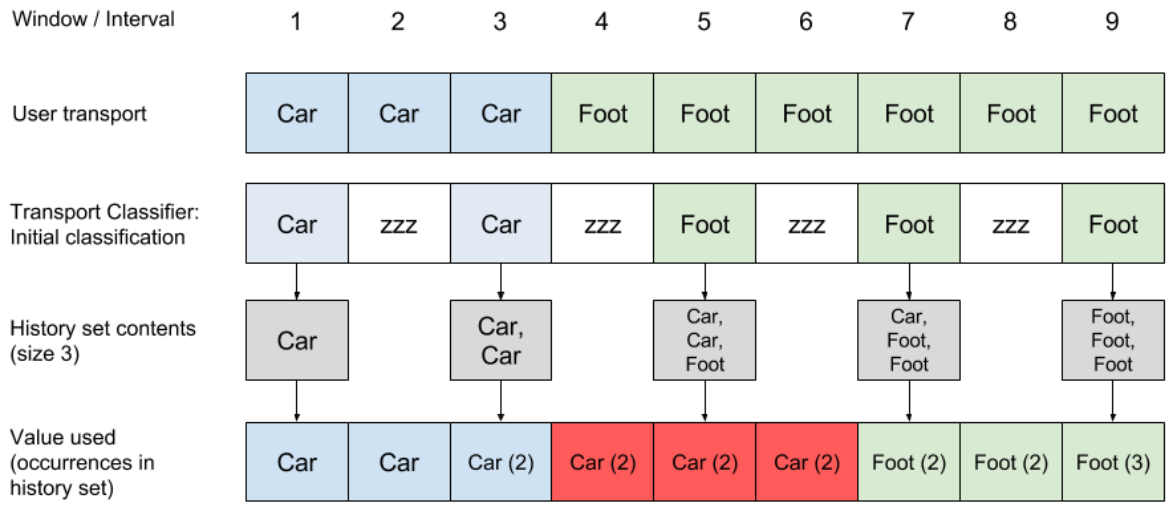

Figure 10, The History set in combination with sleep sessions

4.4.2 Sleep sessions

Due to the popularity of the game Pokémon Go, the associated effects of battery life degradation from its use and the similarity in augmented reality with the *Evergreen* game we are working on, the effects of introducing sleep sessions in-between samplings was also of interest. The expected effects on accuracy is a degradation, but it is of interest as it could be used to plan how much the resulting application will drain the user device's battery. The aim is to figure out approximately how much time the transport detection service can sleep while still retaining a certain classification accuracy, and this was not covered by other authors in previous works.

Initial approaches to use the history set together with sleep settings are visualized in Figure 10 and Figure 11.

In order to maintain the battery performance during testing, the sensor sampling service within the resulting game used an alternating sleep schedule to reduce energy consumption. The

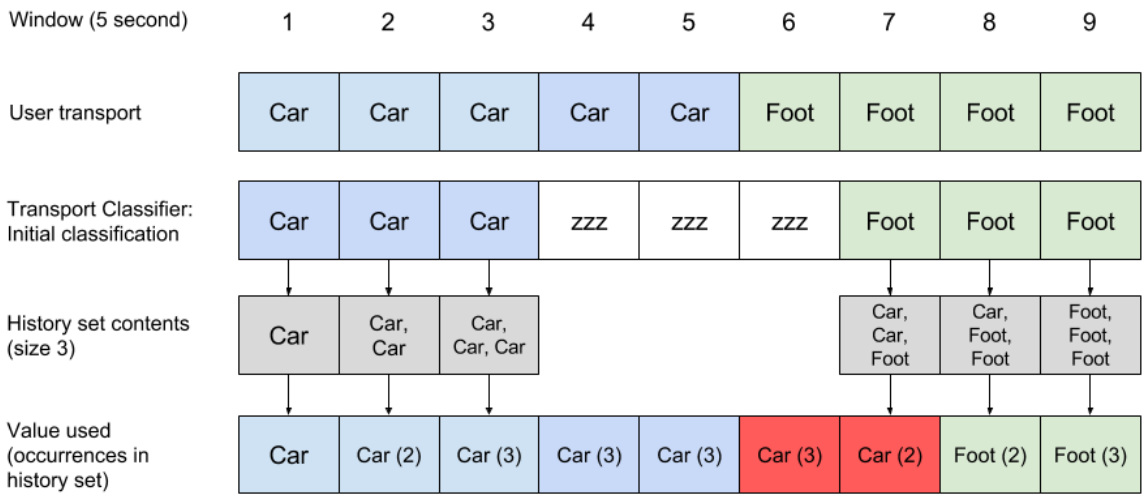

Figure 11, The History set in combination with sleep sessions, alternate approach

qualitative tests (using machine learning within the game) generally included sleeping using a 1:1 ratio of sensing and sleeping (e.g. sampling for 2 minutes, then sleeping for 2 minutes). This is the same kind of method as shown in Figure 11. Figure 12 depicts the relationship between the increased rate of errors and increase in sleep sessions. The errors generally occur at increased rates right after the user changes transportation mode.

4.4.3 Gravity measurement miscalibration

After initial positive tests on classifier accuracy, a real-life test was carried out with the same classifier integrated into the game. Due to the number of errors that emerged, we hypothesized that the device orientation somehow still impacted the transport recognition. Brief tests showed that the total gravity sensed varied with each device and orientation, which would in turn affect all machine learning classifier results including the accelerometer (see Table 4 in section 5.4).

In order to ensure that the whole procedure and data were thoroughly device- and orientation-independent and remove the effect of sensor-axis miscalibration, normalization of acceleration values was applied to the minimum, maximum and averages of the acceleration sensor magnitude values. This was done by dividing them all with the average value, thus centering them on 1.0 instead of whichever value the specific device was calibrated to.

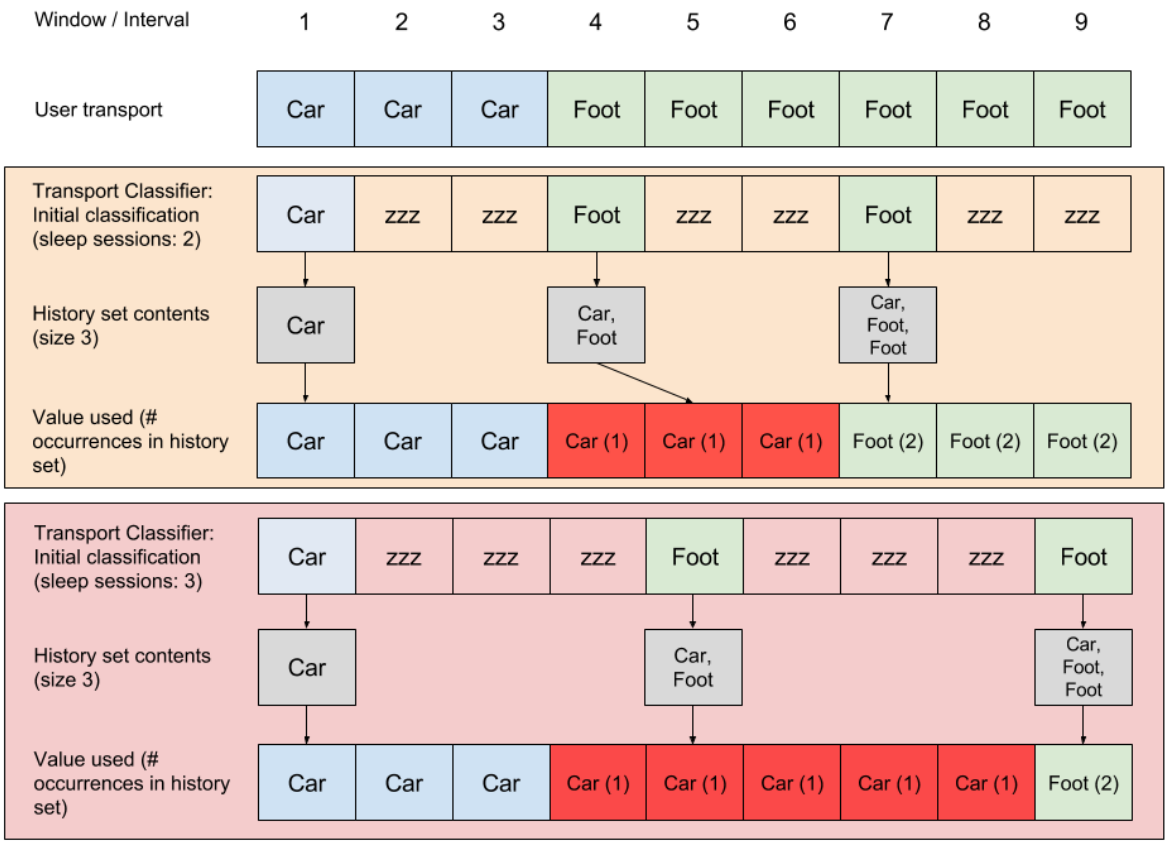

Figure 12, Increase in errors as sleep sessions increase

5 RESULTS

The results are divided into the following sections:

- *game design*, where an analysis is done on respondents' answers to an initial expectations-questionnaire as well as a questionnaire given to all who would test the game.
- *game evaluation*, where an analysis is done on the qualitative feedback provided by testers of the game as to its persuasive effects and limitations,
- *transportation mode data sampling*, where results of data sampling is shown and as well as an investigation into the effects of device orientation on sampled gravity measurements is shown,
- *transportation mode detection*, where results are shown of the various tests on the gathered data, including n-fold cross-validation, the use of a history set to filter noise, and results for when input data has had its acceleration values normalized.

The game that was developed is a persuasive game called *Assaults of the Evergreen* or just *Evergreen*. Its official Facebook page with links to some relevant questionnaires can be found here: https://www.facebook.com/AssaultsOfTheEvergreen/

5.1 Game design

To get an idea of how a game should or could be designed, as well as to assess the viability of a persuasive game's effects on people, two primary surveys were conducted. The first "expectations"-questionnaire was disseminated in January 2017, and the second "pre-testing" survey was disseminated in April 2017. The first "expectations"-questionnaire received more than 40 respondents, and the second "pre-testing" questionnaire received 24 respondents.

Respondents for the initial "expectations"-questionnaire were asked to which extent they thought a game could impact their lifestyle, if they were willing to play a game designed to improve their daily choice of transportation, and asked how they would imagine such a game would look like or be designed. A majority of the respondents had a background of playing digital games (Smartphone, Console or PC), and were of the opinion that games can have some impact on their lifestyles. Figure 13 shows response distribution for one of the questions, where 1 was labelled 'Not at all' and 5 was labelled 'A lot'.

Responses to an open free-text question concerning how a persuasive game would be designed were diverse. Respondents suggested features such as showing real-life data and personal statistics, adapting to players' personal schedules, and using notifications and achievements. Among the concerns were battery life, privacy of collected data (e.g. locational), and that the game does not demand too much time from players. Some respondents said they would play any game if it was fun, while others stated that they would not play the game to improve their daily choices since they were already using the greenest modes of transport (walking or biking).

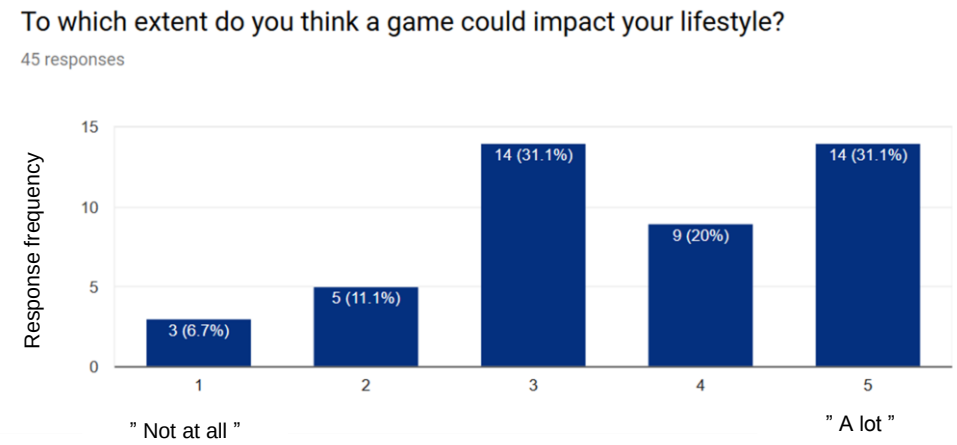

Figure 13, Expectations of how much a game can impact respondents' lifestyles

Some respondents also highlighted the social aspects, including competitions, and leader boards that may motivate players. One respondent mentioned that they would be more interested in features that help them choose greener modes of transport for a specific journey.

When asked how successful a persuasive game could be concerning transportation, some respondents perceived the choice of transport is mostly one of practical nature: some distances and journeys are just not practical with greener modes of transport. One respondent recalled a long-term biking contest that was held at their workplace on a regular basis (weekly, monthly, yearly), and described that people participated mostly because of the competition (as part of the

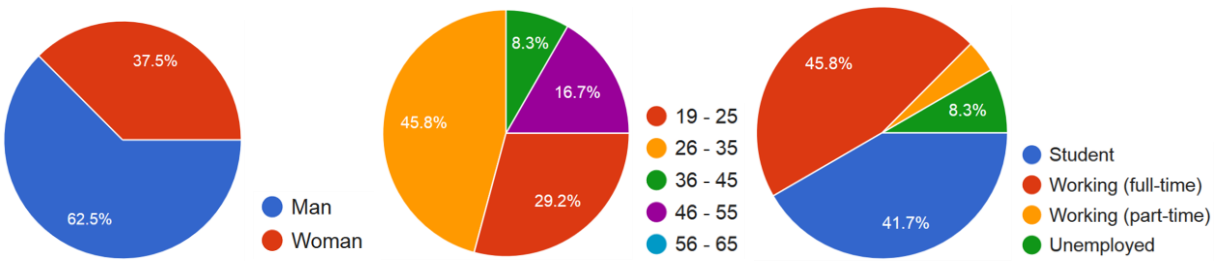

Figure 14, Population distribution of the Pre-Testing questionnaire (Sex, Age, Occupation)

gamification) even though the website of the leader board was not very good. One respondent mentioned that even if the game is just entertainment for some players, it may encourage others to contemplate changes in their lifestyle. One respondent likened the concept to the success of Pokémon Go, claiming that it could be successful only by looking at how that game made players walk around everywhere. Some respondents mentioned that it all depends on the quality of the game and the marketing strategy: that any game can be successful if marketed well.

For the "pre-testing" questionnaire, respondents were asked in more detail who they are and their current habits. There were 24 respondents to this questionnaire. The respondent's distribution regarding to sex, age and occupation is displayed in Figure 14. In total 15 men and 9 women responded, of varying ages with the 26-35 interval being the most common age-group. 11 were working full-time and 10 were students. 11 were recruited personally by the author, while 13 were recommended to try out the game by a friend.

Similar to the results in the initial expectations-questionnaire, respondents of the pre-testing questionnaire had an overall positive view of the potential effects of a persuasive game such as Evergreen, as can be seen in Figure 15. When responding to the question, the value 1 was labelled as 'No' and 5 as 'Yes', with respondents left to interpret the values in-between themselves.

Details for the Expectations- and Pre-testing questionnaires can be viewed in Appendix 8 and 9 respectively.

5.2 Game Evaluation and persuasive effects

The game had 4 testers who played the game in multiplayer mode for at least 10 days. Two out of 4 players were still playing 50 days after launch. The four testers that played the game for at least 10 days each spent either 1-5 minutes or 6-10 minutes a day playing the game, and a similar amount of time talking about it with friends, colleagues or others. They generally thought the game was well-designed and well thought out, that it was generally not too hard to understand and play, and that it had enough character customization. Similarly, the testers generally thought the game had well-designed graphics that made it easy to understand what was happening in the game and enjoyed playing the game.

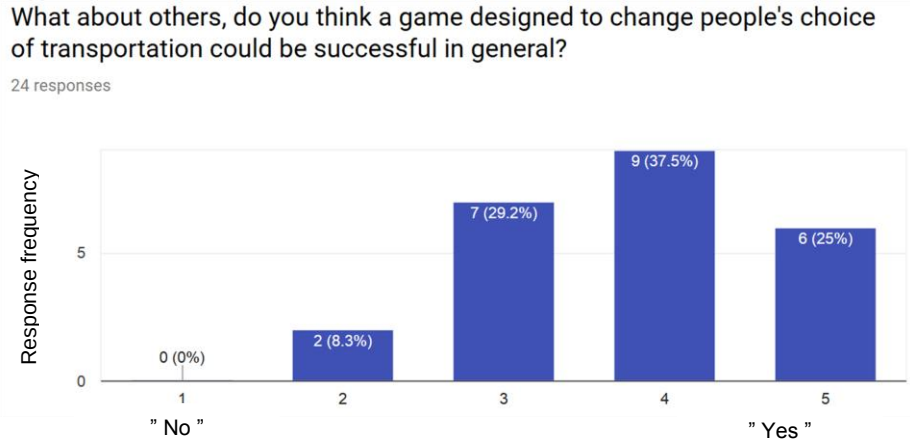

Figure 15. Respondents views on the potential success of persuasive games.

Some criticism from the players included a lack of players to interact with and a lack of a proper tutorial. One player suggested that a more significant decrease of emissions should be added if the player was indeed walking or biking, and that there was too vague of a connection between transports chosen in the real world with consequences in-game. One player also suggested it needs more "in-your-face" pop-ups used in contemporary smartphone games.

Some players expressed a desire for more features in the game, that they wanted to play it more than the few minutes spent each day to decide their daily actions. One suggestion here included Start and Stop-buttons for walks or bike sessions (the green transports) with a selected desired outcome – a bonus of some sort. For example, player A wants to gather berries within the game. The player then activates an active foraging session within the game that verifies that the player is indeed currently walking. After walking for some prescribed time, player A stops walking, and requests a confirmation of what was obtained during the walking session. Depending on the length of the session, player A may obtain an increasing amount of food points representing the berries gathered within the game world (e.g. 1 point of food for each 5, 10 or 15 minutes of walking could be tested). One player who suggested this game mechanic and also mentioned that it would help them go for walks more often, presumably due to the immediate feedback (the game would only give results every 24 hours otherwise), and that it would help their wellbeing as well (since the green transports recognized within the game generally require exercising).

Most players felt that their choice of transport was influenced to some extent while playing the game, where half of participants tried walking more than before, and one tried to drive cars less

than before. When asked how much of their total traveling time was influenced, the answers were 0%, 5%, 10%, and 25% of total travelling time respectively between testers.

