Gamifying Spaced Repetition Software

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Abstract

Anki is a software system that implements spaced repetition. Despite its popularity, its interface for Android devices, known as AnkiDroid, lacks the inclusion of extrinsic motivational elements. Gamification involves the inclusion of game elements and schemes in non-game contexts; its objective is to improve the user experience by providing extra motivational elements in existing tools. The present work provides a gamification strategy aimed at increasing user engagement in AnkiDroid. The key difference from other gamification options is the inclusion of a casual game. The project consists of the design and implementation of the gamification solution, the definition and execution of a study to collect data, and the evaluation of the solution. The results showed that there was no statistically significant difference between a traditional gamification scheme and the proposed one. Those results served as the basis to discuss potential issues in the design and suggest additional work.

Acknowledgements

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Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Sebastian Velasquez*)

To Milena and Gabriela.

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Chapter 1

Introduction

In several activities, the extrinsic motivation is limited by the context of use. That is, once a given benefit or reward is obtained, people are likely to stop doing those activities. In educational environments, there exists a multitude of digital tools that facilitate the learning process. However, the lack of additional motivational elements can make people stop using them. The present work provides a solution aimed at increasing user engagement in an educational tool. The solution is based on the design of a gamification strategy that includes a casual game. The results showed that there was no statistically significant variation in the user engagement between the proposed and a traditional gamification strategy.

1.1 Motivation

Activities such as using a tool, executing an action, or adopting a behaviour have an extrinsic incentive. In many cases, such incentive is a reward in the form of a monetary compensation for a job or good marks in a study program. The lack of additional motivational factors can make people stop doing such activities once the reward is obtained. Likewise, activities that do not offer specific rewards but provide other benefits might also be affected by the absence of additional motivational elements. In contrast, activities that people do for joy or entertainment are likely to be repeated over time.

In the specific case of spaced repetition tools, the main incentive to use them is the memorisation of new content. However, their flexibility to let users define the duration of each session and the interval between consecutive revisions can lead to a gradual reduction of its usage over time. Such circumstance prevents learners from keeping getting the benefits of the technique. These conditions set a perfect environment for

the adoption of a gamification scheme that provides additional incentives to learners. This way, users of spaced repetition tools may mantain a constant pace of study while enjoying the experience.

1.2 Objective

Gamification provides several elements that have been leveraged to improve user experience and increase user engagement. For their part, casual games have characteristics that have converted them into subjects of study beyond the leisure context. They have been proved to provide benefits in different areas including health, work, and study. Spaced repetition has been implemented in a multitude of pieces of software including mobile applications. Specifically, AnkiDroid (Raoul, 2012) has become a popular application that implements a general solution for spaced repetition. Despite its popularity, the application lacks additional motivational elements.

The objective of the present work is to design and implement a gamification strategy aimed at increasing the user engagement in AnkiDroid. Unlike traditional gamification strategies, the proposed solution includes a casual game as a key additional motivational element. The game is integrated such that the gameplay is connected with the revision of flashcards. This way, users are required to review flashcards to get additional benefits in the game. The effectiveness of the proposed solution is then evaluated by analysing the results obtained from the data collected from participants.

1.3 Achieved Results

The process started with the selection of components of interest in AnkiDroid. Those components were chosen based on their relevance from the users' perspective, and their suitability to be modified. Then, a set of game elements and schemes were added such that they were connected to one another to provide an integral gamification experience. After that, a casual game was included to provide another motivational factor. This integration was done by connecting the game with the revision of flashcards using the previously defined gamification components as a link.

Then, the modified application was tested by two groups of participants. Each group of participants tested a different version of the application. One version contained all the additional elements, and the other did not have the casual game. The objective of the study was to collect data from the application. These data were then

processed and analysed to evaluate the effectiveness of the inclusion of a casual game as part of a gamification strategy.

The analysis was done in terms of the variation of user engagement in both groups of participants. To do so, a set of user engagement metrics was defined based on the available information and its relevance. The results showed that there was no statistically significant difference in any of the metrics. Therefore, the inclusion of a casual game as part of a gamification strategy did not have a positive or negative impact on the user engagement. These results served as the basis to discuss potential issues in the design and propose further work.

Chapter 2

Background

The present work relied on two important concepts: gamification and spaced repetition. An overview of both concepts sets the stage for the proposed solution. Gamification provides an alternative to improve user experience, whereas spaced repetition offers a way to ease the retention of new knowledge. Among the several alternatives that implement spaced repetition, Anki and its mobile interface, AnkiDroid, provide a general purpose approach with a large user base. In addition, casual games offer characteristics that make them adaptable to non-leisure contexts including learning. One example is the 2048 game (Cirulli, 2014), which has been the subject of several studies. Finally, statistical testings allow to make inferences about the outcome of an experiment.

2.1 Gamification

Gamification can be defined as the process of adding game elements and schemes into non-game contexts (Deterding et al., 2011). The main objective of gamification is to improve the user experience and increase the motivation to use a product or service. To accomplish such an objective, gamification takes advantage of the inherent nature of humans to play. Unlike mandatory activities such as study and work, playing is voluntary and free; its main outcome is a feeling of joy and excitement (Johan, 1950). These conditions set the environment for the adoption of game concepts and techniques in broader contexts.

Over the past ten years, gamification has attracted the attention of industry and academia. In the industry, companies have found a means to improve the performance and commitment of employees by avoiding traditional schemes of monetary rewards and punishments. Moreover, gamification provides a set of tools to increase the loyalty

and engagement of users and customers. In the academia, gamification has expanded and merged various fields of research given its interdisciplinary nature. It has attracted the attention of researchers in areas such as human-computer interaction, software development, psychology, pedagogy, business management, and others.

Among the many concepts related to gamification, there are three that need to be clearly identified to set the bases of a gamification strategy. The first one is game element, which refers to the specific pieces taken from games, such as points, rewards, achievements, etc. The second one is game scheme or game mechanics, which refers to the rules that users need to follow to get a certain outcome. Finally, a player is the person or agent that uses the gamified system.

2.2 Spaced Repetition

Spaced repetition is a technique that facilitates the retention of new knowledge. It leverages the spacing effect phenomenon to help learners memorise specific contents (Hintzman, 1974). This phenomenon allows learners to increase their capacity of retention by acquiring new knowledge in short recurrent sessions rather than in a single massive revision. In its basic form, spaced repetition sets increasing intervals of time between subsequent review sessions of previously learned material. This means that the more challenging the content, the more frequently it is reviewed by a learner. Then, the frequency of repetition is adjusted as the learner progresses.

Among the various existing techniques for memorisation, spaced repetition stands out due to its simplicity and flexibility. The duration of each revision along with the interval time between consecutive sessions is defined by the learner. In addition, the learner assesses the easiness of the content under revision to determine the frequency of repetition. Finally, spaced repetition is a technique that can be used to learn new content from any field, but it is especially useful when the number of items to memorise is large. Such characteristics allow the implementation of this technique as a piece of software, making it available to a wider audience.

2.3 AnkiDroid

Anki is a platform that implements a general purpose solution for spaced repetition. Thus, it can be used to learn and memorise content from any field. Its community has created an extensive base of content in a multitude of categories including languages,

art, science, and trivia. It provides several interfaces including desktop applications for Linux, Mac, and Windows. In mobile environments, it provides applications for iOS and Android devices. The version for Android devices is known as AnkiDroid, the code of which is publicly available under the GNU general public license.

AnkiDroid has well-defined logic and visual structures (Zamora Suriñach, 2011) that implement most of the features presented in the desktop applications including creation and editing of flashcards, visualisation of statistics of use, and synchronisation with the Anki system to save progress. Moreover, it has been designed to be compatible with the majority of Android versions. Therefore, the application is available for a wide range of devices which has helped to increase its popularity as an educational tool as seen in Figure 2.1.

In addtion, AnkiDroid has an large community of members that collaborate, support, and promote the use and development of the application in web forums and groups. In regard to its development, the structure of the code allows modifications in the application that add or remove new features. The application can be modified to connect to external services, collect information of use, or include new elements. These characteristics have allowed an extensive number of contributors (131) to be part of its development.

