TU WIEN Informatics

Alchemist

A pervasive game to create awareness about food additives

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TU WIEN Informatics

Alchemist

Bewusstsein über Lebensmittelzusatzstoffe schaffen

DIPLOMARBEIT

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Wien, 18. August 2020

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Kurzfassung

In der jüngeren Vergangenheit wurde die traditionelle häusliche Küche aufgrund des modernen westlichen Lebensstils durch das Aufkommen von Fertiggerichten, Fast Food oder Essenslieferdiensten zurückgedrängt. Damit diese Fertiggerichte jedoch zu einem günstigen Preis produziert, über weite Strecken transportiert und für Wochen oder Monate gelagert werden können, um dann ohne großen Aufwand von den KonsumentInnen zubereitet werden zu können, müssen ihnen verschiedene Zusatzstoffe, wie etwa Geschmacksverstärker, Lebensmittelfarben oder Konservierungsstoffe, beigefügt werden. Kürzlich veröffentlichte Studien kamen zu dem Ergebnis, dass sich diese hochgradig verarbeiteten Lebensmittel negativ auf das sich im menschlichen Magen-Darm-Trakt befindende Mikrobiom auswirken und mehrere Krankheitsarten, wie etwa Stoffwechsel- oder Entzündungserkrankungen, auslösen können. Diese Diplomarbeit untersucht, ob ein eigens erstelltes Spiel dazu verwendet werden kann, um Bewusstsein über diese Zusatzstoffe zu bilden. Um eine solche Anwendung zu gestalten, wurden ähnliche Projekte im Rahmen einer Literaturrecherche untersucht und ein bereits bestehendes Konzept analysiert. Basierend auf diesen Ergebnissen wurde ein Kartenspiel entwickelt, welches dazu eingesetzt wurde, um mehrere Vermutungen bezüglich möglicher Spielmechaniken zu testen. Dazu wurde das Spiel während mehrerer Sitzungen mit einer Reihe von TeilnehmerInnen ausprobiert. In dem daraus resultierenden Spielkonzept schlüpfen die SpielerInnen in die Rolle von Alchemisten, welche verschiedene Tränke brauen müssen. Die dazu benötigten Zutaten können aus realen Lebensmitteln, die durch das Scannen des jeweiligen Strichcodes, gesammelt werden. Ein Prototyp dieser Applikation wurde in mehreren Iterationen entwickelt und mit NutzerInnen evaluiert. Zwei Usability Tests wurden durchgeführt und über Fragebögen und Interviews wurde zusätzliches Datenmaterial gesammelt. Die Daten suggerieren, dass durch die Verwendung der Applikation tatsächlich Bewusstsein über Lebensmittelzusatzstoffe geschaffen werden konnte.

Abstract

In recent years the modern western lifestyle caused a decline of traditional home cooking in favor of convenience food, fast food or food delivery services. But to sell these convenience foods at an affordable price, ship or store them for weeks or months and prepare them with little to no effort by the consumers, these products need to contain various additives like flavor enhancers, food coloring or preservatives. Recent studies concluded that these "ultra-processed" foods negatively impact the microbiome of the human gastro-intestinal system and can lead to various diseases like metabolic or inflammatory disease. This thesis explores whether a pervasive game can be used to create awareness about these additives. In order to create such an application a literature review of similar pervasive and serious projects was conducted, and a pre-existing game concept was analyzed. Based on the results, a design game was created that helped to test various assumptions about possible features and mechanics by being play-tested in multiple sessions which involved multiple participants. In the resulting game concept the player takes on the role of an alchemist who needs to create various potions by collecting the required ingredients using their smartphone to scan real-life food products. A prototype of the application was then iteratively developed and evaluated with users. Two usability tests were conducted and additional data was gathered via questionnaires and interviews. The data suggests that the usage of the resulting application is in fact able to create awareness about food additives.