When asked why they were not influenced and what would have had an influence on their choices, one mentioned that the effects of actual transport did not really feel like it was reflected in the game. Another tester stated that while it made them more aware of their actions, other factors stood out to be more important (distance, weather, time, etc). One participant mentioned that they need a car to get anywhere due to where they live, but that if they had lived closer to a city they would have walked or tried taking busses more often. Some further details for the evaluative questionnaire can be viewed in Appendix 10, and full transcripts of all player questions and followed up conversations can be read in Appendix 11.

5.3 Transportation Mode Data Sampling

For data gathering, a total of 21'096 time window features (or samples) were gathered, corresponding to 29 hours and 18 minutes of data, divided into the transport classes depicted in Table 3. To justify the need of acceleration sample normalization, some brief data on Android device orientation gravity measurements are presented in Table 4. The columns represent different volunteers' respective devices, with standard deviations presented both on a per-

Transport class	No Samples	Corresponding Time
Idle	2600	3h 37m
Bus	3327	4h 37m
Foot	1704	2h 22m
Car	3813	5h 18m
Bike	863	1h 12m
Train	2689	3h 44m
Tram	1309	1h 49m
Subway	444	0h 37m
Boat	1274	1h 46m
Plane	3073	4h 16m
Total	21096	29h 18m

Table 3, Breakdown of collected Transport data and corresponding time.

device and per-orientation basis. Note the increased deviations for the *Face right* and *Face left* orientations, which are common for devices placed in pants' pockets while sitting.

Orientations	A	B	C	D	E	F	G	Stddev
Standing	9.867	9.945	9.935	9.844	9.808	9.755	9.817	0.063
Face-up	9.728	9.946	9.837	9.810	9.842	9.957	9.417	0.169
Face-down	9.699	9.926	9.677	9.812	9.826	10.086	9.962	0.135
Face right	8.532	9.794	10.226	9.807	9.641	9.640	9.897	0.491
Face left	10.748	10.038	8.976	9.875	9.751	10.156	9.873	0.489
Upside-down	9.684	9.964	9.361	9.818	9.787	10.028	9.319	0.255
Stddev	0.706	0.080	0.444	0.027	0.073	0.200	0.274	

Table 4, Gravity measurements for sample Android devices and 6 different orientations.

5.4 Offline Transportation Mode Detection

Initial classifier results using 10-fold cross-validation and 2-fold cross-validation using the using Random Forest, Random Tree, Bayesian Network and Naïve Bayes classifiers are presented in in the first 3 columns of Table 5. In the 4th and 5th column of Table 5 are the corresponding results for 10- and 2-fold cross-validation using the normalized accelerometer values (to ensure device and orientation ambiguity).

Classifier	10-fold	2-fold	10-fold NA	2-fold NA
RF	67%	65%	53%	51%
RT	56%	54%	43%	41%
BN	48%	48%	41%	40%
NB	29%	29%	25%	25%

Table 5, Classifier results using 10- and 2-fold cross-validation, without normalized accelerometer values, and with normalized accelerometer values (NA).

Table 6 presents the details of classification for each class when performing the 10-fold cross-validation using Random Forest (RF) as printed within the Weka explorer. See section 3.1.1

TP Rate	FP Rate	Precision	Recall	F-Measure	MCC	ROC Area	PRC Area	Class
0,686	0,024	0,799	0,686	0,738	0,707	0,944	0,827	Idle
0,650	0,085	0,590	0,650	0,618	0,544	0,899	0,688	Bus
0,759	0,023	0,745	0,759	0,752	0,730	0,967	0,837	Foot
0,681	0,082	0,647	0,681	0,664	0,587	0,916	0,761	Car
0,684	0,012	0,707	0,684	0,695	0,683	0,970	0,763	Bike
0,604	0,061	0,593	0,604	0,598	0,539	0,915	0,633	Train
0,508	0,032	0,516	0,508	0,512	0,480	0,925	0,587	Tram
0,288	0,006	0,520	0,288	0,371	0,378	0,904	0,365	Subway
0,759	0,026	0,648	0,759	0,699	0,681	0,975	0,746	Boat
0,707	0,037	0,765	0,707	0,735	0,692	0,938	0,813	Plane

Table 6, Detailed results by class.

Machine Learning Definitions for descriptions of each column if you are unfamiliar with the abbreviations.

Table 7 presents the confusion matrix as well as True-positive percentage rates (on the right-hand side) when analysed within our own test-suite (10-fold cross-validation, RF). Some differences in TP rate can be observed between the results run within the Weka Explorer software compared to our own test suite (compare Table 6 and Table 7). Most classes show near-equal results (<1% difference), with the exceptions of Bike (1.1%), Train (1%), and Plane (3%).

```
Predicted values in each column, True values in each row.
   a    b    c    d    e    f    g    h    i    j
1786  166  107  112   30   50   61   28  164   96 | a -  TP 68,7 Idle
  80 2348   67  403   38  268  151   15   76  128 | b -  TP 65,7 Bus
  75   94 1290   47   67   14   37   11   35   34 | c -  TP 75,7 Foot
  60  395   51 2593   57  342  143    9   53  110 | d -  TP 68,0 Car
  29   25  107   64  600    6   23    1    2    6 | e -  TP 69,5 Bike
  31  280   23  281    5 1651   99   32   74  213 | f -  TP 61,4 Train
  21  179   31  228   18  108  653    3   63    5 | g -  TP 49,9 Tram
  40  123   21   23    2   47   24  127   28    9 | h -  TP 28,6 Subway
  42   99   14   31    0   68   49    4  956   11 | i -  TP 75,0 Boat
  71  161   22  177   20  229   22    6   36 2082 | j -  TP 73,7 Plane
```

Table 7, Confusion matrix for the classes

Table 8 shows the results when using 10-fold cross-validation, while Table 9 shows the results using 2-fold cross-validation. Both tables present the classification results of the chosen classifiers using different sizes of the history set. Percentages displayed are the true-positive rates when using the history set size stated in the top row (0 to 50). Highlighted are those results where the classification rate reached its highest point for that classifier.

Classifier	HSS 0	HSS 10	HSS 20	HSS 30	HSS 40	HSS 50
Random Forest	67%	73%	55%	42%	35%	23%
Random Tree	56%	69%	54%	42%	31%	24%
Bayesian Network	48%	58%	48%	37%	28%	21%
Naïve Bayesian	29%	28%	24%	19%	16%	14%

Table 8, Classifier results when using 10-fold cross-validation for different history set sizes (HSS).

Classifier	HSS 0	HSS 10	HSS 20	HSS 30	HSS 40	HSS 50
Random Forest	65%	93%	95%	95%	94%	93%
Random Tree	54%	89%	91%	93%	94%	94%
Bayesian Network	48%	73%	78%	79%	79%	79%
Naïve Bayesian	29%	34%	36%	37%	38%	38%

Table 9, Classifier results when using 2-fold cross-validation for different history set sizes (HSS) with normalized accelerometer values.

Predicted values in each column, True values in each row.

a	b	c	d	e	f	g	h	i	j		
2568	6	0	0	0	18	0	8	0	0	a -	TP 98,8 Idle
0	3497	0	21	0	2	0	0	21	33	b -	TP 97,8 Bus
0	13	1673	2	0	16	0	0	0	0	c -	TP 98,2 Foot
0	12	0	3750	0	10	0	0	0	41	d -	TP 98,3 Car
0	17	5	1	822	1	0	0	0	17	e -	TP 95,2 Bike
0	5	0	31	21	2626	0	0	0	6	f -	TP 97,7 Train
0	140	28	114	0	1	1026	0	0	0	g -	TP 78,4 Tram
3	222	0	10	0	9	41	155	4	0	h -	TP 34,9 Subway
16	0	0	0	0	0	0	0	1244	14	i -	TP 97,6 Boat
18	42	15	5	8	21	0	7	26	2684	j -	TP 95,0 Plane

Table 10, Confusion matrix for the best results

As can be seen when comparing the tables, 10-fold cross-validation has an initially higher accuracy rate (+2% for RF and RT), while the 2-fold cross-validation achieves higher accuracy at larger history set sizes (HSS) since the amount of data it is tested upon is larger. This is due to the nature of how the history set works, where the bigger the test size is, the higher chances the history set will yield increases in performance.

Table 10 presents the confusion matrix for the best performing offline-results (2-fold cross-validation, HSS 20). Note that almost all classes have now reached over 95% classification TP rate, with the exception of *Subway* (which was under-sampled and is mistakenly identified as *Bus)* and Tram (which was also relatively under-sampled and being mistakenly classified as Bus or Car).

The performance of all classifiers are lower than those results presented by Bedogni et al, but the same ranking of classifiers is shown, where RF performs best, followed by RT, BN and NB (84%, 80%, 78% and 54% accordingly in their results) [32]. Some possible reasons for the lower accuracy rates are less samples for training and testing (roughly half), less total time for the corresponding samples (each sample recorded by Bedogni et al was an average of 10 seconds vs our 5 seconds), and the increased number of classes (10 instead of 7).

Using normalized accelerometer values the accuracy rates generally decrease, reaching at most 65% accuracy for HSS 10 in the 10-fold cross-validation, and 87% accuracy for HSS 30 and 40 in the 2-fold cross-validation (–8% accuracy compared to the displayed 73% and 95%). Table 11 shows the confusion matrix for the best results when using normalized acceleration values (2-fold cross-validation, RF, HSS 30). Most transports have TP rates above 90%, with

```
Predicted values in each column, True values in each row.
   a    b    c    d    e    f    g    h    i    j
2561   16    0    1    0   22    0    0    0    0  a -  TP 98,5 Idle
   0 3372    0   92    0    0    0    0   41   69  b -  TP 94,3 Bus
   0   19 1666   10    0    9    0    0    0    0  c -  TP 97,8 Foot
   0  111    0 3636    0    0    0    0    0   66  d -  TP 95,4 Car
   0   26   11    7  795    4    0    0    0   20  e -  TP 92,1 Bike
   0  406    7  443   26 1766    0    0    0   41  f -  TP 65,7 Train
   0  229   44  345    0   10  680    0    0    1  g -  TP 51,9 Tram
   0  291    0   82   20    0   23    0   28    0  h -  TP  0,0 Subway
  26    0    0    0    0    0    0    0 1218   30  i -  TP 95,6 Boat
  41   76   29    3   11   25    0    0   37 2604  j -  TP 92,1 Plane
```

Table 11, Confusion matrix for normalized acceleration values

the exceptions of *Train*, *Tram* and *Subway*, all of which are being more often mistakenly classified as *Bus* or *Car*.

Table 12 presents the training and prediction times required by the various classifiers when run on a laptop (featuring an Intel Core i7-4700MQ CPU @ 2.40 GHz) to give an idea of the requirements of each classifier. While training the classifiers on the target development Android device (a Sony Xperia Z3 Compact), the corresponding training times were multiplied by a factor of more than 5, making the Random Forest classifier eventually unsuitable for iterated testing (training the classifier would take minutes instead of seconds). The table more specifically shows the total time required to train the classifier and predict all values when performing the 10-fold cross-validation with and without using the history set (HSS 0 and 50). All time values presented are in milliseconds. As can be seen, the use of the history set adds a seemingly indistinguishable amount of extra computation time (in the order of 1-2 ms for 30k predictions at most).

	Training	Prediction				
Classifier		HSS 0	HSS 10	HSS 20	HSS 30	HSS 50
Random Forest	12053 ms	202 ms	183 ms	219 ms	201 ms	200 ms
Random Tree	188 ms	2 ms	2 ms	3 ms	3 ms	4 ms
Bayesian Network	117 ms	13 ms	13 ms	15 ms	15 ms	16 ms
Naïve Bayesian	24 ms	105 ms	105 ms	106 ms	108 ms	106 ms

Table 12, Time consumption of the tested classifiers.

5.5 Online Transportation Mode Detection

In addition to the offline analysis presented above, online tests using the Random Tree classifier was employed within the prototype game. For all tests, the history set was used (usually size 12) and sleep-settings were set to the same number as the history set. Using a setting of 12 meant that the background sensor service should have been active for 1 minute, then sleeping 1 minute, then restarting.

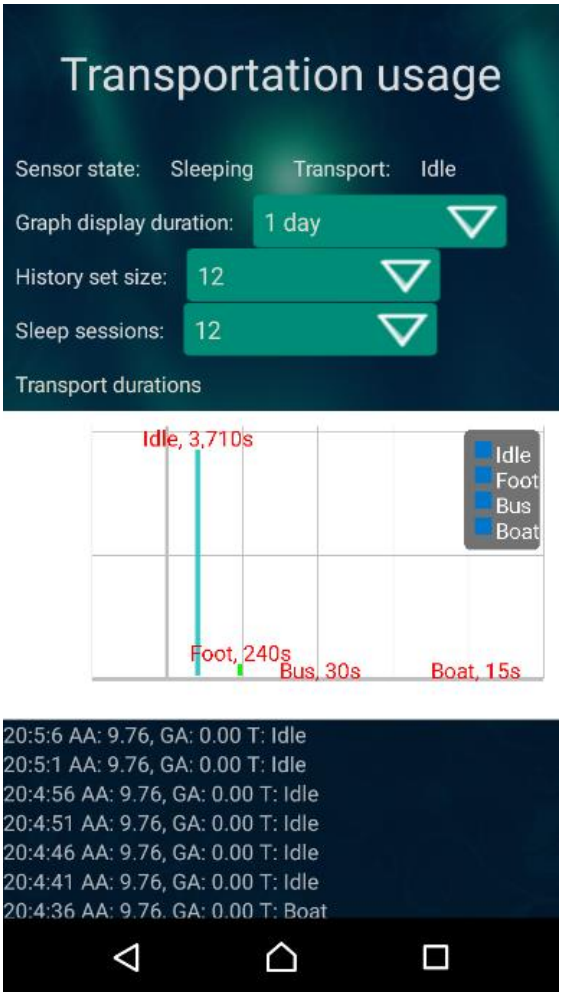

Figure 16, screenshot of the Transportation usage screen within Evergreen (1 day)

A screen within the game enabled users to view the detected transports for the past day, as well as other time-frames (minutes, hours, weeks). Figure 16 shows how the screen was designed within the app. On top the current sensor state and detected transport could be seen, below that some settings could be selected, a graph for the chosen time is presented, and in the bottom a list of the *N* last detected transports are listed. In initial versions of the app (i.e. in progress development phase), the history set size and sleep sessions were configurable for testing purposes. In all tests with the 4 test-users the values of the history set and sleep sessions was locked to 12.

Figure 16 also shows the detection results when being idle followed by a brief walk. The user did not take a bus nor boat during that day, and as such those values are false positives. Figure 17 shows the results for when a user was in a bus and got off at a bus stop to change busses. As can be seen, false positives arise again for *Train* and *Car*, as well as *Plane*. Similarly, Figure 18 shows the results of 1 hour of usage when walking, taking a bus and going by train, and the respective false positives.

For both data gathering, and evaluation, some devices had difficulties or were not able to gather Gyroscope data. For one of the test-users, his device would not let the Transport Detection background service operate normally in the background, resulting always in near-0 total seconds for the past 24 hours, as compared to thousands of seconds for other users.

Appendix 11 contains transcripts of all test-user interviews, some of which relates to the online tests of the transport detection mentioned here.

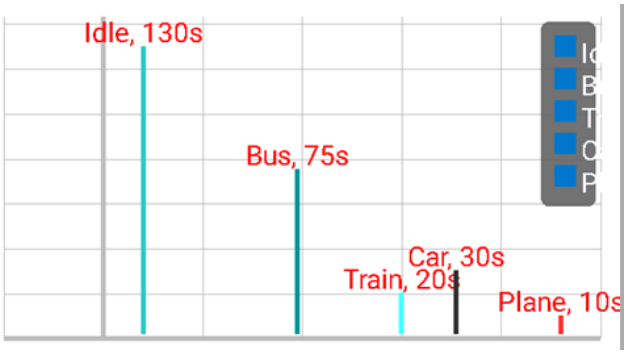

Figure 17, Transportation Detection while in a Bus and getting of at a Bus stop (10 minutes total)

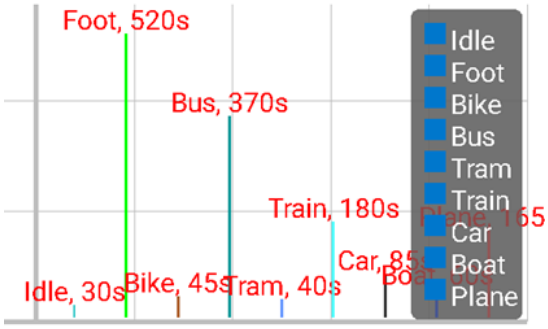

Figure 18, Transportation Detection for Walking, Bus and Train (1 hour)

6 DISCUSSION

Persuasion as a tool to change people's behaviour has already been studied by many and persuasive games as a useful tool is still being explored. One key disadvantage is that the effects are possibly only short-term. Not so many persuasive games make use or focus on multiplayer interactions, however, and by analysing the responses from our questionnaires it seems that social factors such as competition would encourage more users to be persuaded to change their lifestyles.

The testers of the game, *Assaults of the Evergreen*, were few but gave some invaluable insight into the possible effects of deploying such a game on a larger scale. Further testing of this game and similar games is suggested to verify if the potential behaviour changes would indeed come to realization or if they are merely expectations.

To revisit the initial research questions:

- **How well can we induce greener transportation choices by persuasive games?** Travel time may be reduced by between 0 and 25% for participants, depending primarily on the participant's current living situation.
- **What aspects of persuasive games are impactful on transportation choices?** Using a game design based on iterative playing, highlighting co-operative and competitive interactions, and highlighting the impact of real-life vehicle usage within the game.
- **How can one easily identify specific forms of transport (car, bus, bike, walk, train, plane) without manual input and without significantly reducing battery life?** Using Machine learning algorithms together with a history set to remove noise provide a good base for further testing. Random Forest may not be suited for games due to its relative small performance gain and drastically increased computation time compared to Random Tree, at least when a history set is used to reduce noise over time.

The transport algorithm that was presented was mostly an evolved version of one proposed by Bedogni et al [32]. The addition of the normalization of accelerometer values was not found in contemporary literature and could deserve some further analysis. User experience-based analysis may be required in order to fully make the approach device- and orientation-independent, as some orientations were prone to larger errors in gravity measurements than

others (left- and right-side), and there may be biases in the sampled data towards some orientations which may produce errors in specific use-cases.