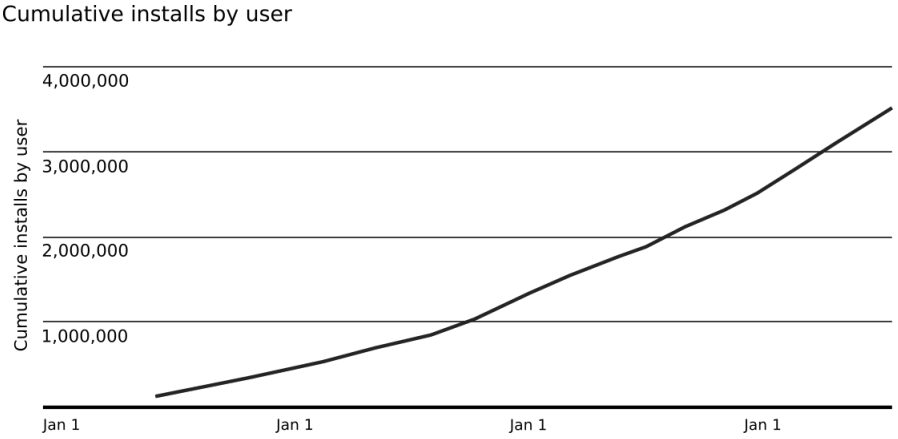

Figure 2.1: Evolution of the number of installations of AnkiDroid. Image taken from the Twitter account of AnkiDroid (https://twitter.com/AnkiDroid).

2.4 Casual Video Games

A casual game has to be fun, it needs to provide a quick way to access, and the gameplay must be easy to understand, as defined by the Casual Games Association (CGA). These characteristics mean that users do not require any previous expertise or skills related to video games. For these reasons, casual games have a broad audience that includes people from all age groups.

The characteristics of this type of games have been leveraged to adopt them to non-leisure contexts including health and learning. In the health context, the use of casual games has been studied as an alternative element to improve mood and decrease stress (Russoniello et al., 2009). Additional studies have demonstrated the effectiveness of playing casual games as a recovery strategy after periods of high work strain (Reinecke, 2009). Finally, casual games have also been studied as an alternative to traditional educational tools (Peirce and Wade, 2010)

2.5 2048 Game

2048 is a puzzle-like casual game cotaining a 4x4 grid as seen in Figure 2.2. The objective of the game is to merge numbered blocks until the player creates one with a value of 2048. The game starts with two blocks, each with value of 2, which are randomly positioned in the grid. The player has to slide the blocks horizontally or vertically. The blocks move in the chosen direction; a block stops if it reaches an edge of the grid or collides with another block. If two colliding blocks have the same number, they are merged into a single block, the value of which is the sum of the values of the forming blocks. In every turn, a new block with a value of 2 is randomly positioned in the grid.

The popularity of the game has turned it into a subject of different types of studies. The majority of these studies aim to analyse the game from the computational complexity perspective (Abdelkader et al., 2016), and propose several artificial intelligence alternatives to win the game including neural networks (Boris and Goran, 2016) and Monte-Carlo methods (Rodgers and Levine, 2014). However, the game has also been studied as an educational element to engage students' interest (Neller, 2015).

Figure 2.2: Grid of the 2048 game.

2.6 Statistical Testing

Statistical testing provides a way to make inferences about the data and tell if the observed pattern is real or due to chance. In research, this type of analysis helps to determine the effects of a treatment on the outcome and the robustness of that relationship. In comparative studies, a new treatment is applied to units in the experimental group, whereas units in the control group receive the standard treatment or no treatment at all.

The outcomes from the control and experimental groups can be described and compared by their means. The difference between both means gives some insights about the groups. However, the difference of means needs to be complimented with the variances of the samples to determine if it is statistically significant. This analysis can be done using the Student's t-test.

The Student's t-test is a method that can be used to do a statistical hyphotesis testing. The method provides a parameter called *t-value* that is the ratio bewteen a signal (difference of means) and noise (variability of samples). This parameter and the degrees of freedom (number of values that are free to vary) are used to find the *p-value*, which is the probability value of having the same mean difference in additional experiments. Therefore, the *p-value* is used to confirm or deny the null hypothesis of the experiment.

Chapter 3

Related Work

Gamification has been considered as an alternative to improve user experience in educational contexts. Its characteristics of flexibility and adaptation have been leveraged to adapt educational tools from different platforms and targeted to distinct audiences. Anki has been a subject of several attempts to be gamified. Some of them were simply aimed at improving the visual aspect of the desktop interfaces, whereas others tried to provide a more complete gamification environment. However, the literature did not report any previous work related to gamifying the mobile interface of Anki (AnkiDroid).

3.1 Gamification for Learning

The characteristics of gamification have gotten special attention in educational environments. Its ability to increase and maintain the motivation makes it a perfect fit to be integrated into educational tools aimed at improving the learning experience. The amount of mental effort required in the learning process greatly depends on the learner's perception of the source of knowledge (Salomon, 1983). Therefore, when people perceive the source of knowledge in a positive fashion, the experience is more pleasant and the results are better. In this context, there have been several approaches that have integrated gamification techniques in educational tools effectively.

Gamification is flexible to be used by different target audiences effectively. The work by (Boticki et al., 2015) used badges as motivational elements in a mobile learning system to explore the individual and collaborative learning of primary school pupils. Their results showed that the quality and quantity of contributions were correlated with the end-year assessment score. Likewise, (Slish et al., 2015) showed how the use of gamification techniques increased the performance of undergraduate stu-

dents, with lower-performing students getting the highest benefits. Finally, tools for the general public have also implemented gaming elements to make them more engaging (Morrison and DiSalvo, 2014).

Adaptation to different environments is another characteristic that makes gamification an option to consider in learning tools. The work by (Su and Cheng, 2015) took advantage of the uniquitous nature of smartphones to improve outdoor learning activities using a mobile gamification learning system (MGLS). Their results showed a positive relationship between the motivation and learning achievement. Web platforms for massive online open courses (MOOCs) have found in gamification a means to increase students' motivation and reduce dropout rates (Gené et al., 2014). Finally, gamification techniques have also been used in desktop environments to make tasks like surveys more enjoyable (Cheong et al., 2013).

The adoption of gamification elements and techniques is facilitated due to its characteristics of flexibility and adaptation. Depending on the context of usage, the target audience, and the platform of deployment of an educational tool, the inclusion of gamification elements and techniques can vary and have different goals. Nonetheless, the ultimate objective of gamifying an educational tool is to improve the learner's experience by providing further motivational elements to make it more enjoyable. Previous work has demonstrated that the integration of gamification has been effective in different contexts and environments.

3.2 Previous Attempts to Gamify Anki

The desktop version of Anki has the ability to increase the available features by means of add-ons. Taking advantage of this characteristic, there have been several attempts to gamify the tool. The majority of the add-ons are aimed at improving the visual aspect of Anki by implementing game elements like progress bar (Glutanimate, 2017a) or random rewards (Glutanimate, 2017b). The mechanics of these elements are straightforward, and their main objective is to provide visual feedback to the user. Even though these options make the user interface more appealing, they lack game schemes to encourage the user to keep using the tool.

Other options include more advanced mechanics to integrate game schemes in Anki. The first attempt aimed at giving Anki a more game-like environment was Anki-Warrior (Proxx, 2010). The mechanics of the game were similar to a role-playing game (RPG) where the learner played the role of a warrior conquering Japanese cities. In

this role, the player had to convince the inhabitants of a city to join the empire. Then, the player had to review more flashcards to convince more inhabitants until the entire city was part of the empire. This alternative made Anki more appealing, but it only implemented a scheme that mapped the number of reviewed cards with the number of citizens convinced by the warrior.

Following the path started by AnkiWarrior, AnkiEmperor (Proxx, 2012) added more game elements and schemes to Anki. Similarly, the learner played a role, but in this case, the objective was to become an emperor. To achieve that objective, the learner had to obtain gold to build constructions like parks, skyscrapers, and landmarks. The gold was also used to unlock new cities. Ultimately, the rank of a player improved based on the amount of gold and the number of constructions. Eventually, the rank was sufficiently high to become an emperor. The learner was motivated to review flashcards in order to earn gold, which was the main resource in the game.

These previous attempts to gamify Anki demonstrated the interest in making the software more appealing for the users. The majority of them focused only on improving the visual appearance of Anki, while others implemented actual game elements and schemes to it. However, the main drawback of these alternatives was their narrow availability since they have been solutions for the desktop interface only (registers of gamified versions of AnkiDroid were not found). In addition, the lack of competitive elements, an essential component of game schemes, might have reduced the overall benefits of these solutions. Nonetheless, this work can be considered for further attempts to gamify Anki.

Chapter 4

Design and Implementation

The inclusion of game schemes and elements in AnkiDroid required an analysis of its original design. The purpose was finding suitable parts in the structure of the application to integrate gamification components. Once these parts were found, the next step was to set an initial gamification strategy to modify the application. Later, it was necessary to design an approach to include a casual game. Such an approach needed to define a scheme to link the game to reviewing flashcards by means of the initial gamification strategy as seen in Figure 4.1. Finally, it was necessary to consider user interface aspects for a smooth integration of the overall solution.