Compared with the results of Bedogni et al [32], our results were generally inferior. This is probably in part due to the lesser quantity of sampled data. The data accumulated and generously shared with us by Bedogni et al totalled 38'061 samples, each representing 10 seconds. This represents a total figure of 105.7 hours, as compared to our total of 29.3 hours. Running the same high-performance classifiers (RF, RT) on their data (7 classes of Idle, Bus, Foot, Car, Bike, Train, Tram) produced in general better results: 87% TP rate for RF, 82% TP rate for RT (see Appendix 6 and 7 for details, compare with Appendix 4 and 5).

For some of our classes data was just insufficiently sampled. For example, Subway only has 444 samples, and since its data shares many characteristics with other transports, the TP rate is logically low. The trend of "*the more, the better*" was observed when gathering samples for all transports. Classification tests were run regularly as each batch of data was collected, and for those transports where classification was low initially accuracy improved after more samples were gathered.

Persuasion as a tool to change people's behaviour has already been noted as being a useful tool but has its disadvantages and limitations (possibly short-term effects). Not so many existing serious games have provided facilities for multiplayer interactions. However, an analysis of the responses from our questionnaires seems to reveal that social factors such as competition would encourage more users to be persuaded to change their lifestyles.

Due to the study being short-term, and few respondents played the game in multiplayer mode for the measured 10-day period, only an assumption could be made on the possible long-term effects and impacts a game such as *Evergreen* could have. Assuming *Evergreen* or a similar game gets popular and more than 5% of the Swedish population start playing it, and assuming an average behavioural change of 10% would be realized, then an estimated one hundred thousand tonnes of carbon dioxide equivalents could be saved each year. This is shown in equation 3, and is based on the Swedish transports emissions for the year of 2014, where Swedes emitted a total of 19.95 $MtCO^2$ from transportation alone [8]. Seeing as the Swedish population has begun emitting more emissions internationally, however, such a game would have to properly identify and integrate transportation by plane – which we have seen in this work might

be feasible. This figure also does not account for the increased battery usage from playing the game.

$$19.9522255\ MtCO^2\text{e}\ \times\ 0.05\ \times 0.10 = 99.7611275\ ktCO^2e \qquad (3)$$

What is worth noting is that even for those people who would not play Evergreen or a similar game for a long time, it could still have effects on the long-term.

As a final note, 2 of the 4 players were still playing the game 50 days after it was initially published. As such, the game's design may be considered a success as far as playing experience is concerned, despite all limitations and possible improvements mentioned earlier.

7 CONCLUSIONS AND FUTURE WORK

We have presented a prototype persuasive game with multiplayer interactions, called *Assaults of the Evergreen*, embedded with a transportation detection algorithm to enable a feedback from real-life actions into the game. An existing approach to transportation mode recognition based on Accelerometer and Gyroscope data was analysed and developed further to ensure that it is fully device- and orientation-independent.

Results from the transport classifier tests show that even with normalized acceleration measurements, the proposed transportation mode detection can reach a classification true-positive rate of up to 87% for 10 classes. The corresponding value for non-normalized acceleration measurements reached a classification true-positive rate of up to 95%. Quantitative and qualitative data was gathered by the help of questionnaires and interviews to measure the expectations and possible effects of deploying a persuasive game such as *Evergreen*.

Results from the game-testers show that deploying persuasive games to promote greener transportation may have some effect, but that it will vary depending on each individual's situation. Testers playing the game for at least 10 days stated that they were trying to choose greener forms of transportation between and 0 and 25% or their total travel time, and highlighted some improvements that could make a game such as Evergreen successful.

Future work could include larger test groups over longer periods of times to evaluate persuasiveness of games such as *Evergreen* and actual change, sampling more data to improve transportation classifier stability, testing the transport classifier with more users to ensure its stability (user-experience tests), and test persuasiveness with other types of behavioural changes.

Other behavioural changes to reduce our environmental footprint could also be worth investigating using persuasive games. One such example is what we choose to eat. Reports suggest that up to 10% of our total consumption footprint, or half of our footprint concerning what we eat, could be reduced by switching to a vegetarian diet [48]. However, using persuasive games with most behavioural changes requires user input for step-by-step analysis of any change, and would thus have different results and evaluation methods compared to the prototype game and behavioural change investigated in this report.

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APPENDIX 1. Evergreen - Paper prototype

Evergreen - the game

Prototype table-top RPG/Strategy rules.

A game/dungeon master (GM/DM) is recommended to control flow of the game, set up house rules and in general balance the game play. The GM/DM also resolves disputes between players where the rules are unclear. All rules are subject to change, but most of the numbers and systems have been tested to some extent.

Setup

- Any number of players.
- Play with six-sided dice (D6), pen and paper. D3 are D6 divided by 2 rounded up.
- Each player starts with
  - 10 **HP**, or Hit points, these represent your health.
  - 5 **Food**, consumed every turn. Try to keep some reserves.
  - 3 **Materials**, used for various actions.
  - 10 base **Attack** and **Defense**.
  - 1 **Shelter Defense**.
  - 0 **Emissions**, attracting the fiends of the Evergreen.
  - 20 Experience points that they may distribute freely among the available skills.
  - 1 weapon, ranged weapon, item, shelter addition or vehicle upgrade.

Playing the game

The game is played in rounds where each player has his own turn. At the start of each round, all players roll 1D6 to see what vehicle they get to use. After vehicles are decided, the players play the rest of their turn individually in clock-wise order. The player who starts plays his turn by choosing some actions to perform and resolves any events related to those actions, such as fights. Then the next player in the order plays, and it continues until all players have played their turn. If two players meet the required conditions, they may decide to play their turns together (e.g. when sharing a vehicle or going on a joint expedition).

After every player has played their individual or joint turn that round, Attack of the Evergreen may occur, as detailed later. Every player will then have to battle and beat an increasing amount of enemies. The game is designed to be harsh, and you should outlive your opposing players, or try to co-operate with them to win together.

If at any one point the Win conditions are met, the game ends. If everyone survives to turn 64, the player with the least emissions wins. If everybody dies, the last survivor wins.

Variations and house rules

Variations may be wanted for different modes of play. A few have been identified so far:

- *Hardcore*, any character that is KO'd (reaches 0 HP) dies, and its player loses the game.
- *Alliance variations*, due to the balancing difficulties of multiplayer games, it may be wise to limit some of the social interactions, or set up some premade static teams for larger games.
- *Choosing transport*, the random transport element is an interesting aspect related to the thesis work, but being able to choose transport each turn instead of rolling it randomly may be preferred.
- *Difficulties*, To make it harder or easier, simply add or remove 1 or more D3s from all encounters.

Winning

Last man standing, conquering 3 or more strongholds, or reaching Level 7 Defenses. If all players are alive and no-one reached any other goal by turn 64, the players will be scored by their amount of Emissions (the fewer being better).

An average game might last 15~50 turns, depending on which rules are used.

Each turn

Deduct 2 Food. If you cannot (already have 0), deduct 1 HP for each missing food unit. If you reach 0 HP, you are knocked out, lose 50% of your Food and Materials, and must skip your next turn. You recover up to 1 missing HP per food consumed.

Roll a D6 each turn to determine the circumstances and what transports you will choose for that turn. If a vehicle emits emissions, roll those dice now and add the value to your total Emissions.

- **1: Walking.** +2 to Picking berries. -25% encountered enemies. Emissions -2.
- **2: Biking.** +1 to Picking berries, +1 to Gather materials, Speed +1. Flee+1, Emissions -1
- **3. Bus.** -2 to Picking berries, +1 to Gather materials, +50%+2 encountered enemies. +1 Attack & Defense from social support. Speed+2. Flee +2. Emissions +2D3+1.
- **4. Train**. -3 to Picking berries, +25%+1 encountered enemies. +2 Attack & Defense from social support. Speed +2. Flee +1. Emissions +1D3.
- **5~6. Car.** +2 to Gather Materials, +50%+4 encountered enemies. +4 Speed. Flee +3. Emissions +4D3+3.

Take 2 actions per turn. For each action, roll an additional D6, where you get Good Stuff (**GS**) if you roll a 6 and Bad Stuff (**BS**) if you roll a 1. GS and BS usually affect the rolls you do or might make you encounter more enemies. All actions mentioning *"deduct"* requires those resources to be available and deducted accordingly, or the action will fail entirely.

- **Pick berries**. Gain 2D3 food, +1 for every hot-spot you've found earlier. Vehicle properties may increase or reduce this (minimum 1). **GS:** Find a berry hot-spot. **BS:** Encounter 1D6+1 Woodland monsters or 1 Troll once they are enabled (+1D3 encountered monsters/10 turns).
- **Recover**: Focus on recovery, Gain 3 HP, deduct 1 Food. **GS:** Recover 6 HP. **BS:** Recover only 1 HP (+ bonuses). HP cannot go above Max HP (default 10). Unless the Survival skill is trained.
- **Build defenses:** Roll 2D3 for building progress, deduct 2 Materials and gain 1 Emission. When reaching 10 progress, the shelter defense increases by 1 point. Successive increases require 20/30/40/50/60/70 progress points, starting at 0 each time. **GS:** Roll an additional D3. **BS:** Roll 1D3 less.
- **Augment transport**: Choose a transport. Roll 2D3 for progress and deduct 1 Material. At 5 (10, 15, 20, etc) progress points increase your vehicle defense. Vehicle bonuses are relevant in all fights outside the shelter when the given transport has been chosen at the start of the turn. **GS:** Roll an additional D3. **BS:** Roll 1 less D3.
- **Gather Materials**: Gain 2D3 materials, +1 for every depot found previously. **GS:** Find a depo. **BS:** Encounter 1D3+1 Scavenger monsters (+1D3 encountered monsters/10 turns).
- **Scout the area:** Roll 2D6. For each Speed value on the vehicle, roll another D6. **GS:** Roll another D6. **BS:** Enemy encounter 1D6 severity (amount of D3s of enemies), random type.
  For each D6, you:
  - 1, find nothing,
  - 2, find 1D3 food,
  - 3, find 1D3 materials,
  - 4, find a trader, with whom you can trade 2 food for 1 material or 2 materials for 1 food.
  - 5~6, find an Abandoned shelter, roll 1D6:
    - 1, Gain 2D3+2 food
    - 2, Gain 2D3+2 Materials,
    - 3, Gain Random weapon,
    - 4, Gain Random item,
    - 5, Find a random player shelter,
    - 6, It is an Enemy Stronghold that you now know the location of and can launch Expeditions to or Steal resources from. Gain 5 EXP.
- **Look for player**, attempts to look for a target player (Given name). On one or more 6s, you find them. Speed bonuses grant additional +1D6 for each point. **GS:** +1D6. **BS:** -1D6.
- **Expedition**, launch an expedition or continue a current one on target stronghold or base.
  - Roll 2D3 progress. At each 5th point interval, fight defenders. Strongholds have 2D6+1 defender waves, where each wave's size is **#D3+#** where **#** is the current wave number. Defeating a Stronghold grants 1D3 weapons, 1D3 items, 2D6 Food and 2D6 materials. Defeating a Stronghold also reduces wave sizes of *Assaults of the Evergreen* by 1D3 cumulatively. **GS:** You get some help. +1 to Attack and Defense at your next battle here. **BS:**
- **Invent**, Deduct 2 Materials, gain 1 Emission and choose a category or item type (a Weapon, an Item, a Shelter Upgrade). Roll 2D6. If you score 1 or more 6s you succeed in inventing. Each additional 6 after the 1st one will grant bonuses to all numbers of the newly invented invention. Dice-based bonuses here are rolled upon inventing and then static during usage in the following turns. Upon successfully inventing something, you may craft 1 copy of it by deducting 3 (Weapons), 2 (Items) or 5 (Shelter Additions) more Materials units. **GS:** Roll 1 more D6. **BS:** Roll 1 less D6. Created stats include:
  - **Weapon:** Attack + 2D3, Damage +1D3, roll 1D6 for additional effects:
    - 1, Defense +1D3,
    - 2, Attack +1D3,
    - 3, Damage +1D3,
    - 4, Parry +1,
    - 5, +1 Bonus attacks each turn at -1 to Attack and Damage.
    - 6, +2 Bonus Attacks each turn at -2 to Attack and Damage.
  - **Ranged weapon:** Attack +1D6, Damage +1D6.
    - With a ranged weapon, each combat, roll 1D3+1. You gain this many ranged attacks before the combat starts. If you are defending your shelter, gain 1D3 ranged attacks, +1 ranged attack for each level of Shelter Defense. The ranged weapon has Attack+1D6 (no bonus attacks), and +1D6 bonus damage. Damage rolls with ranged weapons are done with 2D6 instead of 1D6 (+bonus).
  - **Item:** Most items only give bonuses to 1 player, even if the base is shared. A player may also only use 1 of each item type at a time (e.g. no double body-armors or double harvesting kits). Player may however craft more copies to others, or sell the inventions themselves to other players in trade if they so wish.
    - Harvester kit, +2D3 Food per harvest (Picking berries).
    - Scavenger kit +2D3 Materials per gathering.
    - Recovery kit, +1 HP healed per turn passively (assuming there is Food), +1D3 HP healed when recovering.
    - Body armor, +1D3 Defense
    - Constructor kit, +2D3 progress when building defenses.
    - Lab kit, roll an additional D6 while inventing.

(Continues)

APPENDIX 1. (continues) Evergreen - Paper prototype

  - **Shelter additions**, As with Items, most shelter additions cannot stack their bonuses, having 1 is enough, then you may produce and sell or trade more copies of the invention, or the invention itself to other players. For shared shelters, the bonuses only apply to the first player using the addition each round of turns.
    - *Traps*, for each attacking enemy roll a D6, on 4+, deal an initial 14 Attack 2D6 damage to it. Successive upgrades/inventions increase the Attack and Damage by +1.
    - *Greenhouse*, every turn roll 1D6, on 4+, gain 1 Food. Successive upgrades allows additional dice rolls.
    - *Escape path*, allows fleeing sieges and assaults by rolling a 5+ on a D6. Escaping requires relocating to a new or other existing shelter. All upgrades and half of your resources remain in this shelter and are lost. Upgrades: +1 to the roll.
    - *Crenelation*, +1 Attack and +1 Damage to Ranged attacks. +1 Defense against enemy ranged attacks. Upgrades: +1 to all three aspects.
    - *Recycler*, each time an emission is generated from materials in this shelter, roll 1D6. On 5+, the emission is not generated. Upgrades: +1 to the dice roll.
  - **Vehicle upgrades**, upgrades are usually vehicle-specific, and must be added onto individual vehicles.
    - *Catalyst*, reduces emissions by chosen transport by 1D3. Upgrades reduce it further by 1 per upgrade level.
    - *Afterburner*, increases vehicle Flee bonus by 1 per upgrade level.
- **Craft**, depends on weapon/item/addition intended.
  - Allows manufacturing of specific weapons, items or building additions as listed above in the *Invent* section. Requires 3 materials for weapons, 2 for Items and 5 for shelter additions per turn unless noted otherwise. Roll 2D3 progress and gain 1 Emission. At 10 progress, the weapon/item/addition is completed. **GS:** +1D3 progress. **BS:** -1D3 progress.
- **Spy/Steal:** attempts to get information or resources from target enemy stronghold, NPC or player. Roll 2D6. **GS:** Roll another D6. **BS:** Roll 1 less D6.
  - 18+, steal 6D3 food, 6D3 Materials, 4 items or 2 inventions.
  - 16~17, steal 5D3 food, 5D3 Materials, 3 items or 1 invention.
  - 14~15, steal 4D3 food, 4D3 Materials or 2 items.
  - 12~13, steal 3D3 food, 3D3 Materials or 1 item.
  - 9~11, steal 2D3 Food, 2D3 Materials.
  - 7~8, failed, but not detected
  - 2~6, failed & detected, player traps may activate, player may use ranged attacks on the spy, or stronghold defenders appear (1D6 severity, random type).
- **Attack a player**, you try to ambush a player during their daily activities. To attack a player, you must first have found them during *Look for player* earlier**.** Fights last until 1 of the players is knocked out (0 HP) or runs away. Bonuses from Social Support are not applicable to the attacker of these fights, only the defender. Roll 2D6 to find them (+1D6 per Speed). On one or more 6s, you find them. **GS:** roll 1 more D6 and get +1 Attack/Defense the first round. **BS:** Roll 1 less D6 and get -1 Attack/Defense the first round.

  After having found a player, roll 2D6 to determine the initial conditions of the battle. The first D6 determines the location: 1~3: outside shelter in the vehicle, 4~6: in the safety of the shelter.
  - 5+, Preemptive strike, +1 Attack/Defense the first round,
  - 3~4, equal footing,
  - 1~2, Backlash, -1 Attack/Defense the first round.

Select skill to train/study until next change (EXP gained per turn). Once a skill fulfils the EXP required, you increase its level and gain its bonuses. EXP is reset to 0 after reaching next level. Gain 1 EXP per turn.

- **Foraging**, EXP required 5/10/15/20, foraging gives +1/2/3/4D3 Food.
- **Fleet retreat**, EXP required 5/9/13/17. Reduces Fleeing difficulty by 1/2/3/4. Gain 1/2/4/8 EXP for each successful retreat.
- **Survival**, EXP required 7/9/11/13/15, After suffering a defeat, you do not lose 1 turn, and your HP is set to 1/2/3/4/5. Increases active HP recovery (via the Recover action) by +1/2/3/4/5. Maximum HP increases by 1/3/6/10/15.
- **Architecting**, EXP required 10/20/30, Building Defenses gives +1/2/3D3 progress.
- **Material efficiency**, EXP required 5/10/20/40. For each material deducted, you may roll 1D6. On a 6/5/4/3+, the material is not spent.
- **Inventing**, EXP required 10/20/30. Roll an additional 1/2/3D6 to succeed.
- **Defensive training**, EXP required 5/10/15/20/25. Grants +1/2/3/4/5 Defense, no matter if you are home or away.
- **Unarmed combat**, EXP required 3/6/9/12/15/18. Grants +1/2/3/4/5/6 Attack/Damage, +0/0/1/1/2/2 Defense and +0/0/1/1/2/2 bonus attacks per turn when not using a weapon.
- **Weaponized combat**, EXP required 3/6/9/12/15/18. Grants +1/1/2/2/3/3 Attack and +0/1/1/2/2/3 Damage to attacks with weapons.
- **Marksmanship**, EXP required 5/10/15/20/25/30. Grants +1/2/3/4/5/6 Attack and Damage with ranged attacks. Grants +1/1/2/2/3/4 bonus ranged attacks for regular combat, and +2/2/3/4/5/6 attacks during Attacks of the Evergreen.
- **Parrying**, EXP required 2/7/12/17/22/29. Roll 2D6 every incoming attack. On a 12/11/10/9/8/7+ it is parried and nullified.
- **Thief**, EXP required 5/10/15/20/25, + 1/2/3/4/5 to Steal rolls, reducing risk and increasing profit.
- **Group Combat training**, EXP required 5/10/15/20/25, +1/1/2/2/3 to Attack rolls when fighting with an ally helping you. +1 for each additional ally. +0/0/1/1/2 Defense while fighting with allies.
- **Studious**, EXP required 10/20/30. Grants an additional +1/2/3 EXP every turn.

Take additional actions, one of each max per turn. All actions with other people require that you have met earlier.

- **Co-transport:** 2 people who get the same transport may choose to perform actions together. They gain +1 Defense for each additional participant. Emissions are split among participants.
- **Joint expedition**: you go on a joint expedition. +1 Defense for each additional participant. Combats are played together. Spoils are split.
- **Knowledge-sharing agreement**: the players will share existing and new inventions, knowledge of enemy strongholds, etc.
- **Alliance/Shared-base agreement**: the players will share base and resources together. Defense is base defense + both players individual bonuses. Ambush/attack events on the base are played simultaneously by all involved players.
  - Victory conditions are shared after joining this agreement.

After actions have been rolled, roll 2D6. At 11+, encounter 1D6 enemies of random type. Vehicles give reduce the roll required for encounters to 10+ for Train, 9+ for Bus and 8+ for Car.

Encounters & Fights

Players roll who starts. 4+ player starts. During *Assaults of the Evergreen* the players always start.

For fights, you take turns attacking. The Challenge Rating (**CR**) is your their Defense - your Attack. Based on the CR, you roll to hit the target. Over 4 you have to succeed 2 rolls for 1 attack to hit, and below -3 CR you gain bonus attacks after the first one.

Every attack deals 1D6 damage + any bonuses from equipped weapon, skills, etc. Attacks always deal at least 1 damage if they hit. If unarmed, you deal a base damage of 1D3 instead.

You may also choose to run away from fights. The Challenge Rating (CR) for fleeing is calculated as follows:

$$(Enemies - 1)/2 - Flee\ bonuses$$

CR	Dice rolls
11	11+, 11+
10	11+, 10+
9	11+, 9+
8	11+, 8+
7	11+, 7+
6	11+, 6+
5	11+, 5+
4	11+
3	10+
2	9+
1	8+
0	7+
-1	6+
-2	5+,
-3	4+
-4	4+, 11+
-5	4+, 10+
-6	4+, 9+
-7	4+, 8+
-8	4+, 7+
-9	4+, 6+
-10	4+, 5+
-11	4+, 4+

When you have the CR, you roll as usual as is instructed in the CR table on the right. If you succeed, you run away. If you fail, the enemies get 1 free round of attacks on you.

Flee rolls may be re-attempted if they previously failed. For each attempt the CR decreases by 1, but defense also decreases by 1 as you are exposing yourself to the enemies.

For example, meeting 5 enemies would normally give a difficulty of 2. Having a bike (Flee+1) would reduce it to a challenge rating of 1 (requiring an 8+ result with the 2D6). Should you fail, the 5 enemies all get to try and hit you, maybe inflicting 2~3 damage. After that, you could try to flee again at a CR of 0 (roll 7+).

The Assaults of the Evergreen

Once every now and then, the monsters inhabiting the surroundings will strike out at the players. By default this happens on preset turns. The Emissions which stack up from vehicle usage may also trigger extra or stronger assaults from the Evergreen.

For each attack, randomly choose 1 enemy type that attacks.

Turn	6	10	13	15	16	22	26	29	31	32
Size	1D3	2D3	3D3+1	3D3+3	4D3+4	1D6	1D6+3	1D6+6	2D6+8	2D6+10
Turn	38	42	45	47	48	54	58	61	63	64
Size	2D6+2	2D6+6	2D6+10	3D6+13	4D6+16	2D6+3	3D6+6	4D6+12	5D6+25	10D6+50 Or final battle

Each *Emission* value works as follows:

- Increases amount of attacking enemies during *Assaults of the Evergreen* by $Emissions/5$
- Increases amount of attacking enemies in all other battles by $Emissions/25$.
- Increases attacking enemies' Attack values by $Emissions/10$.
- Increases attacking enemies' Defense values by $Emissions/20$.
- Increases attacking enemies' Damage per attack by $Emissions/50$.

Emissions are calculated per person or per group during the action encounters, and summed up for all players in the shelter for *Assaults of the Evergreen*. The table below summarizes the effects described above, to be used for quick reference.

Emiss.	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100

(Continues)

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# AotE	+1	+2	+3	+4	+5	+6	+7	+8	+9	+10	+11	+12	+13	+14	+15	+16	+17	+18	+19	+20
# Out					+1	+1	+1	+1	+1	+2	+2	+2	+2	+2	+3	+3	+3	+3	+3	+3
+Attack		+1	+1	+2	+2	+3	+3	+4	+4	+5	+5	+6	+6	+7	+7	+8	+8	+9	+9	+10
+Defense				+1	+1	+1	+1	+2	+2	+2	+2	+3	+3	+3	+4	+4	+4	+4	+4	+5
+Damage										+1	+1	+1	+1	+1	+1	+1	+1	+1	+1	+1

Below is the list of monsters in the evergreen, first the basic ones you can meet in the beginning, and then more that are enabled later on in the game.

All enemies gain +1 to Attack, Defense and HP for each 8 turns after which they were enabled. E.g. during turns 24~29, the Woodland Monsters & Scavenger monsters get +3 to their stats, and the Rock Beasts and Swarms get +1 to their stats. Similarly, during the last turns of the game (turns 58 to 63) the initial monsters get +7 to their stats, and the other groups of monsters get +5, +3 and +1 bonuses. See the table below for quick reference.

Enemy tier	Bonus T1 to T8	Bonus T9 to T15	Bonus T16 to T23	Bonus T24 to 29	Bonus T32 to 39	Bonus T40 to 47	Bonus T48 to T55	Bonus T56 to 63
1st (initial)	0	+1	+2	+3	+4	+5	+6	+7
2nd (T16+)			0	+1	+2	+3	+4	+5
3rd (T32+)					0	+1	+2	+3
4th (T48+)							0	+1

In the enemy descriptions, if *Turn Bonus* is mentioned, this refers to the Bonus based on played turns as described above. As such, they should be replaced with the correct number while playing the encounters.

Active from the beginning, both granting 2 EXP per unit defeated:

- **Mutated Shrubs**, 6 Attack, 8 Defense, 10 HP.
  - Slow yet cunning, the shrub monsters are one of the easiest enemies to tackle in the beginning.
  - On a successful attack, roll 2D6 + Turn Bonus. On 11+ the target is partially ensnared, losing 1 Attack and Defense for 2 turns.
- **Scavenger monsters**, 7 Attack and 7 Defense, 7 HP,
  - These sly creatures hide between various debris, waiting for unsuspecting prey.
  - +1 Attack the first turn. Turn bonuses increase this.
    - E.g. during turns 24 to 29, the Scavenger monsters have 10 Attack, 10 Defense, 10 HP, and an additional +4 Attack during the first turn of combat.
  - Turn 32 and onwards:
    - Deals +1 damage the first turn.

Active after turn 16:

- **Rock monsters**, 12 Attack, 12 Defense, 5 HP,
  - These beasts have infused the crystalline structure of the mountains themselves, making them very resilient for being so small.
  - Halve incoming damage.
  - Roll 2D6 + Turn Bonus every time the beast is attacked with a melee weapon. On a 12+ the attacker takes 1 damage.
  - Grants 3 EXP.
- **Swarms**, 11 Attack, 11 Defense, 2 HP
  - Swarms of mutated insects that may easily trample you if left to grow.
  - +50% encounter amount (rounded down).
  - Each turn, roll 2D6 for every swarm to see if they multiply. On a 10+, a new Swarm is created.
    - Each swarm may only multiply once, and the newly created Swarm may not multiply itself. This means that should you encounter 8 Swarms, you will at most have to fight 16 Swarms during that encounter.
  - Grants 3 EXP.

Active after turn 32:

- **Trolls**, 17 Attack, 15 Defense, 23 HP,
  - May pay the toll (2 Materials per troll) to soothe them and avoid combat.
  - +1 attack if inside any vehicle except a bike or walking.
  - -1 to Flee rolls against them.
  - 50% of encounter amount (rounded down, minimum 1).
  - Troll subtypes, roll 1D3 to select.
    - Bridge trolls: 30 HP.
    - Rock trolls: +1 Defense.
    - Moss trolls: +1 Attack.
  - Grants 9 EXP
- **Raptor**, 16 Attack, 11 Defense, 12 HP,
  - 2 attacks per turn.
  - 50% of encounter amount (rounded down, minimum 1)
  - Grants 7 EXP.

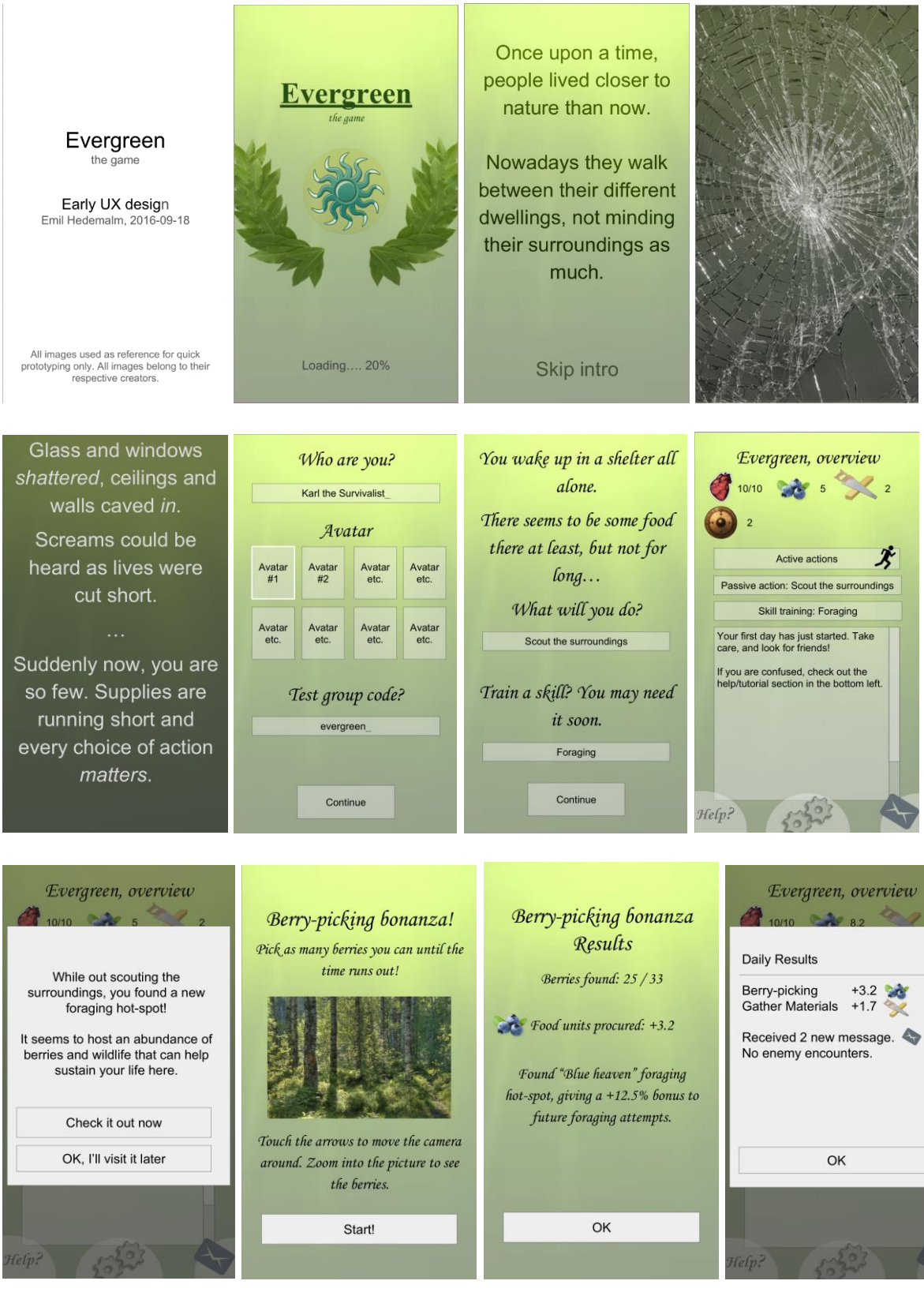
Active after turn 48:

- **Dragon**, 20 Attack, 14 Defense, 25 HP,
  - For each dragon, you may offer 3 items or weapons to sooth it and avoid fighting it.
  - 25% of encounter amount (rounded down, minimum 1).
  - Roll 1D3 every turn. On
    - 1, Attack normally. Deals 1D3 damage.
    - 2, Tail whip, +3 Attack. Deals 2D3 damage.
    - 3, Breath attack, +5 Attack, Deals 3D3 damage.
  - Grants 20 EXP.
- **Ent**, 17 Attack, 20 Defense, 40 HP,
  - An element of nature itself, manifested as a walking mutation of trees.
  - 25% of encounter amount (rounded down, minimum 1).
  - For each Ent previously defeated this fight, the Ent gains +1 Attack.
  - For each 3 Ents previously defeated this game, the Ent gains +1 Attack.
  - Deals 2D3 damage on successful attacks.
  - Grants 25 EXP.

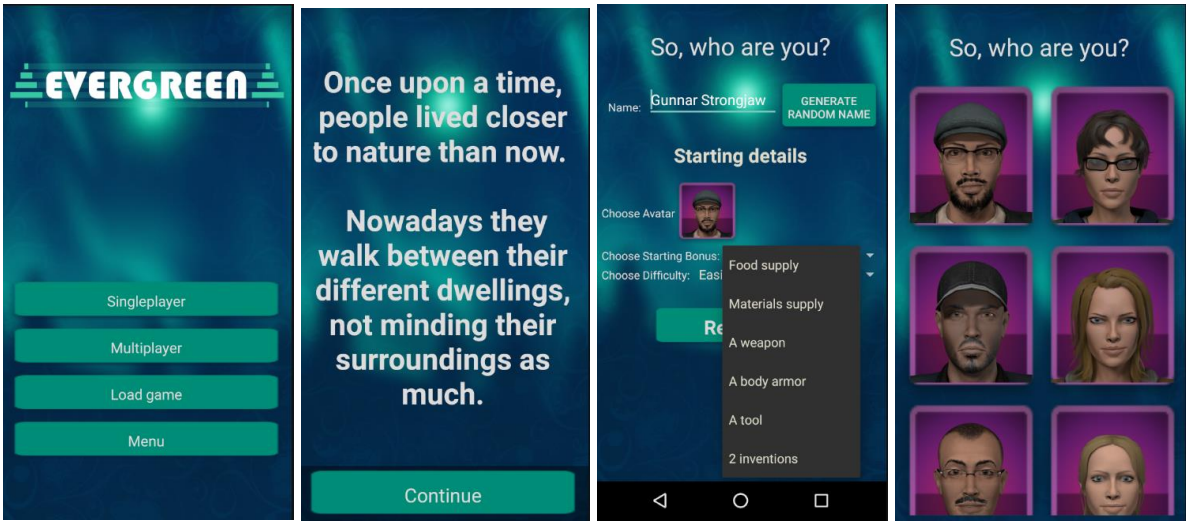
Turn 64, Final battle version:

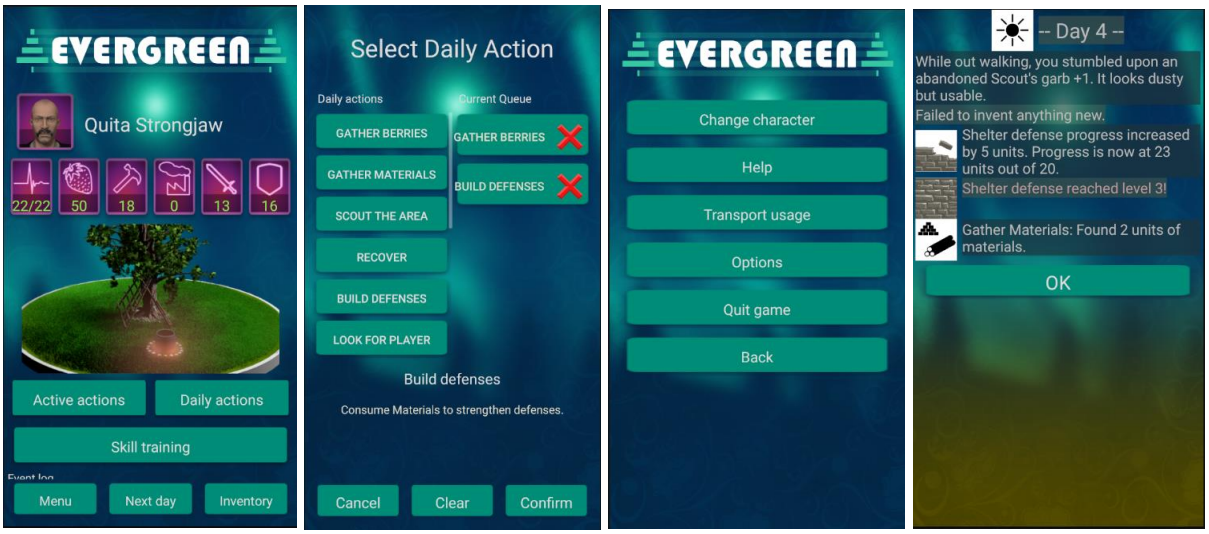
- **Gaia protector**, 30 Attack, 30 Defense, 150 HP
  - Each turn, roll 1D6.
    - 1~4, Attacks, Dealing 2D6+5 damage per attack.
    - 5, Heals self for 3D3 HP.
    - 6, Casts a spell "*Wind of the heavens*", removing 1 item or weapon per opposing character and dealing 1D6 damage.
  - Below 75 HP, Roll a second 1D6.
  - Below 25 HP, Roll a third 1D6.
  - Regenerates 1 HP every turn.