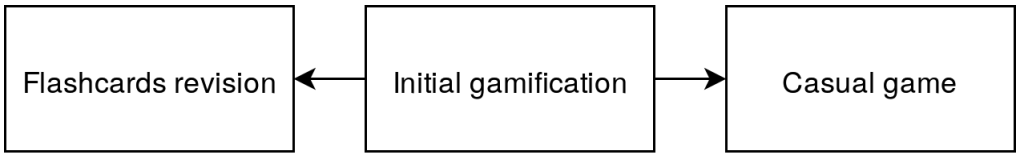

Figure 4.1: High level view of the design components and their relationships.

4.1 Components of Interest in AnkiDroid

AnkiDroid is a mature application with a clear structure and well-defined logic. It has a user interface that follows the best design principles for mobile development. Despite its multiple features and functionalities, the core element is the flashcard reviewer. Here is where the application allows the users to benefit from the effects of spaced repetition. The available interactions to review flashcards permit the user to progress by checking the front of a flashcard (question), revealing its back (answer), and assessing it, which automatically leads to a new flashcard as seen in Figure 4.2.

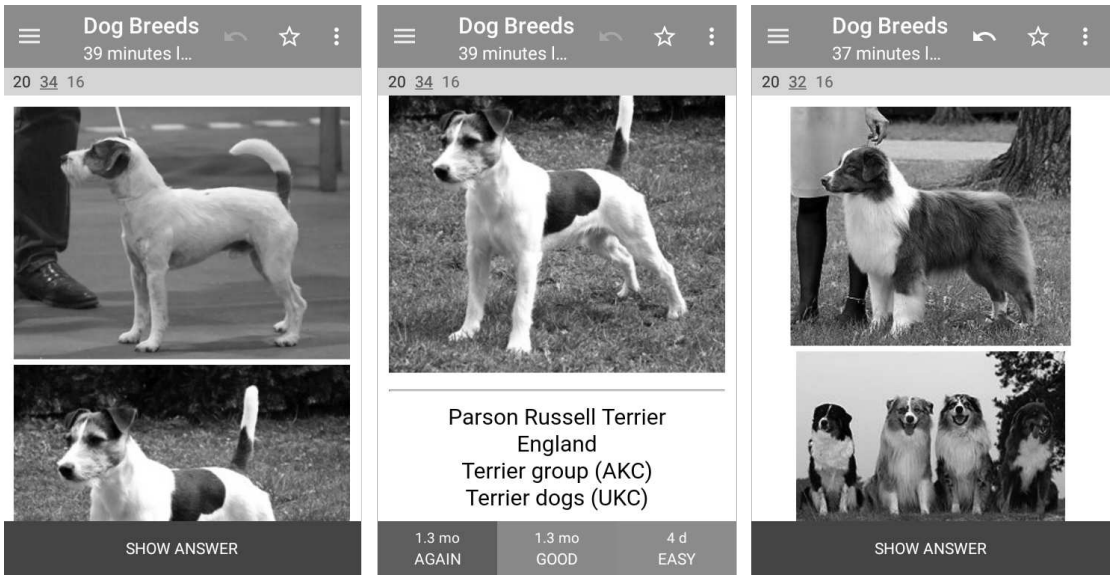

Figure 4.2: Flashcard reviewer showing the front, back, front flow.

Many other secondary components are developed around the revision of flashcards, with the deck picker as the most relevant one. This component is the first contact users have with the application. Its main role is displaying the available decks of flashcards as seen in Figure 4.3. It also allows several actions on the decks including selection, deletion, and addition. When users select a deck, the application starts the flashcards revision process. The deck picker connects to other parts of the application like statistics and settings. Finally, the deck picker displays other information including the number of flashcards and the time reviewing them.

The visual and logic characteristics of the flashcard reviewer and the deck picker were used to facilitate the inclusion of game elements and schemes. Visually, both elements present a structure that allows a smooth incorporation of new elements that do not interfere with their main purpose. In regard to logic, the deck picker allows getting access to new components of the application. On the other hand, the flashcard reviewer has a flow of events that can be linked to additional actions, which could provide instant feedback to users.

4.2 Initial Gamification Strategy

The process started with the definition of a model of extrinsic motivation based on rewards (Richter et al., 2015). The basic tangible component of this model had the form

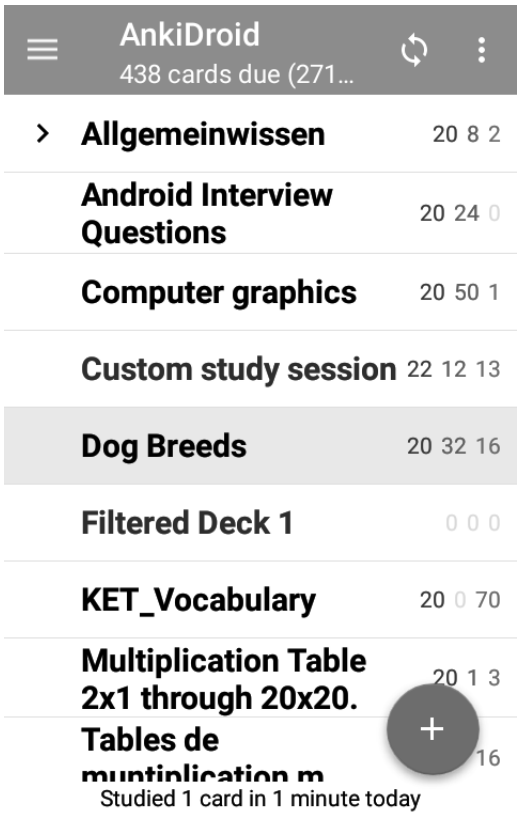

Figure 4.3: Deck picker showing the decks of flashcards.

of coins, which were tied to the revision of flashcards. The approach was extended to include points as an additional reward element that complemented the role of coins. Coins and points presented characteristics that allowed them to be used beyond the reward model. However, coins differed from points on how they could vary in number and the way users could use them.

The model of motivation was extended to include more advanced game elements built upon the basic rewards. It incorporated a set of achievements that was defined based on the number of points. The achievements were also set to provide a more game-like mood to the overall user experience. Later, a customisation scheme made use of the characteristics of points to link them to achievements. Points along with customisation were also used to define a social and competition scheme. Additional elements were defined to keep users informed about their progress.

4.2.1 Rewards

In games, a reward is something given to a player as the result of executing a task. In many cases, the objective is to motivate the player to do the same task again. In addition, rewards can also be defined as resources for later use; therefore, they can be accumulated. Based on this scheme, a virtual currency was defined in the form of coins. Since the core of the application was the revision of flashcards, such coins were given to users each time a flashcard was reviewed. Specifically, the number of available coins was increased each time the user assessed a flashcard.

A reward scheme requires the benefit the player receives to be proportional to the effort done. The content of the flashcards varied from one deck to another; it could be as simple as text, or as complex as images and audio. Therefore, the effort exerted in each flashcard was different. Thus, the number of coins granted in each flashcard was defined by the amount of effort. The most suitable way to calculate the effort of users based on the content of flashcards was by measuring the time spent on them. Hence, the number of coins per flashcard was defined as a function of time. However, a couple of restrictions had to be considered to avoid undesired behaviours from users.

Given that coins were also resources, users could be tempted to obtain them with minimal effort. One potential misbehaviour was passing flashcards as fast as possible to obtain the highest number of possible coins. Moreover, users could intentionally spend more time reviewing flashcards to obtain more coins. Diminishing these issues required setting ranges of time. Therefore, there were three ranges to calculate the number of coins in each flashcard: null, linear, and constant. The null range was one second long and started the moment a question or an answer was displayed. The linear range was three seconds long, and the number of coins was proportional to the amount of time. Finally, the constant range lasted until a new answer or question was displayed and no coins were given.

$$c(t) = \begin{cases} 0 & \text{if t} \leq 1 \\ t & \text{if } 1 < \text{t} \leq 3 \\ 3 & \text{if t} > 3 \end{cases} \tag{4.1}$$

Equation 4.1 describes the calculation of coins, where c is the number of coins as a function of the elapsed time in seconds, t. The number of coins was always an integer value. It is important to note that there were minimum and maximum numbers of coins that could be earned in each flashcard, 0 and 6 (3 for the question and 3 for

the answer) respectively. A potential drawback when calculating coins was the repetition of a flashcard since AnkiDroid allows undoing the previously reviewed flashcard. Therefore, users could earn additional coins for the same flashcard. However, reviewing a previous flashcard again was not penalised, and the previously earned coins were kept.