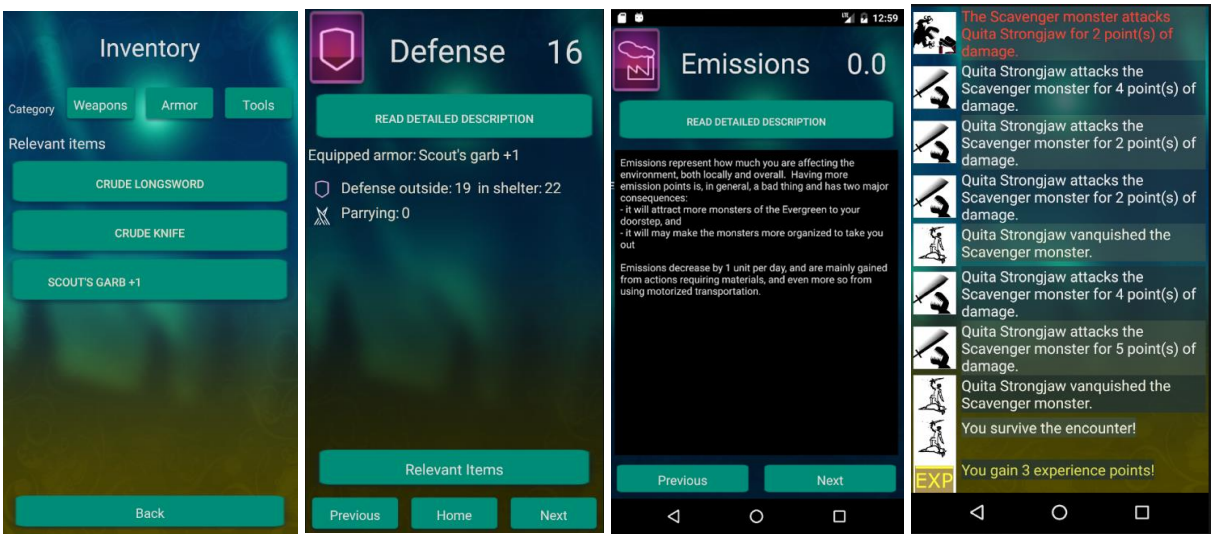
APPENDIX 2. Evergreen – Visual mockup



APPENDIX 3. Evergreen – Android prototype screenshots







APPENDIX 4. Classification results on sampled data – RF

```
=== Run information ===

Scheme:       weka.classifiers.trees.RandomForest -P 100 -I 100 -num-slots 1 -K 0 -M 1.0 -V 0.001 -S 1
Relation:     sensor-weka.filters.unsupervised.attribute.Remove-R1
Instances:    21096
Attributes:   9
              accMin
              accMax
              accAvg
              accStdev
              gyroMin
              gyroMax
              gyroAvg
              gyroStdev
              transport
Test mode:    10-fold cross-validation

=== Classifier model (full training set) ===

RandomForest

Bagging with 100 iterations and base learner

weka.classifiers.trees.RandomTree -K 0 -M 1.0 -V 0.001 -S 1 -do-not-check-capabilities

Time taken to build model: 11.95 seconds

=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances       13985               66.2922 %
Incorrectly Classified Instances      7111               33.7078 %
Kappa statistic                          0.6136
Mean absolute error                      0.0918
Root mean squared error                  0.2122
Relative absolute error                 52.547  %
Root relative squared error             71.7917 %
Total Number of Instances            21096

=== Detailed Accuracy By Class ===

                 TP Rate  FP Rate  Precision  Recall   F-Measure  MCC      ROC Area  PRC Area  Class
                 0,686    0,024    0,799      0,686    0,738      0,707    0,944     0,827     Idle
                 0,650    0,085    0,590      0,650    0,618      0,544    0,899     0,688     Bus
                 0,759    0,023    0,745      0,759    0,752      0,730    0,967     0,837     Foot
                 0,681    0,082    0,647      0,681    0,664      0,587    0,916     0,761     Car
                 0,684    0,012    0,707      0,684    0,695      0,683    0,970     0,763     Bike
                 0,604    0,061    0,593      0,604    0,598      0,539    0,915     0,633     Train
                 0,508    0,032    0,516      0,508    0,512      0,480    0,925     0,587     Tram
                 0,288    0,006    0,520      0,288    0,371      0,378    0,904     0,365     Subway
                 0,759    0,026    0,648      0,759    0,699      0,681    0,975     0,746     Boat
                 0,707    0,037    0,765      0,707    0,735      0,692    0,938     0,813     Plane
Weighted Avg.    0,663    0,050    0,667      0,663    0,663      0,614    0,930     0,735


=== Confusion Matrix ===

    a    b    c    d    e    f    g    h    i    j   <-- classified as
 1783  150  103  125   33   52   69   31  158   96 |    a = Idle
   78 2163   64  374   38  251  139   19   67  134 |    b = Bus
   61   89 1294   56   64   19   42    8   37   34 |    c = Foot
   67  370   53 2598   66  330  137    9   51  132 |    d = Car
   23   28  108   66  590    6   31    0    2    9 |    e = Bike
   23  293   26  287    4 1624   94   36   82  220 |    f = Train
   27  161   30  235   15  107  665    1   56   12 |    g = Tram
   36  117   16   36    3   43   25  128   26   14 |    h = Subway
   55   74   14   36    1   54   52    4  967   17 |    i = Boat
   79  224   30  204   20  252   35   10   46 2173 |    j = Plane
```

APPENDIX 5. Classification results on sampled data – RT

```
=== Run information ===

Scheme:       weka.classifiers.trees.RandomTree -K 0 -M 1.0 -V 0.001 -S 1
Relation:     sensor-weka.filters.unsupervised.attribute.Remove-R1
Instances:    21096
Attributes:   9
              accMin
              accMax
              accAvg
              accStdev
              gyroMin
              gyroMax
              gyroAvg
              gyroStdev
              transport
Test mode:    10-fold cross-validation

=== Classifier model (full training set) ===


RandomTree
==========

<Tree details omitted to conserve space>

Size of the tree : 13141

Time taken to build model: 0.22 seconds

=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances       11683               55.3802 %
Incorrectly Classified Instances      9413               44.6198 %
Kappa statistic                          0.4896
Mean absolute error                      0.0893
Root mean squared error                  0.2986
Relative absolute error                 51.1167 %
Root relative squared error            101.0269 %
Total Number of Instances            21096

=== Detailed Accuracy By Class ===

                 TP Rate  FP Rate  Precision  Recall   F-Measure  MCC      ROC Area  PRC Area  Class
                 0,658    0,048    0,656      0,658    0,657      0,609    0,805     0,474     Idle
                 0,494    0,093    0,499      0,494    0,496      0,402    0,700     0,326     Bus
                 0,655    0,030    0,658      0,655    0,656      0,626    0,814     0,461     Foot
                 0,564    0,098    0,560      0,564    0,562      0,465    0,734     0,396     Car
                 0,565    0,018    0,569      0,565    0,567      0,549    0,774     0,341     Bike
                 0,459    0,074    0,477      0,459    0,468      0,392    0,693     0,288     Train
                 0,439    0,046    0,389      0,439    0,413      0,372    0,697     0,206     Tram
                 0,255    0,018    0,238      0,255    0,246      0,229    0,618     0,076     Subway
                 0,560    0,026    0,580      0,560    0,570      0,543    0,767     0,352     Boat
                 0,631    0,061    0,640      0,631    0,635      0,574    0,785     0,457     Plane
Weighted Avg.    0,554    0,064    0,555      0,554    0,554      0,490    0,745     0,372

=== Confusion Matrix ===

    a    b    c    d    e    f    g    h    i    j   <-- classified as
 1711  140  110  123   46   81   69   56  133  131 |    a = Idle
  146 1643  106  456   46  340  195   86   84  225 |    b = Bus
  122   92 1116   69  116   27   39   41   29   53 |    c = Foot
  140  415   73 2150   97  346  268   38   61  225 |    d = Car
   38   57  119   86  488   16   35    7    1   16 |    e = Bike
   76  345   32  402    9 1234  148   57   79  307 |    f = Train
   45  143   46  235   17  111  575   25   58   54 |    g = Tram
   54   83   25   32    8   54   23  113   24   28 |    h = Subway
  132   99   30   62    7   74   73   30  714   53 |    i = Boat
  143  278   39  223   23  306   52   22   48 1939 |    j = Plane
```

APPENDIX 6. Classification results on data provided by L. Bedogni – RF

```
=== Run information ===

Scheme:       weka.classifiers.trees.RandomForest -P 100 -I 100 -num-slots 1 -K 0 -M 1.0 -V 0.001 -S 1
Relation:     sensorBedogni-weka.filters.unsupervised.attribute.Remove-R1
Instances:    38061
Attributes:   8
              accMax
              accAvg
              accStdev
              gyroMin
              gyroMax
              gyroAvg
              gyroStdev
              transport
Test mode:    10-fold cross-validation

=== Classifier model (full training set) ===

RandomForest

Bagging with 100 iterations and base learner

weka.classifiers.trees.RandomTree -K 0 -M 1.0 -V 0.001 -S 1 -do-not-check-capabilities

Time taken to build model: 15.07 seconds

=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances       33135               87.0576 %
Incorrectly Classified Instances      4926               12.9424 %
Kappa statistic                          0.8188
Mean absolute error                      0.0542
Root mean squared error                  0.1643
Relative absolute error                 26.3967 %
Root relative squared error             51.2826 %
Total Number of Instances            38061

=== Detailed Accuracy By Class ===

                 TP Rate  FP Rate  Precision  Recall   F-Measure  MCC      ROC Area  PRC Area  Class
                 0,878    0,003    0,913      0,878    0,895      0,891    0,993     0,954     Idle
                 0,689    0,007    0,782      0,689    0,733      0,726    0,977     0,809     Bus
                 0,566    0,008    0,747      0,566    0,644      0,638    0,972     0,721     Foot
                 0,910    0,049    0,859      0,910    0,884      0,845    0,981     0,937     Car
                 0,704    0,014    0,731      0,704    0,718      0,703    0,976     0,768     Bike
                 0,898    0,087    0,888      0,898    0,893      0,811    0,971     0,963     Train
                 0,903    0,016    0,916      0,903    0,910      0,893    0,993     0,972     Tram
Weighted Avg.    0,871    0,054    0,869      0,871    0,869      0,819    0,978     0,933

=== Confusion Matrix ===

     a     b     c     d     e     f     g   <-- classified as
  1127     0     0   107     0    49     1 |     a = Idle
     0   899     2    26    89   151   137 |     b = Bus
     0     2   893    16    27   623    16 |     c = Foot
    62    15     5  8546    25   727    16 |     d = Car
     1    84    38    21  1349   176   246 |     e = Bike
    45    37   250  1209    51 14834    85 |     f = Train
     0   112     7    24   304   140  5487 |     g = Tram
```

APPENDIX 7. Classification results on data provided by L. Bedogni – RT

```
=== Run information ===

Scheme:       weka.classifiers.trees.RandomTree -K 0 -M 1.0 -V 0.001 -S 1
Relation:     sensorBedogni-weka.filters.unsupervised.attribute.Remove-R1
Instances:    38061
Attributes:   8
              accMax
              accAvg
              accStdev
              gyroMin
              gyroMax
              gyroAvg
              gyroStdev
              transport
Test mode:    10-fold cross-validation

=== Classifier model (full training set) ===


RandomTree
==========

<Tree details omitted to conserve space>

Size of the tree : 10117

Time taken to build model: 0.28 seconds

=== Stratified cross-validation ===
=== Summary ===

Correctly Classified Instances       31042               81.5586 %
Incorrectly Classified Instances      7019               18.4414 %
Kappa statistic                          0.7436
Mean absolute error                      0.0527
Root mean squared error                  0.2295
Relative absolute error                 25.6533 %
Root relative squared error             71.6301 %
Total Number of Instances            38061

=== Detailed Accuracy By Class ===

                 TP Rate  FP Rate  Precision  Recall   F-Measure  MCC      ROC Area  PRC Area  Class
                 0,867    0,005    0,848      0,867    0,857      0,852    0,931     0,739     Idle
                 0,639    0,013    0,632      0,639    0,636      0,623    0,813     0,416     Bus
                 0,537    0,021    0,526      0,537    0,532      0,511    0,758     0,302     Foot
                 0,830    0,056    0,830      0,830    0,830      0,774    0,887     0,731     Car
                 0,608    0,022    0,598      0,608    0,603      0,582    0,793     0,383     Bike
                 0,849    0,115    0,850      0,849    0,849      0,734    0,867     0,787     Train
                 0,868    0,023    0,880      0,868    0,874      0,850    0,923     0,785     Tram
Weighted Avg.    0,816    0,070    0,816      0,816    0,816      0,746    0,873     0,718

=== Confusion Matrix ===

     a     b     c     d     e     f     g   <-- classified as
  1113     1     1    97     1    68     3 |     a = Idle
     1   833     9    42   128   126   165 |     b = Bus
     2     7   847    26    62   605    28 |     c = Foot
   126    40    27  7796    33  1345    29 |     d = Car
     2   122    57    37  1164   169   364 |     e = Bike
    68   125   647  1361   165 14014   131 |     f = Train
     1   189    21    34   393   161  5275 |     g = Tram
```

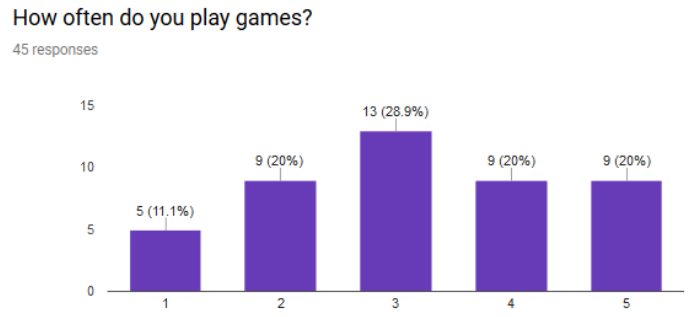
APPENDIX 8. Expectations Questionnaire

Persuasive games & Transportation: Expectations

An initial analysis of perceptions around games, persuasive/serious games in general and their relation to choice of transportation. The survey is anonymous and serves as a basis for a Master thesis work in Pervasive computing and communications for Sustainable Development.

Q1. How often do you play games?

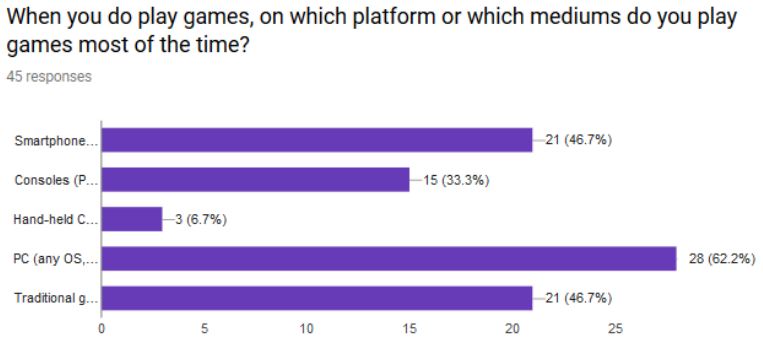
Answers between 1 and 5. 1 labelled “Rarely if ever”, 5 labelled “Several hours a day”



Q2. When you do play games, on which platform or which mediums do you play games most of the time?

Check all checkboxes that apply.

- Smartphones (iOS, Android, Blackberry, Windows phone, etc.)
- Consoles (PlayStation 3/4, XBox 360/One, Wii U, etc.)
- Hand-held Consoles (PlayStation Portable/Vita, Nintendo 3DS, etc.)
- PC (any OS, any distribution form: Steam, Origin, digital download, bought discs etc.)
- Traditional games (board-games, pen & paper RPGs, card-games, etc.)

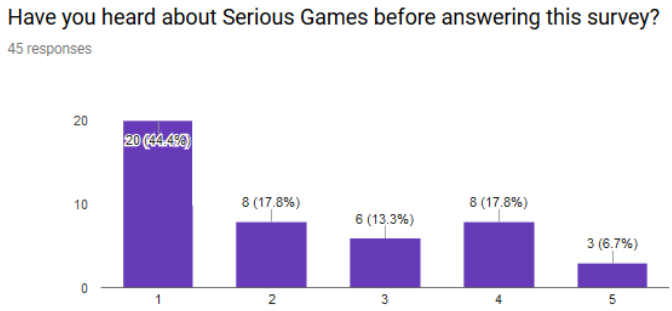


(Continues)

APPENDIX 8. (Continues) Expectations Questionnaire

Q3. Have you heard about Serious Games before answering this survey? *

Answers between 1 and 5. 1 labelled ”Never heard of it!”, 5 labelled ”I’m an expert!”

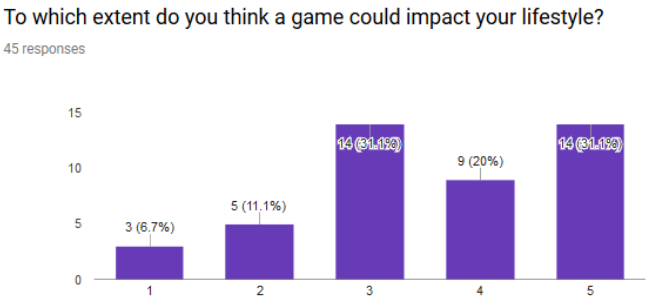


Serious Games

Serious games are games designed for another purpose than pure entertainment. They can made from an educational, promotional or other kind of viewpoint. Examples include Edutainment games supposed to educate you in a fun way, and Exergames which promote physical fitness. Simulators are also related as they are usually used for purely educational purposes, often lacking the "fun" present in other games.

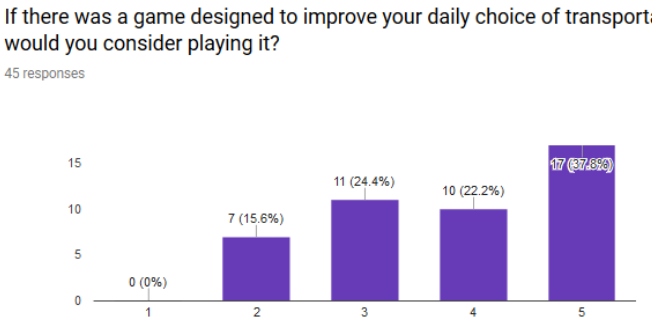
Q4. To which extent do you think a game could impact your lifestyle?

Answers between 1 and 5. 1 labelled ”Not at all”, 5 labelled ”A lot”



Q5. If there was a game designed to improve your daily choice of transportation, would you consider playing it?

Answers between 1 and 5. 1 labelled ”No, never!”, 5 labelled ”Sure, why not”



APPENDIX 8. (Continues) Expectations Questionnaire

Q6. Depending on your answer to the previous question: If you would consider playing it, how do you image the game could look like? How would it work? How would you design it? If you would rather abstain, how come?
Long text answer.
Answers listed below. Irrelevant or too short ones omitted. 4 answers were omitted as basically saying ”Don’t know”

- I love puzzles, so, I would enjoy picking up the best suitable choice of transportation for a certain destination, having in mind the importance of time, distance, number of passengers...
- I think the game would endeavor to convince me that my current choice of transportation is bad through the presentation of real-life data and statistics.
- The game would have to be natural and adjust to my schedules. I imagine a game that helps me wake up and finding the best route somewhere
- Entertaining, informative and thought provoking.
- No idea, I would just play any game if it was fun
- Depends how it's linked to my other apps. People have too many apps anyway so having one more is out of the question. Maybe working like health monitors that could gather your transportation choices and show weekly/monthly summary.
- A lot of "how " questions :P
- Maybe a mobile app with leaderboards, competitions, rewards, etc (/re gamification)
- I don't like games much so I've no idea about this.
- Maps showing paths and images of transport to use, with some exciting challenges.
- I imagine it could enlighten the impact of our transport, on the global warming and our daily lives (pollution etc). Show us that a difference actually can be made as an individual, without any extreme efforts. The game would need to be stimulating and giving feedback, in order for people to continue and progress. Spontaneous thought, a city-building game such as SimCity, with parameters included such as CO2 emissions that is calculated and presented, depending on what choices the player has made regarding buildings, public transport etc. The city could thereafter maybe be "scored" on a scoreboard where it is compared to other theoretical/online-players cities, so there's a factor of competition in it (fun & motivating?).
- I would probably have to design it very well, it would be very hard to incentivize or influence people into changing mode of transportation with a game.
- Some sort of simulation or more of a puzzel type of game. Where you need to get and remember important parts.
- Maybe resource management, try and design so the player realizes the advantages of other transportation. Would be hard though needs to be on a global scale to show the seriousness but still local enough to make the player feel like he/she can make a difference.
- I use my bike to go everywhere. So I don't k how to improve my means of transportation without paying for the bus or get a car.
- A game that involves physical activity
- Some kind of assignments and getting rewards in forms of superpowers or recognition.
- Android game
- the subject doesn't seem interesting
- I'm always using the same transportation, so I wouldn't play it to improve the daily choice.
- Like a city builder maybe
- Har ingen aning hur det skulle funka!
- Maybe it should ask me a daily question about where i am going, and how i intend to get there. Maybe causing a subconscious feeling of guilt or something to get your into the mode of "not being a slacker".
- Pokemon go is on a good start here. But developing that further and involving peoples life choices and sharing it with others is a short term solution. In the long run you not only have to reward good choices but also punish bad once.
- Like every other WWII-game! Drive a tank and BOOOOOM!
- Probably a game where u get to create your green vehicle. IDK..that is a very shallow idea i have
- Your game idea is pretty interesting. I guess just try to simplify it more for first deployment and you can develop more if it is a success.
- I am not so influenced by games. But if I were to be influenced, I would want some kind of reinforcement, or in other words the game should some how strongly show me that I am benifitting / benifitted in some way by making this choice.
- Work in the background, and sends me notification of achievement or possible future achievements if certain things are done .
- reward rather than punish user for its actions, not time consuming, need to still be interesting even after few days/weeks, social aspect?
- I would say on smartphone but it has to have low battery consumption. It would be using my location and not send it to a third party

(Continues)

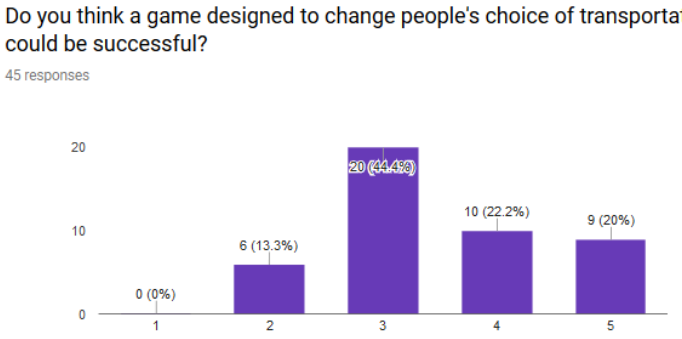
APPENDIX 8. (Continues) Expectations Questionnaire

(Answers to Q6 continued)

- A neat game for your smartphone devices not necessarily demanding much performance, it should have a summarisation of your emissions where you can easily track them.
- I could play if it doesn't take much time
- Maybee if the game contains sportcars
- It feels that it would be limited if you have to incorporate educational elements.
- I'm not very interested in playing to learn about my daily transportation. BUT, If I would try, though, maybe it would make me choose between local bus, car or bike, to arrive to a location. Depending of which type transportation you choose, the game will show various other alternatives to reach the location in ,an enviromentally, or just in a more efficient way. Also, it could show pros and cons with every altrernative.

Q7. Do you think a game designed to change people's choice of transportation could be successful?

Answers between 1 and 5. 1 labelled ”No”, 5 labelled ”Sure”



Q8. Depending on your previous answer: Why? Why not?

Long text answer.

Answers listed below. Irrelevant or too short ones omitted. Some answers translated from Swedish.

- Yes, provided that the game is still pretty close to reality and as mentioned, enlightens how the player could make a difference, and also what actions has been performed in-game that had positive effects on the virtual-environment.
- Because any game can be successful, if well designed and well-advertised enough.
- Maby for the newer generation, but not the older.
- Hard to change a persons routines, not impossible but very hard.
- People tend to be good at finding their optimal transportation routines.
- Because people are nowadays open minded and welcome new ideas
- It could influence people to make more "greener" choices etc. It's also a conversation starter for both social and environmental diskussions.
- It depends in the person paying the game and how they affected by it
- If it is well promoted
- Depends on the medium, on the graphics and, most of all, on the advertising. Could be that everyone likes it, but it's possible that no one would play it at all.
- If enough people play it and discuss their experiences with it.
- Might be
- Would probably depend on how satisfied they are with the current situation.
- Because we are a lazy breed and we are good at making excuses for choosing the more comfortable way of transportation. But we are at the same time the opposite.
- Depends on where the person lives
- Its right in time at the moment
- Can be fun

(Continues)

APPENDIX 8. (Continues) Expectations Questionnaire

(Answers to Q8 continued)

- If the game have really good game design and elements, why not?
- It may be used as awareness to shared transport like I appreciate the idea of blabla car.
- A person need to really want to change his habit
- People need more incentives than a game can provide
- People are usually set in their way, it takes quite a lot to change habits
- It's a way of introduction and also to give a wider way of options for improving a system.
- I think the underlying choice of transportation is separate from games. A game might be the final drop that make some people ride a bike instead of driving a car, but there'll be just as many people who just won't play, if not more.
- On spring I launched an experiment among my workers. Just invited them to bike to work certain Friday. Many people did it, because they felt it as a challenge. Then I find out at our university every department has a team of people biking and collecting kms, there is a leader board of which department has biked the most kms In a week/month/year. Funny thing, they do it because they like the competition although the website of leaderboard is bad. Moreover the people doing it usually lives far or takes extra long routes home to collect more kms. Many people do it and there are always more. I guess this are gamified activities that changed their lives.
- For some it could just be a form of entertainment but for others it may encourage them to actually think about changing their lifestyle choice.
- Maby for a short while, but people would go back to thier ways.
- Depends how it's linked with the other apps the user is used. If well then possibly yes.
- It could be successful to some extent.
- it depends on how much people really understand the ultimate purpose of game instead of playing just for the sake of entertainment
- I am not really sure about it. If you tell people you want them to play a serious game that will change their choice of transportation, you might be able to convince a specific group of people who are motivated to do so, but I am not so sure about the gen. Pop . Update: you should write the thesis content thing on top. So thst people will understand what are you tryin to do. Multiplayer, focus on social interaction can totally skew this survey in positive side if people read it before/ on the very top.
- Because Pokemon go made everyone walk everywhere that's why
- there is a frontier between game and reality, the action taken in games are not always the same that the ones taken in real life (generally speaking, not serious game wise). translating some morale/ways of doing from the virtual world to the real one might be a challenging task. Does using augmented reality lower the difficulty to cross virtual->real world for morale?
- It would be awesome! I think the game would open people's minds on they're choice of transportation. The game would give the people they're own way to go and follow in the most desirable fashion.
- depends on the art and the mechanics. how a game pierces a persons mind
- It is hard to convince people to change their way of living
- Again hard to say
- It would get some mileage from being a "better option"-game but contentwise I think it would fall short.
- It would be great to present it to students who are about to take their drivers license. Everyone could have use of that kind of information, really.
- I guess people would be more influenced if they were more aware of how their emission costs looked like.
- I guess to younger people with more free time it could. I would target schools for distribution

(Continues)

APPENDIX 8. (Continues) Expectations Questionnaire

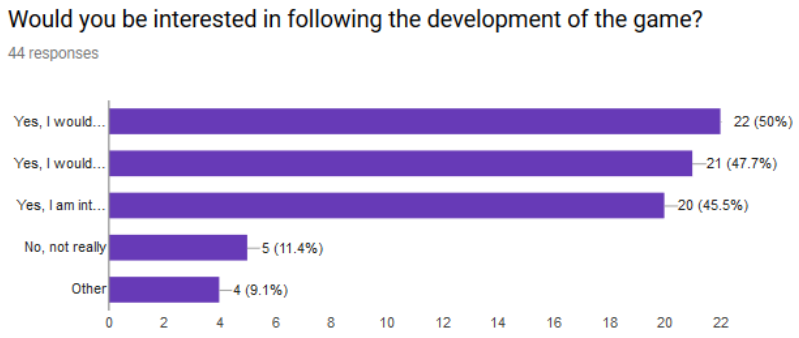
Thesis content: Multiplayer Strategy/RPG game

I will be working with developing a Smartphone-based Multiplayer Strategy/Role-playing game to try and promote greener modes of transportation. The game will have a heavy focus on regular gameplay and social interactions, but will also have elements of gameplay that are directly related to real-life actions. Development has already begun on an Android prototype.

Q9. Would you be interested in following the development of the game?

Check all checkboxes that apply.

- Yes, I would like to test the final game (March/April)
- Yes, I would like to be a beta-tester (starting December/January)
- Yes, I am interested in the design of the game. Do you have a blog?
- No, not really
- Other:



APPENDIX 9. Pre-testing Questionnaire

Evergreen testers: Background & Expectations
Please enter information so that a comparison can be conducted at the end of the study. The play-testing trials are set to be a duration between a few days up to a couple of weeks or longer. Playtesting in conjunction to this Master thesis research may end at any point in time, but may also continue for a longer period of time if there is interest from players.

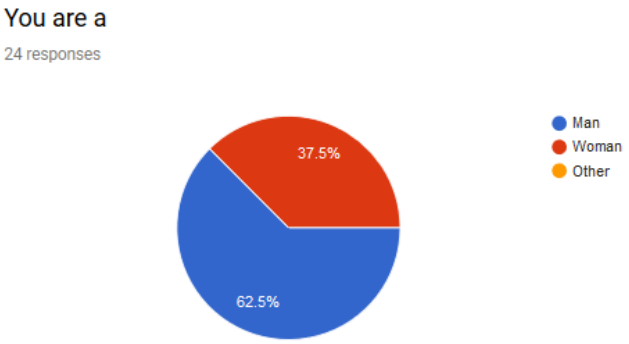
Testers are free to leave the study at any point in time, but are encouraged to fill out the evaluation form whenever they intend to cancel their playtesting. Testers are also encouraged to invite other testers, since the game is multiplayer in nature.

The game has been developed during a limited period of time, so bear that in mind!

The e-mail addresses are collected for statistical correlation purposes, and will be used to correlate your answers now with answers provided in the evaluation questionnaire. All data will be anonymized before presentation.

Q1. Email address *

Text answer. 24 unique respondents.



Q2. You are a *

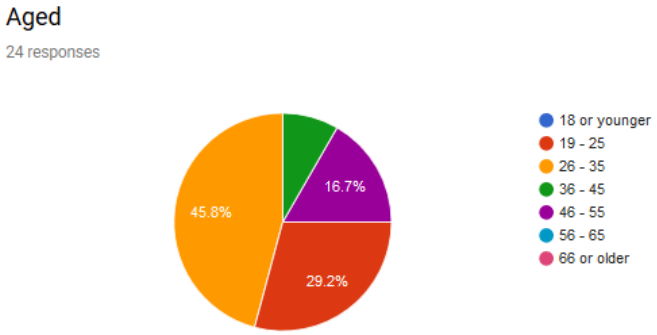
Mark only one.

- Man
- Woman
- Other

Q3. Aged *

Mark only one.

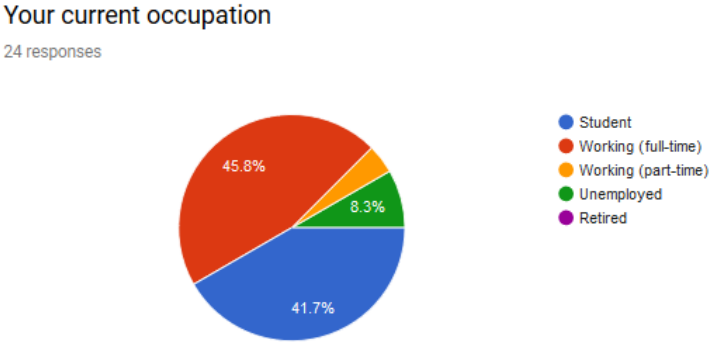
- 18 or younger
- 19 - 25
- 26 - 35
- 36 - 45
- 46 - 55
- 56 - 65
- 66 or older



Q4. Your current occupation *

Mark only one.

- Student
- Working (full-time)
- Working (part-time)
- Unemployed
- Retired



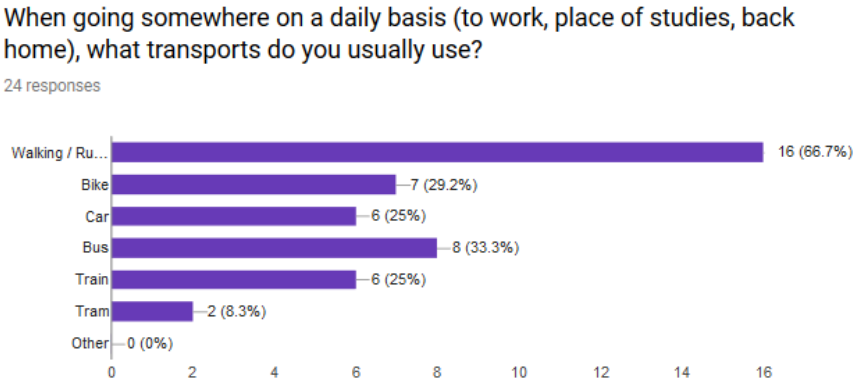
(Continues)

APPENDIX 9. (Continues) Pre-testing Questionnaire

Q5. When going somewhere on a daily basis (to work, place of studies, back home), what transports do you usually use? *

Check all checkboxes that apply.

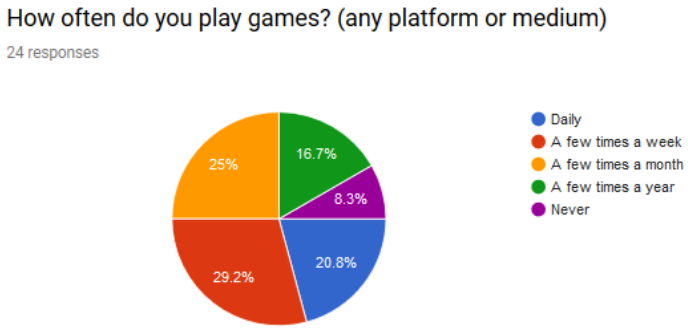
- Walking / Running
- Bike
- Car
- Bus
- Train
- Tram
- Other:



Q6. How often do you play games? (any platform or medium) *

Mark only one.

- Daily
- A few times a week
- A few times a month
- A few times a year
- Never



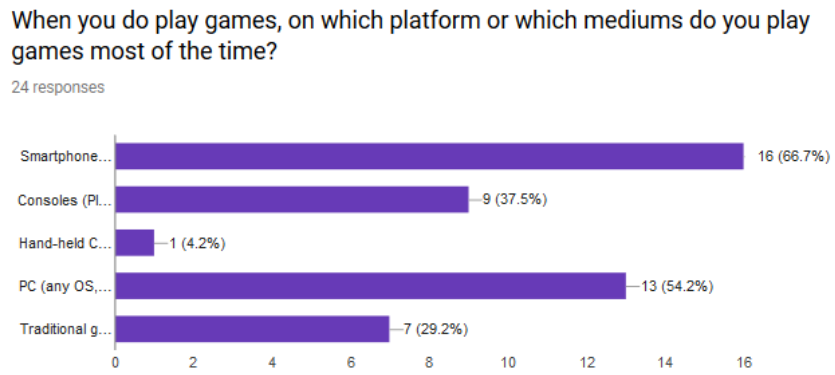
(Continues)

APPENDIX 9. (Continues) Pre-testing Questionnaire

Q7. When you do play games, on which platform or which mediums do you play games most of the time? *

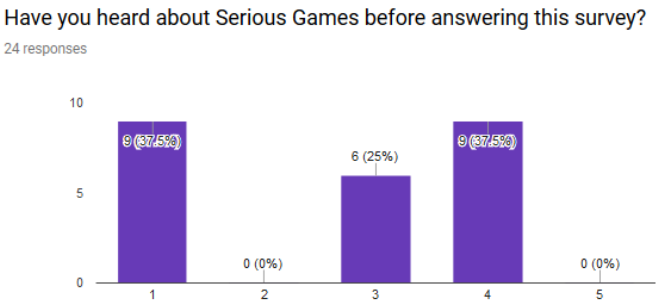
Check all checkboxes that apply.

- Smartphones (iOS, Android, Blackberry, Windows phone, etc.)
- Consoles (PlayStation 3/4, XBox 360/One, Wii U, etc.)
- Hand-held Consoles (PlayStation Portable/Vita, Nintendo 3DS, etc.)
- PC (any OS, any distribution form: Steam, Origin, digital download, bought discs etc.)
- Traditional games (board-games, pen & paper RPGs, card-games, etc.)