Coins could be spent by users to get benefits that will be explained later. This dynamic characteristic and how they were calculated could potentially reduce their potential benefits as rewards. Thus, it was necessary to implement a new element with a similar earning scheme but additional characteristics. Points are common elements in games. Their objective varies from context to context, but usually, they are used as additional rewards and provide information about progress since they are accumulative. Other educational platforms have added points as a motivational element (DiSalvo, 2014).

Points were designed to be calculated in a similar way to coins. There existed ranges of time to earn coins. The first range had the same objective as the one for coins, so, its duration was similar. A second range was meant to earn coins proportionally to the time; however, the relation is not linear but logarithmic as seen in Equation 4.2, where p is the number of points as a function of the elapsed time in seconds, t. Since logarithms are negative for values less than one, a max function between 1 and the logarithm was applied to avoid negative points. Finally, the number of points was always an integer.

The logarithmic relation and the lack of a limit for points had two objectives. First, the creation of an additional distinction between points and coins. If the number of coins and points in a flashcard were greater than 0, it was unlikely that they were the same value. The second goal had to do with the limit for coins. Since the content of some flashcards could require more time than usual to review, the maximum number of coins per flashcard acted as a penalisation for flashcards with large content. Therefore, the lack of a limit for the number of points earned in a flashcard compensated for the coins penalisation in large flashcards.

$$p(t) = \begin{cases} 0 & \text{if t} \leq 1 \\ max(1, 10log(t)) & \text{if t} > 1 \end{cases} \tag{4.2}$$

4.2.2 Achievements

Rewards are by nature obtained after doing small tasks. Several games implement more advanced elements that increase the players' motivation; they are known as achievements. They are similar to rewards, but the main difference is the size of the tasks to get them. Those tasks usually require more time, the execution of a sequence of steps, or the repetition of smaller tasks. The most basic task in AnkiDroid is the revision of flashcards, which served to define the achievements scheme; moreover, the accumulative nature of points was also useful in the design.

In the solution, the achievements were designed to be obtained after the repetition of a small task (revision of flashcards). The number of points was used as the element to inform users of the progress to reach each achievement. Unlike rewards like coins or points that do not have a limit, achievements were defined as a set of specific elements to be gotten with a specific number of points. Therefore, users were aware of the number of available achievements and the required points to obtain them. Moreover, the application provided information about the reached achievements and the remaining ones.

In addition, to give AnkiDroid a more game-like mood, achievements were depicted as pets to be rescued. Those pets were called ankimals, a term that merges the words Anki and animals to provide a sense of identity with the application. The feeling of rescuing pets was complemented with notifications to inform users when a new ankimal was freed. The notifications were designed to encourage the users to rescue more pets by earning more points; therefore, they indirectly asked users to review more flashcards as seen in Figure 4.4.

4.2.3 Customisation

Games provide customization aspects to give a more personal experience to players. In the solution, this scheme was defined with two elements. The first one was a nickname that could be set by the user. This element was meant to give a higher sense of participation within the application. The second aspect of a more personal experience was an avatar. It was meant to provide a visual representation of a player, which helped to create a sense of individuality. Both elements aimed at creating a sense of identity, but they differed in levels of customisation and constraints.

Nicknames were quite customisable and flexible. The only restriction was the maximum number of characters (12). Users were able to set their nicknames at any point.

Figure 4.4: Notification shown to user when an achievement is reached.

On the opposite, avatars were limited to some images, and users were required to get a number of points and icons. Unlike some games and applications where users can use any image to set an avatar, the application allowed users to choose one of the rescued ankimals. Moreover, since coins were defined as resources, users needed to spend a number of them to set ankimals as their avatars as seen in Figure 4.5. An additional level of customisation permitted users to colour ankimals since they were originally depicted in greyscale.

4.2.4 Social and Competition

The informative nature of points was also used to integrate another common element of games: leaderboard. In the solution, the leaderboard had two objectives. First, it provided a social context to the users. Thus, they knew that there were other people using the application. The social context was boosted with the inclusion of nicknames and avatars as seen in Figure 4.6. That meant users could have a broader context of their identities within the application. Not only were they able to define their nicknames and avatars, but the leaderboard also provided a way to see others'.

The second objective of the leaderboard was aimed at adding a new level of motivation for the revision of flashcards. Since positions in the leaderboard depended on the number of points, users needed to review more flashcards to increase the number of points, hence, improve their positions. In addition, the positions were depicted as chess pieces, which could be interpreted as achievements. However, unlike rescuing

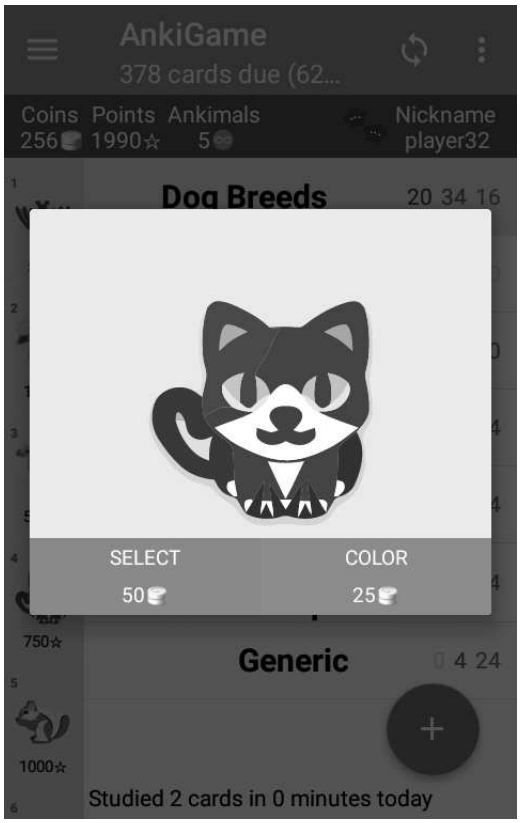

Figure 4.5: Dialog to select and colour a rescued ankimal.

ankimals, reaching a position in the leaderboard was not definitive. A position in the leaderboard could be lost against other users.

4.2.5 Progress

It was necessary to keep users informed about the state of the new gamification elements of the application. Similar to games that provide elements to inform about progress and other aspects, the solution added a status bar to provide information about the points, coins, rescued ankimals, avatar, and nickname. This new visual element was designed to be easily integrated into relevant parts of the application as seen in Figures 4.7 and 4.8, where it is located and constantly visible below the main bar of the application. Moreover, the design allowed instant updates of its elements.

Additionally, a list of elements was also added in the deck picker to show the rescued and not rescued ankimals as seen in Figure 4.8. The list had the same informative purpose of the status bar; however, they differed in the interactions. While the status bar did not enable any kind of interactions, the list allowed users to pick any ankimal

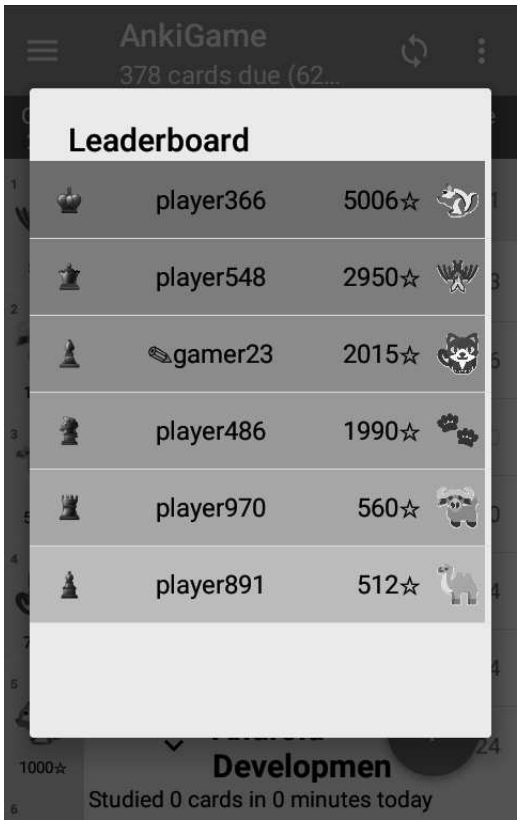

Figure 4.6: Leaderboard showing the nicknames and avatars of users.

to set it as their avatar or add colour to it. The interactive nature of the list of ankimals was consistent with the list of pickable decks. Moreover, they shared the same vertical layout.

4.3 Game Integration

The most important design decision in the solution was the inclusion of a game. The integration of a game was the key difference with other gamification approaches. Unlike the previously described elements that added new features to existing functionalities, a game was a completely new component in the application. Therefore, it was required that the game be easy to play and avoided an unnecessary level of complexity. For this reason, a casual game was the most suitable option. Casual games are straightforward and their gameplays allow short periods of play, which convert them into activities that can be executed during work or study breaks.

The game needed to be integrated into AnkiDroid in a way that it fitted in the structure easily. Moreover, the integration required the definition of a linkage between

Figure 4.7: Modified flashcards reviewer displaying informative gamification elements.

the game and other components of the application. These conditions set the scenario to modify the game and use the previously described gamification elements. The final design set the game as a component with some flexibility to use and smoothly connected to the rest of the application. However, the design also included some constraints aimed at increasing the user engagement of flashcards revision.

4.3.1 Modifications to the Game

2048 is a simple yet challenging game due to the high number of turns to form the block 2048 (1024 turns in the perfect case). Another aspect that increases the difficulty of the game is the limited space. If there are no more empty cells in the grid, and no further movements are possible, then the game is over. Such difficulty along with the need to connect the game with the rest of the application set the starting point to modify the game. Such modifications had to be consistent with the easy-to-use paradigm of casual games. Moreover, they needed to maintain a consistency such that their behaviour and results were easy to understand.

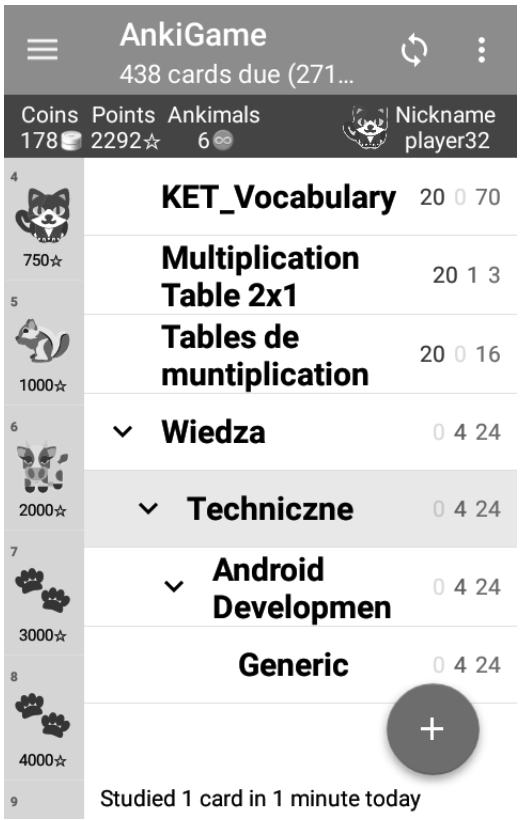

Figure 4.8: Modified deck picker displaying informative gamification elements.

Based on the requirements to modify the game, a set of elements was defined to ease the gameplay. Those elements took the form of cheat tricks aimed at providing more alternatives to win. Each trick changed the state of the grid so that players had more options in a next move. The state of the grid was defined by the positions of the blocks and their values at a given turn. Therefore, there existed several approaches to change the state of the board. Moreover, each trick needed to provide a different degree of benefit; thus, they were not equally valuable. The modifications included four cheat tricks as seen in Table 4.1. It is important to note the restrictions to use them based on the state of the grid.

4.3.2 Connection with Flashcards Revision

A connection meant finding existing elements in AnkiDroid that could act as the glue material between the game and the revision of flashcards. In other words, the connection had to be done to include a motivational aspect to encourage users to review more flashcards to obtain benefits in the game. Thus, the user engagement could increase

Name	Benefit	Usage conditions
Gift	Adds a randomly positioned block that can merge with any block whose value is less than 512.	There is at least one empty cell in the grid.
Doubler	Doubles all the blocks whose values are 2.	There is at least one block with a value of 2 in the grid.
Remover	Removes all the blocks whose values are 2.	There is at least one block with a value of 2 in the grid. There is least one block with a value greater than 2.
Undo	Undoes the last movements (up to 10 previous movements).	There are previous movements.

Table 4.1: Cheat tricks for the game, their benefits, and usage conditions.

by adopting elements from AnkiDroid to the logic and structure of the game. The original application did not present elements that could be easily adjusted to the game. However, two of the gamification elements defined earlier provided a way to make the connection.

The first elements were points, which already provided a motivational aspect in the revision of flashcards. The informative nature of points was previously used to define achievements in the revision of flashcards. Following the same scheme, they were also used to define achievements in the game. In this case, the cheat tricks in the game were linked to a specific number of points based on the benefits they provided; the higher the benefit, the higher the number of points. Therefore, the tricks were initially hidden, then, users needed to obtain the corresponding number of points to reveal each trick. Finally, unlike ankimals, users were not notified when a trick was revealed since the main interest was the revision of flashcards, not playing the game.

The number of available tricks was small (4), and revealing each of them was a one-time event. This situation could potentially limit the connection between the game and the revision of flashcards. Therefore, it was necessary to take advantage of coins, which were already used as resources to select and colour ankimals. In the game, once the tricks were revealed, players could use them at any point as long as they had the required number of coins. In some sense, users needed to buy tricks with the coins they earned reviewing flashcards. Similarly, a specific number of coins was set for

each trick based on the benefit level as seen in Table 4.2.

Cheat trick	Benefit level	Points	Coins
Gift	Low	100	10
Doubler	Medium	500	20
Remover	High	1000	30
Undo	Higher	2000	40

Table 4.2: Costs of cheat tricks in terms of points to reveal and coins to use them.

4.4 User Interface Considerations

Several user interface aspects were considered to implement the game elements described earlier. First, the modifications in the game required the addition of interactive elements for each cheat trick. Initially, opacity information was used to differentiate the cheat tricks and to provide clues about their status (blocked, enabled, usable) as seen in Figure 4.9. Moreover, since the gameplay required the users to slide vertically and horizontally, cheat tricks could easily be selected by mistake. Avoiding that problem required designing a translucent curtain to be removed by the user before selecting cheat tricks.

In AnkiDroid, the main considerations to implement the game elements were related to keeping consistency in the overall aspect of the application and the visual clues for the user. The first aspect required using the same colour scheme along with other elements like the font type and size. On the other hand, visual clues were meant to provide information about modifications in the game elements. This was done by implementing animations where necessary. For instance, when the number of coins or points changed, animations that updated the corresponding visual elements were implemented. Finally, the visual structure was maintained as much as possible to avoid the new components from being intrusive.

Figure 4.9: Modified game showing the cheat tricks with different status at the top of the grid. Icons by Freepik from www.flaticon.com

Chapter 5

Experimental setup

The proposed solution was tested in a study that required the definition of several conditions. First, it required to define the type of data to be collected. Then, the structure of data and the mechanisms of the collection were established. It was also important to identify the type of participants and divide them into groups to test different versions of the application. The versions of the application were distributed over a platform to let participants install them with ease. Finally, the study was set over a period of time, and the application was delivered to a broader audience.

5.1 Type of Data

The required data to analyse and evaluate the solution came from the application. The data were automatically generated every time users interacted with the application. This type of data had a quantitative nature; therefore, it was possible to measure and analyse it from a statistical point of view. This type of data were collected from the start to the end of the period of the study.

Originally, AnkiDroid collects a lot of useful information, which is available to users in the form of statistics. These data are quantitative and give users a perspective on their progress based on the number of flashcards review, the number of sessions, the amount of time in sessions, and more. The application even forecasts the number of flashcards to be reviewed in the near future. This information was not collected for analysis since it provides a general overview of the usage from the perspective of users and lacks details related to the integrated game and the gamification elements.

5.2 Collection and Structure of Data

Quantitative data were generated in points where users interacted with the application, e.g. playing the game, selecting a deck, or reviewing flashcards. Each time an important interaction was done, the application processed the relevant information and sent it to an external server to save it. Therefore, it was necessary to define a scheme to format the information before storing it. The format was also aimed at facilitating the analysis and interpretation of results. Thus, quantitative information was grouped into four categories as seen in Table 5.1.

Category	Description
Common	Details of time and user.
Game	Details about the game.
Gamification	Details of game elements.
Anki	Details of flashcards and decks.

Table 5.1: Categories of quantitative information collected from the application.

The common category was meant to identify the time, date, and user that generated the interaction. This type of data was part of every relevant interaction in the application. The next category of information was related to the game; it included details about the score, cheat tricks, and state of the grid. The gamification category had to do with the added game elements to AnkiDroid. It included details about the number of coins, number of points, and names of the ankimals. Finally, the Anki category referred to details about the decks, flashcards, and revision times.

The categories of information were stored in the form of logs. Logs were a scheme to assemble and structure information from different categories based on the relevant interactions generated in the application. Logs were grouped into two main classes: game logs and Anki logs. Game logs contained information from the game category; however, some data from the gamification category was also registered in these logs. Anki logs contained information from Anki category with some data from the gamification category. Information about common category was recorded in both groups of logs as seen in Figure 5.1.