Q8. Have you heard about Serious Games before answering this survey? *

Answers between 1 and 5. 1 labelled ”Never heard of it”, 5 labelled ”I’m an expert!”



Serious Games

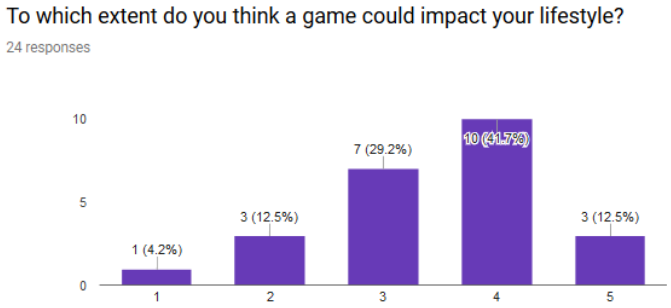
Serious games are games designed for another purpose than pure entertainment. They can made from an educational, promotional or other kind of viewpoint. Examples include Edutainment games supposed to educate you in a fun way, and Exergames which promote physical fitness. Simulators are also related as they are usually used for purely educational purposes, often lacking the "fun" present in other games.

(Continues)

APPENDIX 9. (Continues) Pre-testing Questionnaire

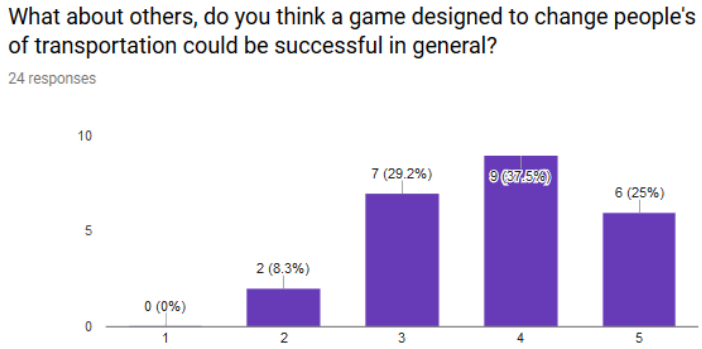
Q9. To which extent do you think a game could impact your lifestyle? *

Answers between 1 and 5. 1 labelled ”Not at all”, 5 labelled ”A lot”



Q10. What about others, do you think a game designed to change people's choice of transportation could be successful in general? *

Answers between 1 and 5. 1 labelled ”No”, 5 labelled ”Yes”



Q11. Depending on your previous answers: Why? Why not?

Long text answer.

Answer listed below.

- If gaming regularly, the idea of the game could become ingrained subconsciously...
- transportation mode is bounded by several factors: available transports, distance, time. Someone with a car might need it because he lives far away from work, and the bus might have hard constraints (too early, too late, possibility of missing it, have to walk before/after, too many people, etc.). Even if a game makes you understand your impact, I think it have a low probability of changing your behavior.
- Game can engage people very well. If it is well designed, it can effectively change people's choice and habits.
- Experience of competitions to walk more have shown people are then motivated to move
- People are quite set in their usual lifestyle and do have reasons for the choice of transport: convenience, necessity, or others. Certain distances are better bridged by car. And some people hate unreliable public transport, waiting in the rain for a delayed bus or getting sneezed at in an overcrowded bus. A game will most likely not change this. A change in behavior may occur when circumstances are right, e.g. close distance which would allow walking, or convenient bus link e.g. a direct reliable connection without changing the bus. And a game may certainly trigger such a change, especially when there is some fun reward for walking or cycling. For me there is basically no other choice than car. I did walk a few times in summer - is 1 1/2 hours walk and is only OK in good weather.
- No Idea what this is about. will have to try first.

(Continues)

APPENDIX 9. (Continues) Pre-testing Questionnaire

(Answers to Q11 continues)

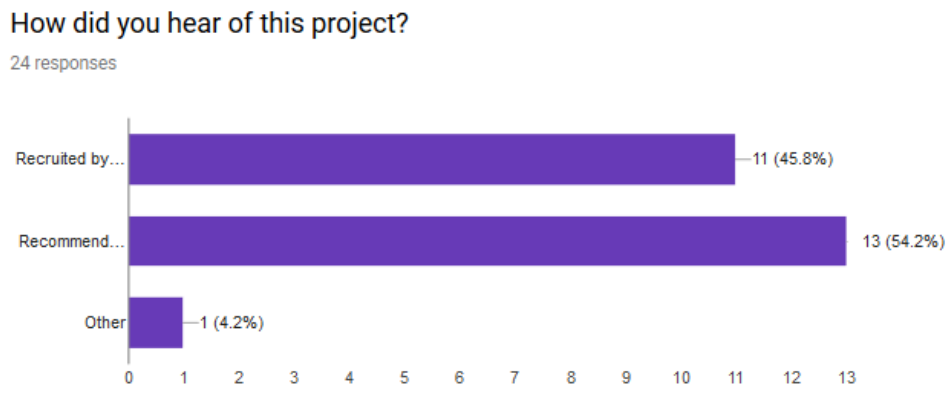
- It depends on the culture of the people, how people regard games, how intrusive it can be, how addictive it can be. If it's a "free" game there's probably lots of subliminal messages and adverts. If the player has to pay for it, why would he do so? How to get the players integrate that game into their daily lives, it has to meet the players' needs in some ways.
- I really don't know
- With The right approach (which i don't know-how what it is) possibly some impact couldnt be made :)
- I think it will
- It's possible that players change their behaviors while playing games but I doubt that it will stick.
- Learn people habits and show them alternatives
- If it is made correctly, and is aimed at the right points, it could seriously impact everyone who plays it.
- If Pokemon can cause traffic, anything is possible.
- It will motivate people, same idea like Fitbit has

Evergreen: A serious multiplayer Strategy/RPG game

Q12. How did you hear of this project? *

Check all checkboxes that apply.

- Recruited by the organizer as an initial volunteer.
- Recommended by a friend.
- Other:



APPENDIX 10. Evergreen: Evaluation Questionnaire highlights

Quantitative questions omitted. All questions text-based answers. None of the test-based questions were required.

Q1. Did you play any similar kind of game before? Mention examples.

- Mostly other old jRPGs, not anything similar on mobile that I can recall.
- no
- No.

Q2. What was bad with the game? What could have been better?

- It needs more "in-your-face-AAA-stuff-popups".
- Base-sharng, more players to test with, too few right now. More obvious showing of emissions and eased ways to reduce it.
- A significant decrease in emissions if player was actually walking or biking on that day (ergo, transport detection must be good).

Q3. If you were not influenced, why not? What would have had an influence on your choice?

- Because the effects of actual transport did not really feel like it was reflected in the game.
- the game can make me more aware of my action, but other factors are more important (distance, weather, time, etc.)
- I need my car to get anywhere since i live in <Omitted>. Otherwide I would have walked more or even tried the bus
- Not sure

Q4. If you have any other thoughts, please share them. Any feedback or ideas are appreciated.

- more feedback on the transportation choice at the end of the day? (you produced xx emission with transportation today), a ranking/leaderboard, to increase competitiveness?
- I am the power.
- This game is a really good idea but there should be something to do while waiting for the next round to be played. Some sort of mini games perhaps. It would be great if it was possible to play mini games where you gain or earn something by walking or taking a bike ride. Perhaps you could scout for monsters that way? Or perhaps just gain more knowledge about your surroundings and get even more berries and building materials?

APPENDIX 11. Tester Interview Transcripts

Public game testing announced the 12th of April on Facebook.
April 23rd the Evaluation form was disseminated.
All chat with testers recorded below, starting on the 12th of April or later.
Each separate chat-exchange occasion is separated by a new line.
Exchanges have been formalized and de-contextualized to increase readability.
All transcripts were approved and verified by the interviewees after they had been transcribed. Screenshots cited within the transcripts are available in Appendix 12.

Interviewee/Player 1: (code named Sparris)

Author and Sparris exchanged screenshots of their game status (log messages of what had happened the first day).
Sparris: Nothing happens if I click on event log. Can't I view it anymore?
Author: It requires having some log messages there. Try restart the app and hit 'new day' again. It will make the text there clickable next time.
Sparris: It showed up when I restarted the app.

Sparris shows a screenshot of from the Transport Usage screen, where Idle is the most detected mode, Boat being the second. (Sparris 1)
Sparris: Why does it say boat is the transport? But yeah, the graph has got Idle and Foot quite right.
Author: Probably due to sampling of the boat transport.

Sparris: Why is there an update now?
Author: Only Facebook was updated. The game will update as usual in the evening (10 pm GMT).

Sparris: I just took this screenshot now. After I clicked update, it went to my previous status. It should be day 4 already now.
Author: Either you are in single-player mode, or you are confused. I am also on day 4 now. There shouldn't be any problem.
Sparris: Alright.

Author: Do you want to fight? I can give you a Gladius (a weapon).
Sparris: Give it to me! I have nothing.
(Later on) Sparris: Why didn't you give it to me?
Author: I don't have you in the "Known Players" in-game. I am too busy dying at the moment. Find me and I can give it to you.
Sparris: So, the action to look for you will manifest later?
Author: That is correct. All daily actions manifest as the turn updates (at 10 pm daily).
Sparris: Alright!

Sparris: I just posted on Assault of the Evergreen's Facebook page. Is that OK?
Author: Yes.

Sparris: You still didn't give me the Gladius (the weapon)! I already found you and sent a message "hi" to you.
Author: That is what I was thinking about. Just because you sent me a message does not mean that I can reply or send you things. So maybe I should add in the server that if you send a message, the other player will automatically get to know you? Otherwise I was considering adding an action to "Inform player whereabouts". So that you can spread connections more easily. Do you think it is needed?
Sparris: Indeed. I think it would be better if you get to know the sender and can opt to connect or not.
Author: That is not up to the receiver. It should be up to the sender. Maybe a "Share known players" action would be needed, where the recipient will get to know all that you know.
Sparris: Yes, maybe like that.

Author: The server has been updated. Try to share knowledge to me. And please check the transport usage for the past 2 weeks. Print screen, and tell me what is correct and incorrect with the percentages.
Sparris shared a screenshot (Sparris 2)
Sparris: No car it seems, although I drove last monday. I shared knowledge with you in-game now.

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

Author: Are you sure that you shared? Hm. Maybe I'm not saving every action. When I query I am not seeing the message, so maybe the data of all players is only saved after each new turn right now, and not after each (your) request. So when I killed the server to restart it some data was lost. So maybe the game should save the file after each request.
Sparris: Yep.
Author: For now, can you just resend the knowledge sharing?
Sparris: Now there are no known players for me! Maybe I have to search for you again.
Author: That could also be my fault. I will diagnose the save file. Wait. Try now and update. I hopefully fixed the code now.
Sparris: I shared the known player whereabouts now.
Author: I send you the Gladius (weapon) now. Try equipping it. Did you receive it?
Sparris: I have received and equipped it! :D
Author: Can you give me some resources? I need materials.
Sparris: How much do you need? Is 6 enough?
Author: Yeah, that would be good.

Sparris: Mutated shrubs almost killed me!
Author: Oh, my.

Author: By the way, did I send you some item earlier already? Should I send you something more? I have some new gear, Harvesting tools among them.
Sparris: Yeah, I got a Gladius from you.
Author: I send you some new items. Equip the tools and you should get even more food when you look for food later.
Sparris: Alright.

Author: We are thinking of the future of Evergreen and would like some feedback.
Author shows Sparris a plan of new features to add. Features include new icons, localization to other languages, adding a tutorial, improving or removing transport mode detection, server lifetime, maximum players per server, removing dead/inactive players, adding a disclaimer for the transport mode detection that it may not be accurate, and price to pay for the app.
Sparris: Alright. I will read it. Pay or no pay for the app?
Author: When browsing the Android Play Store, yes. Most games cost, and there is a perceived value in increased costs.
Sparris: I think you should start with a free version, and include an in-game store.
Author: What kind of add-ons?
Sparris: For example access to more tools and weapons.
Author: Monetization via in-game purchases is very common, we but haven't considered it earlier. There are also balance issues since it is a multiplayer game.
Sparris: Alright.
Author: Does the rest look good, or what?
Sparris: Revival possibility is good.
Author: I added in-game purchases as a possible feature.
Sparris: I am thinking that you could do like the Supercell start-up. If I remember correctly, Clash of Titans was free. I was trying to look for the info, but the browser is so slow. First you need to attract people to play the game.
Author: That is another question entirely. We are not really caring about the amount of players at the moment, but rather of the quality of the playing experience.
Sparris: You would have to put a price that a person would not fell like they are spending. 0.99 euros for example.
Author: Are you still playing the game, by the way (April 23rd, 11 days into testing)?
Sparris: Aha, once a day.
Author: Is there anything you feel that is missing?
Sparris: Putting a disclaimer that transport detection is of low quality is maybe not a good idea... better yet remove it if it cannot be improved... or does keeping it eventually help in improving the detection?
Author: Not by just keeping it, no. We would require more user interaction or gathering more data to improve it.
Sparris: You could maybe give the gamer an option to help gather data in return for a free berry :D
Author: A free berry for each 5 minutes of data?
Sparris: 15 minutes. More berries for data that is difficult to gather.
Author: That would mean integrating the transport data gathering app into the game app.

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

Sparris: Yes.
Author: And have a button to upload it to the server. Then I could analyze the data and give berries if the data is good?
Sparris: Yes, since you really do need to improve the detection. You should give berries automatically. You could add ranged weapons? Like bows?
Author: If you stop focusing on the plan and think about the gameplay so far. Do you like it? What do you like? What don't you like? Anything that you feel missing?
Sparris: Mmm.. I like it. I am just missing ranged weapons.
Author: How do you think ranged weapons should/would work? A few free attacks before melee combat?
Sparris: A few free shots depending on the level of ranged weapon, yes, before melee. I don't know how to improve interaction with other players... can you accidentally bump into someone without searching for them explicitly?
Author: Yes, you can when you are scouting. We could possibly add so accidental player discovery to other actions as well, perhaps.
Sparris: Because I think for some, scouting is not a priority.. so chances of bumping into another player will be rare... maybe boring.
Author: Indeed. Bon (another player) was playing mostly solo, for example, even though he is also on the multiplayer server.
Sparris: Are we on day 10 in-game? And there has been no encounters with other players yet, at least not for me.
Author: There are too few people actually playing it, decreasing chances. With more people it would be more chaos and player discoveries would occur much more frequently.
Sparris: And if we encountered another player, one could challenge the other to fight or just trade goods or just move along.
Author: All of that is already possible, yes, just like we traded resources and items. We also tested stealing and fighting in the test-phase before the public tests.
Sparris: Yes, but we did not 'meet'... I had to use the "Search for player" action.
Author: Of course, but we met after searching.
Sparris: Like, maybe instead of just meeting random monsters, one can also meet random players.
Author: That has been added to the "Scout" daily action, as I mentioned. Or you meant that you want AIs as well? Interactable ones, that may request and give you something.
Sparris: Yes, but I mean you do not need to Scout to meet monsters.
Author: That is the whole point of the game: that the Evergreen wants to wipe out humanity due to all emissions. So, yes.
Sparris: Hmm.
Author: Just like in some other role-playing games (e.g. Final Fantasy series) you can run around in circles and just constantly fight monsters - if that is what you wish to do. If you want to meet other players or progress the story usually you have to go to cities and look for interactable players or NPCs (non-player characters, AIs).
Sparris: Then maybe it is fine.
Author: You will not meet people unless you are actually looking for them (say, for example, in a city). Now consider yourself in a post-apocalyptic scenario and the city has been destroyed by monters. People will be spread out. People would not necessarily be so easily found. Thus, the "Look for Players" action - which enables you to look for any player.
Sparris: Aha.

Sparris: Hey, was it so that HP recovers automatically every day without doing the "Recover" (daily) action?
Author: It should, yes, but very slowly. Maybe it should be updated to be like 2 HP per day or something. Right now it might only be 1 HP per day.
Sparris: Yes, make it 2.

Author adjusted the History set size used in the transportation mode recognition after roughly 1.5 weeks.
Author: Did you download the new version which I gave you? Have you checked the transport usage the past few days with it? Has it felt more correct?
Sparris: I did download the new one and just checked usage now. It shows Idle as highest, but is not showing car or foot so much, even though I have been walking and taking the car a bit. Then there is Boat which is always present for some reason... (see Sparris 3)

Author showed Sparris an updated detailed long-term plan.

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

Sparris: Crafter's garb... to withstand the heat of the flame.
Author: See in-app purchases as well, just some ideas. "Explore" active action would make people walk more. Opening the app before and after the walk, gaining bonuses based on duration they walk.
Sparris: I only see "Exploration Insignia" and "Veteran's memories" in this file I have.
Author: Yes, we do not want to add any items yet.
Sparris: Aha.

One month later (24th May) Author asks again.
Author: If you look at the transportation usage in Evergreen post update (dun remember when) did the transportation detection feel more accurate?
Sparris shows some screenshots. Idle is being detected. Boat is as usual always present as a false positive. Foot is being detected as well. Bus is being detected as a false positive.
Sparris: It doesn't seem so accurate.
Sparris sends a screenshot of the Transport Usage screen after walking home (Sparris 4). Foot is detected properly. Boat is the largest false positive as usual.

Sparris sends a screenshot for when walking from a public event area (Sparris 5). In it Foot is being detected accurately, with Bike being a significant false positive.

Interviewee/Player 2: (code named Stone, transcribed from Swedish)

Author: The game has been published now. You should create a character in the game. But the next day update is in around.. 20 hours, so you can easily do it tomorrow as well. Then we must crush everybody who will join the game (jokingly)! If we are to have some co-operation, maybe one can gather resources while the other is crafting? I have been focusing on "Inventing" in the beginning, anyway.
Stone: I will do it tomorrow. I can get the resources. :)
Author: I suggest levling up Foraging for gathering food and Scanvenging for gathering Materials. Without them it will be rather slow.
Stone: Yes, I have tested both with and without them (in Singleplayer mode). It makes a huge difference when they increase in levels! :D

Author shows Stone a screenshot of his progress.
Author: I failed to invent anything the first day at least...
Stone: I hade so much to do yesterday that I forgot to play the game.
Author: You can start now.
Stone: I have begun to gather berries and teaching myself to get better at Foraging.
Author: I got 0 materials after the last turn. I need to gather some first.
Stone: I am not sure if the game is working for me. Should we not have played the days turn now?
Author: In one hour, the update will be at 10pm GMT.