Specifically speaking, there were 6 types of game logs and 9 types of Anki logs as shown in Table 5.2. Game logs were generated in the game context. Something similar occurred with Anki logs; however, the design of the solution allowed one Anki

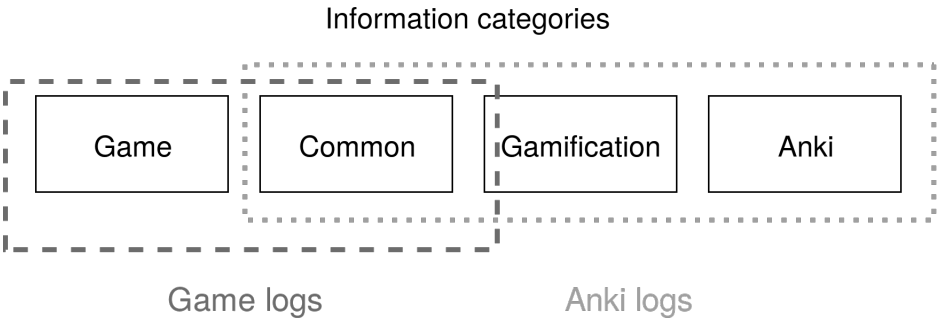

Figure 5.1: Types of logs and their relationships to information categories.

log to be generated in the game context: Leaderboard checked. This was possible because users could open the leaderboard either in the game context or in the Anki context. The reason for this design is that the leaderboard provided information about the social aspect. Despite the fact that the leaderboard displayed gamification data (points), users were not asked to do a specific action in Anki or the game contexts to see their positions.

Type of log	**Name of log**
Game log	Game won
	Game lost
	Game restarted
	Trick used
	Trick failed
	Switched to anki
Anki log	Leaderboard checked
	Custom study set
	Flashcard answer revealed
	Flashcard assessed
	Deck selected
	Ankimal rescued
	Ankimal selected
	Ankimal coloured
	Switched to game

Table 5.2: Types of logs collected from the application.

5.3 Participants

The study required recruiting a group of participants to use the application. The main requirement was to have an Android device to install the application. It was not necessary that participants had a specific profile. However, to maintain some level of homogeneity, the recruitment was done based on previous experience with AnkiDroid or other interfaces of Anki. The selected participants did not have any previous contact with Anki. Therefore, they were new to this educational tool and the modifications explained in chapter 4.

Participants were recruited while the application was in the development phase. During this process, they were informed about the objective and duration of the study. Since they did not have any previous experience with AnkiDroid, they were taught about the objective, benefits, and functionalities of the application. In addition, they were also informed about the gamification features and the casual game. Participants were not forced to be part of the study from start to end. They were free to leave the study at any point as this situation provided additional insights into the application.

5.4 Groups of Participants

As described in section 4.3, the key difference between the proposed solution and others was the inclusion of a casual game. For this reason, the application was split into two versions. The first version had the causal game and all the other gamification elements; this version was named AnkiGame (Velasquez, 2018a). The second version did not have the integrated game, but the other gamification elements were available; this version was named AnkiPlay (Velasquez, 2018b). Therefore, it was possible to analyse the effectiveness of the integration of a casual game as a means to increase user engagement.

Since there were two versions of the application, the participants were divided into two sets, each with six randomly selected members. The resulting sets were defined as the control group and the experimental group. Participants in the control group were given the AnkiPlay version, whereas participants in the second group were given the AnkiGame version as seen in Figure 5.2. None of the participants were told about the existence of the other version of the application. This decision was made to reduce any potential bias in the use of the application.

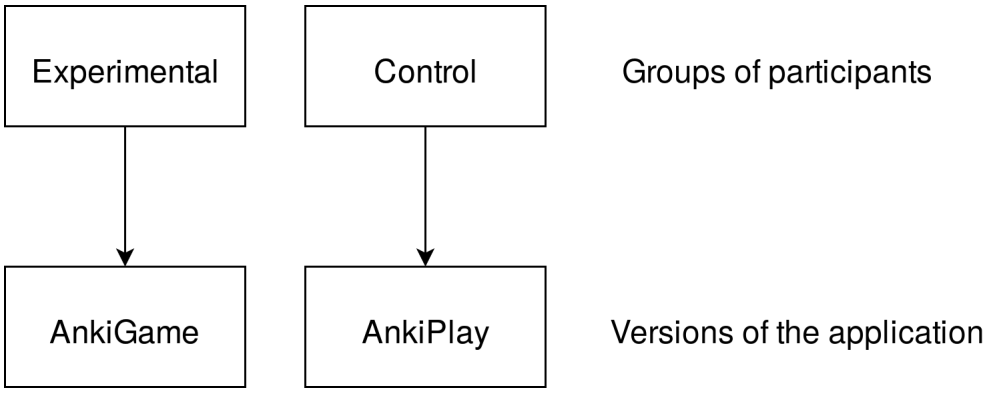

Figure 5.2: Groups of participants and the assigned versions of the application.

5.5 Distribution of the Application

The application was distributed in the Google Play Store. This platform allows having multiple versions of the same application in independent contexts. Therefore, it was possible to publish AnkiGame and AnkiPlay simultaneously. Thus, participants had an easy way to find and install the corresponding version on their devices. Another advantage of this platform is the different testing stages it offers. This feature was used to set a beta testing phase where potential issues were found and additional improvements were added to the application before making it available to participants.

In addition, Google Play Store allows making updates to correct bugs, add new features, or release new versions of an application. The updates are automatically installed in devices that already have the corresponding applications. Moreover, the distribution platform provides insights into the use and performance in the form of statistics. Users have the option to provide additional quantitative data by rating the application.

5.6 Duration of Study and Broader Audience

The study was set to last four weeks when participants used the application and generated data. The study period was divided into two stages as seen in Figure 5.3. The first stage lasted three weeks, and users were suggested to use the application at least during this period, but as explained in Section 5.3, they were not forced to do so. At the end of this period, participants could stop using the application. For the second stage, participants were recommended to keep using the application if they wanted to.

A study with two phases was intended to provide more insights into the use of the application from those participants who kept using it.

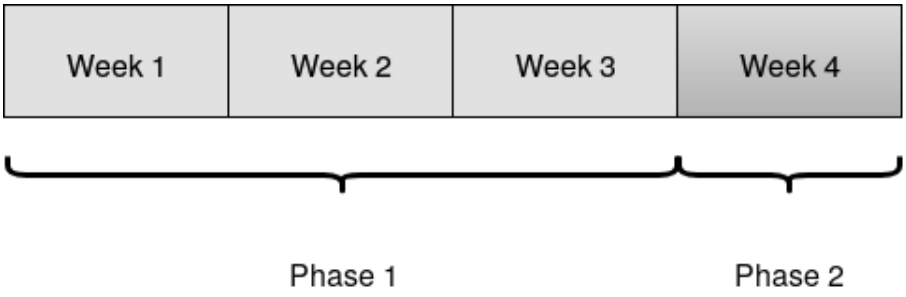

Figure 5.3: Duration and phases of the study period.

Since the application was openly distributed in Google Play Store, it was possible to make it available to a broader audience. Therefore, additional data were gotten from other people. This data provided extra insights into the use of the application. In this case, the application was advertised in AnkiDroid forums; therefore, it is likely the majority of new users had a previous contact with the original application. Therefore, the information from these new users was isolated from the information from the participants to avoid any incorrect analysis. The users that were not part of the original study were also informed about the nature and objectives of the application.

Chapter 6

Evaluation and Results

The data collected from the study was processed and compiled to extract information aimed at evaluating the effectiveness of the integration of a casual game as part of the gamification strategy. The evaluation was done in terms of user engagement, which required the definition of some metrics. These metrics provided insights into the behaviour of users in every group. Then, a hypothesis testing showed that the user engagement did not present a statistically significant variation between the control and experimental groups.

6.1 User Engagement Metrics

Evaluating the solution in terms of user engagement required the definition of some metrics. There are many alternatives to measure user engagement in mobile applications. The selection of one option over others depends on the aim of every application. As seen in Section 4.1, the core element of AnkiDroid is the flashcard reviewer. This component is where users get the benefits from the effects of spaced repetition. Therefore, the metrics of use for user engagement are defined around the actions and parameters that depended on the interactions done in this element.

Based on the original functionality of the flashcard reviewer, the first metric was the total number of flashcards reviewed during the period of study. This metric included the repetitions of flashcards since they are the foundations of the spaced repetition technique. Thus, the metric did not consider the performance of users. In other words, it did not penalise users based on their previous knowledge or ability to learn new things.

The flashcard reviewed was modified to include the earning of coins and points.

These two parameters were also considered for the evaluation since they gave additional information about the number of flashcards. It is important to note that, as expressed in Equations 4.1 and 4.2, the number of points and coins depended on the time reviewing flashcards, which complemented the information from the total number of cards.

The total number of flashcards reviewed by each user depends on the amount of content of every flashcard. Since users were free to review flashcards based on their interests, chances are that they did not use the same decks. Therefore, the number of flashcards might not provide enough information. For this reason, another metric of use was the amount of time (measured in seconds) reviewing flashcards. This information was somehow encapsulated in the number of coins and points, but as seen in Equations 4.1 and 4.2, some flashcards could have given zero points and coins.

Other important metrics obtained from the compiled logs included the number of interactions, days using the application, average interactions per day (AIPD), the period of use, average time between sessions (ATBS), and the number of decks. The values of these metrics are detailed in Tables 6.1 and 6.2. At a glance, the values are better for the experimental group, e.g., the number of reviewed flashcards is visually higher for the experimental group as seen in Figures 6.1 and 6.2. However, these comparisons are not enough to evaluate the user engagement.

Participant	1	2	3	4	5	6
Total cards	738	125	51	40	37	0
Total points	1990	263	402	131	252	0
Total coins	818	93	173	54	105	0
Time in cards (seconds)	2317	386	354	143	223	0
Interactions	1532	266	106	88	83	2
Days using app	12	5	2	2	3	1
Period of use (days)	22	11	8	2	8	1
Decks	3	3	3	3	2	1
AIPD	128	53	53	44	28	2
ATBS (days)	1.8	2.2	4	1	2.6	1

Table 6.1: User engagement metrics per user in control group.

Participant	1	2	3	4	5	6
Total cards	745	625	370	114	74	51
Total points	6221	1152	1311	1489	447	211
Total coins	2169	449	549	460	163	78
Time in cards (seconds)	7826	1495	1252	2433	554	252
Interactions	1699	1301	1250	294	180	114
Days using app	12	9	28	6	7	3
Period of use (days)	18	14	28	12	22	3
Decks	16	4	4	5	3	2
AIPD	142	145	45	49	26	38
ATBS (days)	1.5	1.5	1	2	3.1	1

Table 6.2: User engagement metrics per user in experimental group.

6.2 Hypothesis Testing

The proposed solution was designed to implement a gamification strategy that integrated a casual game. The objective was to provide users another extrinsic motivational element aimed at increasing user engagement. In other words, the goal of the project was the integration of a casual game as part of the gamification strategy to increase user engagement. Specifically, the hypothesis for the study was formulated as follows:

> **User engagement is higher in the experimental group than in the control group.**

The hypothesis was tested using the Student's t-test analysis over the defined user engagement metrics. This required defining the null hypothesis as follows:

> **User engagement does not differ in the experimental group and the control groups.**

The results of the t-test are shown in Table 6.3. As can be seen, the majority of mean absolute values are larger in the experimental group. However, the p-values are not significantly small, which means that the null hypothesis could not be rejected. Moreover, the intervals of confidence at 95% confirm that the results are not statistically significant, as seen in Figure 6.3. Therefore, the difference of the means for every metric were due to chance. Thus, it was not possible to conclude that user engagement

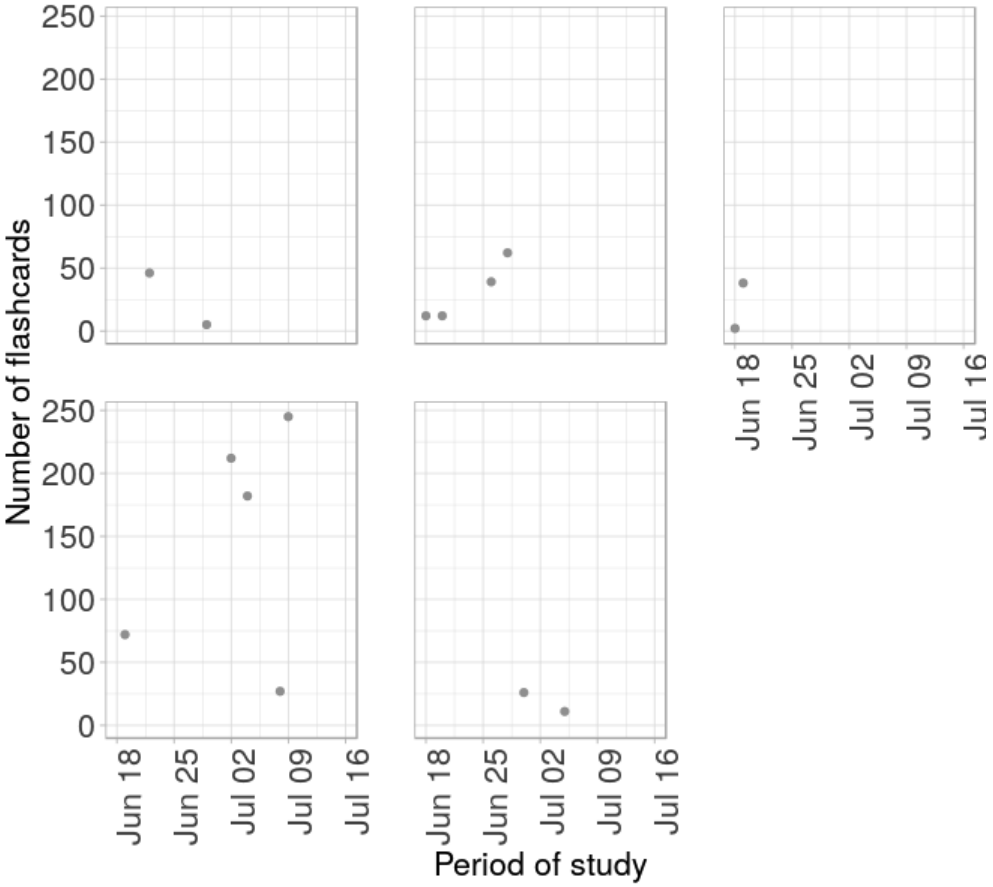

Figure 6.1: Number of reviewed flashcards per user in the control group.

was affected by the integration of a casual game in a gamification strategy. Similar results were obtained from the data collected from users of a broader audience as seen in Table 6.4.

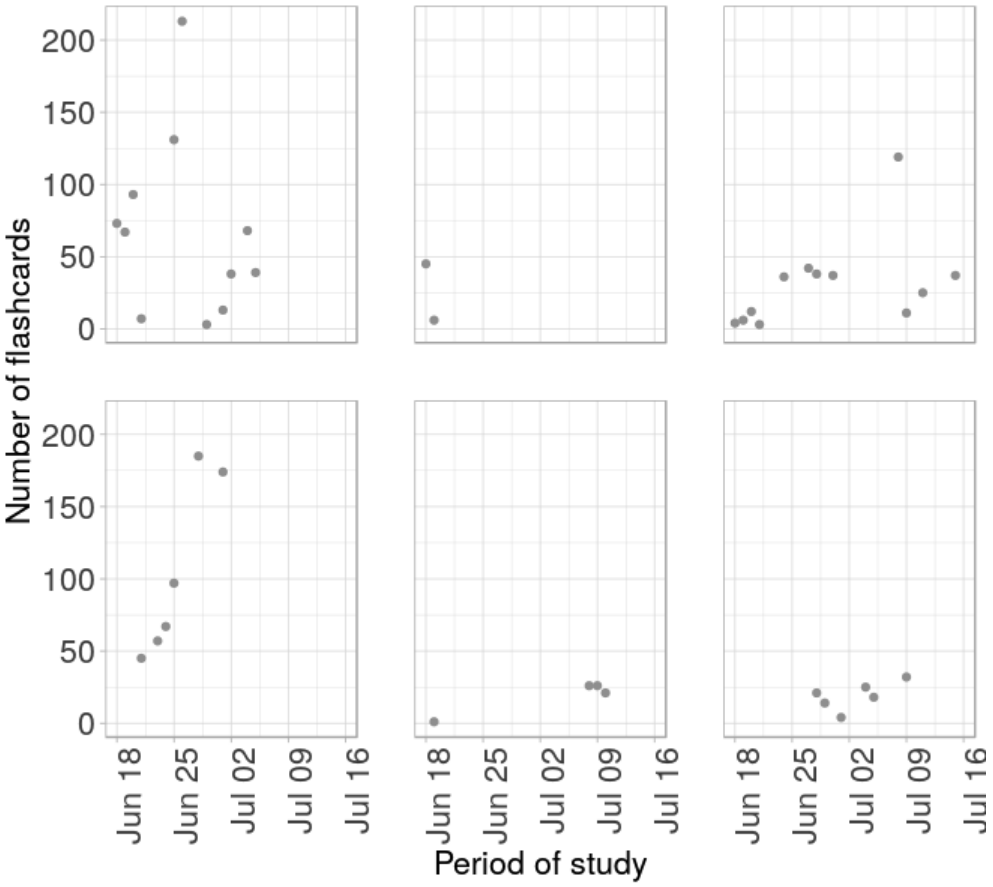

Figure 6.2: Number of reviewed flashcards per user in the experimental group.