Author: Oh, yeah! I made a Knife! Do you need it? Should I search for you? What is your in-game name, if so?
- No response from Stone (same day)

Author: I almost died!
- No response from Stone (2 days without response)

Author: Hey. (4 days after last response)
Stone swears a lot and explains that he has not received any notifications from my messages on his devices for days. He also says his in-game name.
Stone: I have a lot of food and materials that I could share with you.
Author: Cool, you would just need to find me to give it then! I went and died, but I have some gear so that I can craft more items.
Stone: I have not met any monsters yet. What is your name?
Author gives his in-game name.
Stone: There we go. :)

Author: I got a Fighter's Armor +1 randomly while walking. It is crazy.
Stone: Nice! :D

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

Author: I updated the game, by the way. See the e-mail or on Facebook.
Stone: I saw the mail. I will update when we get home.

Author: Damn you sent me a lot of resources! Nice! Is there any special gear that you want? I can craft. By the way, you must send me a "Share Known Player Whereabouts" active action to me in order for me to send stuff to you. Otherwise I would have to look for you myself - and that would take some time.
Stone drifted off into other conversation topics without replying what he wanted.

End of testing phase, 23rd of April Interview/Discussion.
Author: I am thinking about some things: does the game need more content (maybe single-player story, AIs, pictures) or? Aim to get Evergreen a public release on the Android store.
Stone: One thing I have been thinking about is when you have built a weapon or something, should one not get a larger picture saying "TA-DAAAAAAAAAA!!! Look what you just made!"
Author: I am wondering about the timeline for publishing, anyway.
Stone: How complete are the multiplayer parts? Should the single player game have some story that you follow or should it be the same as multi-player minus other players?
Author shares a draft of plans with Stone.
Author: The multiplayer part is basically done. If one wants to add more features, then that is feasible, but it will always change the balance of the game, which requires testing for each feature you would want to add. Some brainstorming may be needed.
Stone: I am thinking about weapons. Can one make more than one type of axe, for example?
Author: I may not have been very clear. I will clarify. When inenting weapons right now there are 10 different types. The same applies for crafting. Then there are quality levels that affect how and which statistics they get.
Stone: Will the better quality weapons have different appearances?
Author: Pretty much.
Stone: One could make some variations of each weapon and give them a finish each. The first ones rusty, maybe the sledgehammer could be made of stone, etc.
Author explains how that is pretty much the current idea.
Stone: Maybe it would be good to accompany any visual representations of the weapons with a number to display in some sense how good or useful it is. And it would also be really nice if you got a big pop-up with a picture of the weapon when you have just succeeded crafting it.
Author agrees to the general idea.
Author: If it is to be published, other questions arise, such as payment ,duration of server, maximum numbero f players, number of servers, etc. The transport detection right now is not optimal either, so the question is if it should be torn out and randomized, kept in a sub-standard state, or spend time and resources to improve it.
- Stone didn't reply until later and missed the question.

Author gave a link to the evaluative questionnaire.
Author: Can you please fill in the evaluative questionnaire.
Stone: Oh, I missed that you had written to me again. :(

Author: I see you put a 1 on Character customization (in the evaluative questionnaire). Why is that?
Stone: It crashed the first time I tried to pick character (avatar). So I played with the default character that I was given. That's why I gave it a one. :P
Author: Even in the multiplayer mode? Usually it would only crash in the single-player mode.
Stone: Yep. I must have cryptonite in my cellphone. Instead of regular minerals.
Author: It seems you missed a question. You may go back to the questionnaire and edit your previous response.
Stone: Nice! When one knows that it is a work-in-progress then the evaluation becomes different. Like, things will get fixed. There will be more characters later, and maybe a tutorial and more help-sections will be added. If one needs a lot of help to get started, that is. Maybe a small tutorial.
Author: Indeed.

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

Stone: That one then can choose to skip. There. I filled in the questions I had skipped last time. The only thing I can think is sad/boring/not good is that I cannot play so much each day. I would like that there was more things to do in the game than just wait for the next turn. Some kind of mini-game perhaps.
Author: Indeed, promenade/walk-based mini-games with specific goals would be cool indeed.
Stone: It would help me exercise more. Kind of like how Pokemon Go (a sarcastic negative phrasing of the game name was used) made people walk around and look for monsters.
Author: Yes, precisely.
Stone: The difference is that I like this game. :P

Author quotes an old question to Stone concerning the transport usage and its perceived correctness.
Stone: I am running the newest version of the game app. I took a screenshot I intended to send.
Stone sends a screenshot (Stone 1). Idle looks decent, Car is being displayed as disproportionally highly used (139k seconds the past 2 weeks, or 38 hours), and most others have low (noise) values.
Author: I suspect that you have not been driving more than you have been sleeping. This means the detection is broken. Can you take a screenshot with just 1 day, or 3 days?
Stone: I will, later. :)

Author tries to contact Stone to no response for 3 days again. More problems with the communication software and devices.

Interviewee/Player 3: (code named Bon)

Bon: Good morning. Choosing an avatar in solo-mode of the game crashes it. It then returns to the menu.
Author: Indeed. It happens only on some devices it seems.
Bon: I guess I will use the basic face (avatar) then. By the way, why is the game conducted in 24 hour turns and not 12 hours, or any other amount of time?
Author: Well, we could consider using 12 hour turns, but we will start off with 24 for now, since 12 provokes the question when to update during the day. Even casual players checking in once a day should not be penalized, is my reasoning.
Bon: Indeed. It was just a question, because I played some small games in the past, and it allowed one action when I woke up, and one before going to bed. But yeah, the system should not penalize players who cannot spare so much time as well.
Author: My thought precisely.
Bon: Also, does it have push-notifications when a new day starts, to help users remember? I know it cna help the first time, but then it can become extremely annoying later on.
Author: It kinda does, it just works miserably - only inside the app itself. I didn't have time to fix it. I thought that I would do a Facebook post to remind players in the meantime. Every night or morning.
Bon: I guess that kind of stuff can impact how long the user will keep playing the game.
Author: Yes, many factors impact the user experience.
Bon: That is true.
Author: I will probably gather feedback and iterate the game after 1-2 weeks. Did you try single player first, or went straight into multiplayer?
Bon: Singleplayer first. I played a few days. I put way too many tasks on the first day, then got the advice (that you should pick less than 4 or 5 to remain efficient). (Sarcastically) Damn character cannot do 20 things at the same time. (Sarcastically) What a loser.
The Author laughs.
Bon: Then I almost died, was walking naked outside it seems like.
Author: Or almost, yes. Some gear and combat skills are good if you don't want to get knocked out early on by the attacking monsters.
Bon: Crafting a weapon does not automatically equip it?

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

Author: Nah. We should perhaps change it for the initial weapon - so that it gets equipped automatically, but for subsequent weapons it is not as obvious (if they should get automatically equipped and change the currently equipped weapon).
Bon: I had to delete my character to start the multi-player game. I couldn't switch back to the main menu - it was the easiest way to do it.
Author: Indeed. It is possible to hit the back button sometimes, but that issue has not been fixed yet. We are aware of it.
Bon: I guess it's "Change Character" (an in-game screen)? Because "Quit Game" does what it says.
Author: That ("Change Character") allows creating new characters within the same game mode (single/multi-player). I didn't add a toggle for single/multi-player in that specific screen though. Change Character works if you managed to create both characters before, anyway.
Bon: Oh, alright.
Bon shows a screenshot of when walking to the coffee room at his office (Bon 1). The app had detected Foot properly, but was displaying Bus as detected falsely.
Bon: I did not take the bus. I went to the coffee room, the cafeteria and played with my rolling chair.
Author: I will actually request similar screenshots later, so you can save more if you find it is working decent or bad. Longer periods of time preferred. For bonuses, any transports over 300 seconds the past day are considered.
Bon: I hope Idle offers a lot of bonuses :D
Bon sends another screenshot (Bon 2), this time displaying 1 week. It shows only a total of 940 seconds for Idle, some Foot, falsely detected bus and low, probably noise-induced, time durations for the other transports.
Bon: But yeah, I will keep you updated on it. I don't know how you check exactly the transportation type, but is duration take into account? Bus usually takes more than 1 minute.
Author: Not really, right now. Idle is neutral (no specific bonuses or penalties).
Bon: Evergreen monsters shouldn't find me if I stay geeking inside all day long! It's a scam! XD
Author: They can smell you! ;P
Bon: Damn, they're smart.

Bon shows another screenshot 1 day later (Bon 3), again showing a very low total amount of seconds (almost 2k for 2 weeks of time), and Boat being detected 2nd most often after Idle (which seems to be common for all nearly all qualitative tests by now).
Bon: Do I walk as fast as a boat? :D
Author: (sarcastically) It seems so. More likely it is confused with Idle or other transports. Walking is usually easy to identify.
Bon: I did have to walk very fast yesterday, so could be that also. But yeah, car/tram are being detected when I in fact have been Idle.
Author: Did you have the mobile in your pocket while working, or actively been using it?
Bon: When walking yesterday it was mainly in my pocket. When tram and car were being detected it was mostly in my hands.

5 days later Bon sends a another screenshot. Again it is supposed to represent 2 weeks of data, but contains only around 7k seconds worth of detected transports.
Bon: I only walk, no other transportation. Bus and boat are usually (being detected) when I'm idle/doing small movement with my phone in hand. I think I saw Bike being detected when I was walking last time.

Author: I saved your comments, and am almost done with feedbacks.
Bon: But what if I have more feedback on the game too? :D
Author: Then you can provide that as well. I forgot to mention that. :P
Bon: I will feedback that feedback. You will see.

Bon sent an e-mail reply with feedback as response to an e-mail I had sent addressed to all possible testers asking for feedback. The contents below:

- For emission production, I never saw anything related to transportation in the logs. Maybe my motorized transports are not important enough, but is there feedback regarding emission when you use them?
- what are the gain of scouting the area? I found no interest in it at the beginning, and just gather food or resources when I need them.

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

- should the item description explicitly name the resource associated? Right now scavenging, foraging + value (related to skill name)
- How skill improvement works? Do we absolutely need to study, is it parallel to action, i.e. the skills selected for the day will improve? Study gives xp, but for what? (less important, the yellow progression represents the total progression or towards the next level?)
- still don't know if it's possible to go back to the main menu to change from singleplayer to multiplayer, and creating a new character seems to do it on the same type (solo/multi).
- Is co-op that important? Haven't seen anyone, didn't try to find anyone, no emphasize on it
- defensive training affects the spawn of monster? or similar to parrying?
- small tutorial for the first day? might be hard to implement/not extremely useful

I think that's all right now

As a reply to clarify, Author replied the following:

- Transports affect most actions in the background through an aggregate multiplier, random events may also be generated if u use a particular transport enough.

- Scouting - u can find items, other players and encounters as well

- Skills are trained whenever u gain EXP, which is initially 20 or so, daily 1 or 2 points, from encounters (varies) and from the Study action. Updates to the buttons mean a new level has been reached.

- Indeed, still didn't fix the single/multi,

- Co-op should help since it eases specialization (e.g. one gathers stuff, other crafts, or some other combo). At least where training skills is concerned.

- Defensive training basically increases the Defense by 1 point per level (makes them miss more).

Seems to be mostly how the game works - which I intentionally left to be figured out by players, but I guess adding more FB posts to clarify or expanding help-pages in game or on a web-page could help that?

5 days later, Bon reported again a screenshot with overall low total seconds (around 6k for 3 days), with all kinds of transports being falsely detected.
Bon: Bike, tram, train, car, plane and boat still incorrect. I did use the bus last week, but I think it was more than 3 days ago.
Bon goes on to ask how the implementation is done and suggests improvements. I explain how it is implemented and that noise removal is already there to some extent (via the History set).
Bon: But do you have the same behavior on your phone, or are my sensors really noisy?
Author: Right now mine is super accurate, but I've only been Idle at home, so it's not a good comparison. What I notice in your graph is that Idle is relatively low. In most others Idle is usually the highest of all by far. So some sensing might be working differently, or sleeping alltogether on your phone. On other devices 50 to 90% of all detected seconds should be Idle - as we live mostly sedentary lifestyles (at least the testers), then various degrees of the remaining time should have been distributed somewhat similarly to what modes of transportation you have been using.
Bon: Well, with the two weeks view Idle is first, but it is not far from the others. But all the wrong stuff (bus, car and all) should be idle in reality.
Bon shows another screenshot, with the Graph display duration set to 2 weeks. Idle is at only 1080 seconds, Foot at 910, Bus at 790, etc.
Author: Yes, 1k Idle seconds is very low.
Author sends a screenshot of his results, showing more than 28k Idle seconds being detected for a period of 3 days, with low seconds amounts for all other transports (Author 1).
Author: 3 days, 28k seconds.
Bon: Indeed.

(Continues)

APPENDIX 11. (Continues) Tester Interview Transcripts

Author: Maybe your phone likes to kill the transport classifier service or something, while you are not using it actively. >> This means that we would need much more time and devices to test on to perfect the code to make it work similarly on all devices.
Bon shows a screenshot of teh app from a status screen, displaying how long the application has been running, including its background services. It has only been running for 11 minutes. See picture Bon 4.
Bon: 11 minutes, so, yeah, my phone doesn't liek you, it seems xD
Author: Hm, that is the timestamp of when it started? Usually it should restart when you leave the app, or starting the app again, loading saved data each time, so it should be fine. It might be something in the sensing thread or classifier then.
Bon: It was a time counter since launch of service, yeah. I will try tonight and check the same values before launching the game. See if it's still running then.

Bon: My phone did kill your app.
Author: Interesting.
Bon: Stupid phone, I guess.
Author: Or it doesn't like background services using a megabyte of memory or writing to disc every now and then.

May 11th, almost 1 month after the game was launched publicly. Author discovers Bon is still playing the game, based on server records.
Author: You are still playing Evergreen, eh? Seems like transport detection is never working for you.
Bon: Still playing, yup.
Bon sends another screenshot (Bon 5).
Author: Cool. Well, Idle looks more correct at least (but still low for being 2 weeks).
Bon: Foot is way too low, but I did use the bus this week.
Author: Looking at the "daily" data sent to the server, then bus or some transport is always on top for you, but never more than like 500 seconds.
Bon: Should have 20 mins of bus yesterday, and 40min of walking daily more or less. I guess my sensors are always sleeping when my screen is off. You should probably ditch out my data (Bon contributed some data to both the initial transportation sample gathering for training the classifiers, in addition to the game/qualitative testing).
Author: Mm, must be, or the app thread is sleeping. But I will report your results anyway, that even if it works on one device it did not work on some other.

4 days later, Bon sends a screenshot of the battle log from the game.
Bon: Freaking rock monster! More than 100 lines of text to see the beginning of the fight.
Author: Did you win?
Bon: It was a looooong fight. And noooo. :(
Author writes a consoling gesture: *patpat

50 days have passed.

Bon is still playing the game at the time of this writing (05-29, 50 days after game launch). Sparris is still playing, but took some weeks' break (2-4 weeks). Author and Stone stopped playing shortly after the 10-day test period was reached.

Bon: I am still playing, I want to see the max defense level.

APPENDIX 12. Tester Interview Discussed Screenshots

Sparris 1

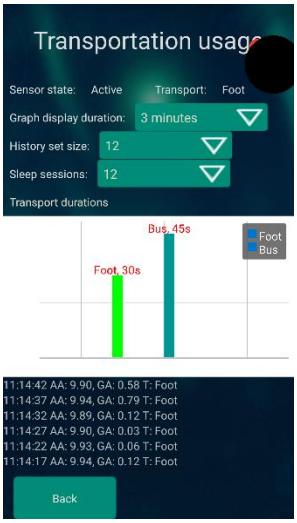
Sparris 2

Sparris 3

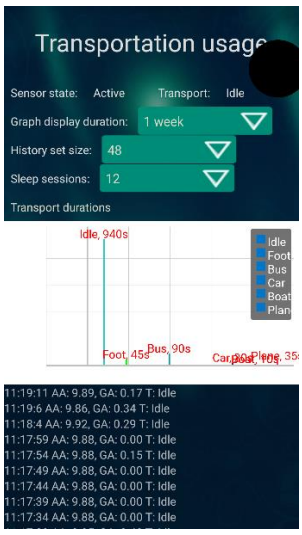
Sparris 4

Sparris 5

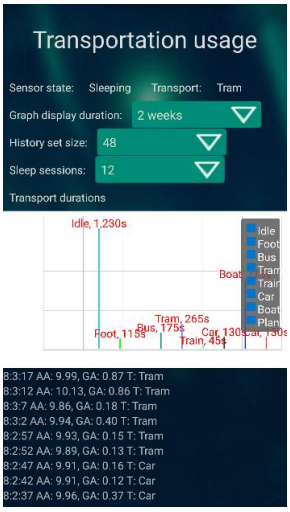
Stone 1



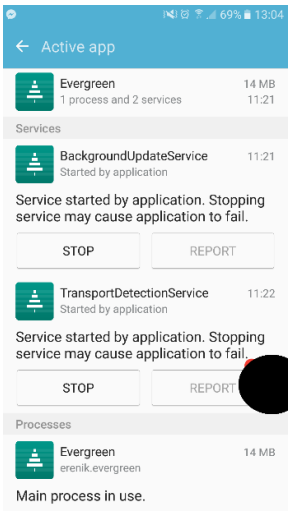
Bon 1



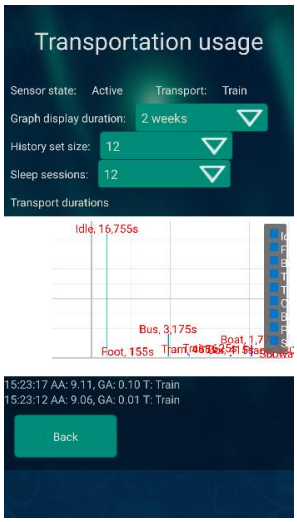
Bon 2



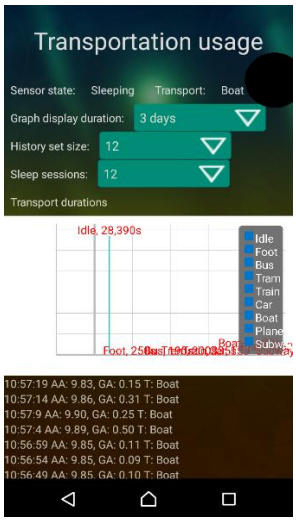
Bon 3



Bon 4



Bon 5



Author 1