Metric	μ CG	μ EG	t-value	p-value
Total cards	65.2	329.8	-0.98	0.35
Total points	506.3	1805.2	-1.36	0.22
Total coins	207.2	644.7	-1.29	0.24
Time in cards (seconds)	570.5	2302	-1.44	0.20
Interactions	346.2	806.3	-1.25	0.24
Days using app	4.2	10.8	-1.66	0.14
Period of use (days)	8.7	16.2	-1.60	0.14
Decks	2.5	5.7	-1.48	0.20
AIPD	51.3	74.2	-0.81	0.43
ATBD (days)	2.1	1.7	0.74	0.48

Table 6.3: T-test values for user engagement metrics in the study groups. CG stands for control group, EG stands for experimental group.

Metric	μ AP	μ AG	t-value	p-value
Total cards	1815.42	524.67	0.74	0.48
Total points	14156.33	5087.10	0.58	0.57
Total coins	5106.25	1676.92	0.68	0.50
Time in cards (seconds)	15493.33	10400.92	0.30	0.77
Interactions	3707	1126.5	0.72	0.49
Days using app	5.33	5.83	-0.13	0.90
Period of use (days)	8.58	6.50	0.48	0.63
Decks	3.75	3.5	0.14	0.89
AIPD	178.5	50.25	0.91	0.38
ATBS (days)	1.90	1.08	1.83	0.09

Table 6.4: T-test values for user engagement metrics in the broader audience. AP stands for AnkiPlay, AG stands for AnkiGame.

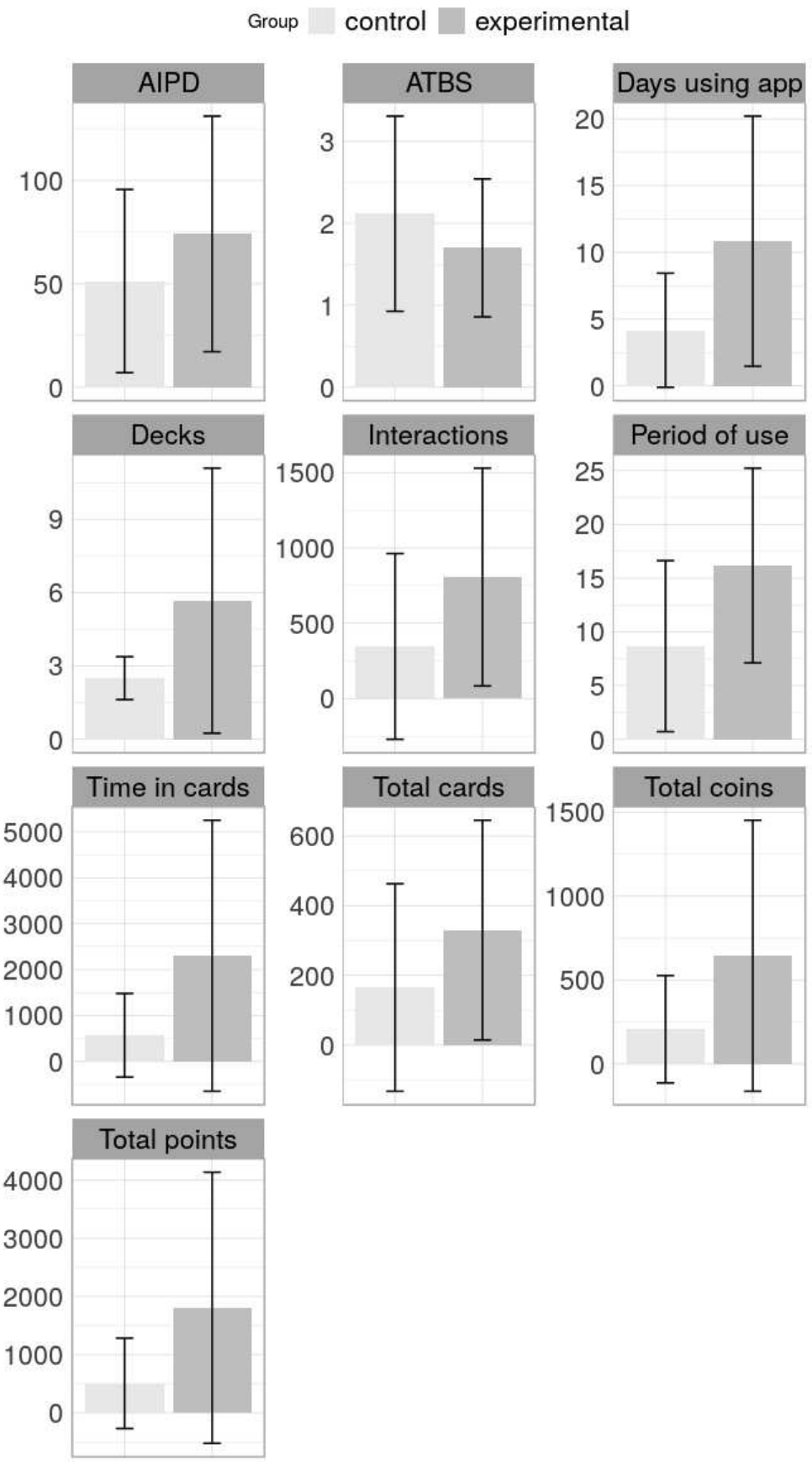

Figure 6.3: Means and intervals of confidence at 95% for every metric.

Chapter 7

Conclusions

The present work described the process of gamifying an educational tool along with an evaluation based on the results obtained from data collected from new users of the application. The discussion was based around potential issues in the designed gamification strategy as well as the profile of the selected participants. It is important to note that gamification and other techniques that include extrinsic motivational elements are unlikely to give good results if the users lack the intrinsic motivation. Finally, a set of future projects were proposed based on the results and potential issues of the presented solution.

7.1 Discussion

Gamification provides a way to include extrinsic motivational elements in different contexts. In educational tools, these elements can be used to make the learning experience more appealing, which may be reflected in a higher user engagement. The current project presented a gamification strategy in AnkiDroid aimed at increasing user engagement. The key difference with other gamification alternatives was the integration of a casual game as an additional motivational element. The results showed that the proposed alternative did not have a statistically significant variation of user engagement compared to a traditional gamification strategy.

The structure of the solution was aimed at creating a link between the revision of flashcards and the casual game such that users had an extrinsic motivation to review more flashcards. However, one of the potential issues of the solutions might have been the flow of the connection between the game and the flashcards revision. Switching between the game and the revision of flashcards used the deck picker as an intermedi-

ary point. The design was done in that way considering that the deck picker was the place in the application to get access to other functionalities.

Since the participants selected for the study did not have previous experience using AnkiDroid, the learning curve to use the application might have been another potential issue. AnkiDroid is a mature application, but it contains many features that might be difficult to understand at the beginning. Moreover, the application presents information to users that makes sense as long as they understand some concepts of spaced repetition. In addition, the modifications done to the application added an extra complexity to the application even though they were implemented so as not to be intrusive.

In addition, it is important to note that gamification provides the tools to include additional extrinsic motivational elements. It is critical that the users have the intrinsic motivation, i.e. learning something. If users are not interested in getting the benefits of an educational tool, other extrinsic motivational elements are unlikely to help. In the study, the participants might have lacked the intrinsic motivations; hence, they might have been lacking interest in the application overall.

7.2 Future Work

The presented work used a gamification strategy that integrated a casual game aimed at increasing user engagement in AnkiDroid. The obtained results were non-conclusive about the gamification strategy, and further evaluation must be performed. However, this does not mean that gamification has to be discarded as an alternative to improve the user experience. Based on the potential issues discussed before, additional work can be done aimed at testing the effectiveness of the gamification strategy with people that are guaranteed to have the intrinsic motivation, e.g. students of different educational levels, employees starting a new job, or people interested in learning new topics from a specific field.

Gamification techniques can also be studied in the context of facilitating the use of tools to new users. As discussed, AnkiDroid has an important level of complexity that requires users to spend some time to understand its features and functionalities. A gamification strategy could be aimed at providing a better user experience for new users and increasing retention. Moreover, the effects of gamification can also be studied in more advanced users only.

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