Contents

CHAPTER 1

Introduction

Given the rising popularity and wide distribution of smartphones, a device for accessing the internet, and therefore a vast body of knowledge and information, is at hand at almost every moment. As of the year 2020 it is estimated that a total of 3.5 billion people worldwide own a smartphone. [1] For a majority of smartphone users the primary purpose of such devices is no longer making calls or writing text messages but being a companion or assistant for everyday life. [2] [3] Due to the integrated technology and sensors smartphones can be a powerful tool in a broad spectrum of situations and for a wide variety of tasks. This is only amplified by the fact that the users can expand the functionality of their smartphones by installing additional applications. [4]

One category of these applications is focused on the subject of health and fitness. These applications range from mental health apps to apps that provide workout routines or act as running coaches and apps that target diet and nutrition and provide recipes or nutritional information of various food items. [5] [6] A popular example for such an app is MyFitnessPal[1], which allows its users to track various health related metrics, like caloric intake, and provides nutritional information for over eleven million different food items.

1.1 Problem Statement

A by-product of the modern western lifestyle is the decline of traditional home-cooking in favor of convenience food or fast food. Possible factors which support this trend include the collapse of the traditional division of domestic labour or family life, or the omnipresence of convenience foods. In turn, there is less time or interest in cooking at home then there was a few decades ago. As an accompanying effect, an erosion of cooking skills and a reduction of the knowledge about food items was documented. [7] This can be explained by the increasing consumption of convenience foods like ready-meals or

[1] https://www.myfitnesspal.com, last accessed: 2020-03-30

fast food or the widespread availability of food delivery services that, in turn, requires less expertise in the kitchen and therefore causes a deskilling and also prevents adults or children from being in the kitchen where they could pick up valuable cooking skills. [7] [8] To produce these convenience foods at an affordable price, ship and store them for weeks or months and prepare them with little to no effort by the consumers, these products need to contain various additives like flavor enhancers, food coloring or preservatives. [9] [10] Recent studies concluded that these "ultra-processed" foods negatively impact the microbiome that is present in the human gastro-intestinal system. [10] [11] Because of this negative connection and because approximately 99% of the microbiome is located in the gastro-intestinal system, ultra-processed foods can lead to various diseases like metabolic or inflammatory disease. They are also linked to an increased caloric intake – and therefore also weight gain in general – which also decreases the overall wellbeing. [9] [12]

1.2 Aim of the Work

The goal of this thesis is to explore if a pervasive game can be used to create awareness about food ingredients - especially additives - and in turn influence consumer buying or eating behavior. In the proposed game the players take on the role of an alchemist who has to create various potions - ranging from medicine all the way to poisonous mixtures. The pervasive nature of the game stems from the fact that, in order to acquire the necessary ingredients, the players need to use their smartphones to physically scan the bar code of products that contain those required ingredients. After they have successfully collected all ingredients the players can create and sell their potions. Then they can use the revenue made from the sale of their mixtures to service and upgrade their equipment in order to create more powerful brews. The goal of this interaction and the resulting feedback loop is to prompt people to pay more attention to the ingredients of products that they consume or encounter on a daily basis. In order to do that a functional prototype of "*Alchemist*" needs to be designed, implemented and distributed to participants. Therefore the research question guiding this work is: "Can a pervasive game be used to create awareness about food ingredients and food additives?". Further, this question implies the following question: "Can a pervasive game influence shopping decisions in regard to food items?".

1.3 Methodology

The methodological approach encompasses the adaption of a pre-existing concept based on similar pervasive and serious games found in related research. This concept will be the starting point for the creation of a design game which aims to test some key assumptions about the design of the *Alchemist* application. The resulting game is going to be tested in some game sessions with a number of participants with a changing rule set. Some of these assumptions deal with the type of interaction that players would expect from such an application and what type of gameplay it could entail. Based on the outcome

of the design game, the initial concept is going to be adapted and a first prototype of the application, which will act act as a technical proof-of-concept, will be created. This prototype should already possess a majority of the technical infrastructure needed to provide the intended features and information but it should be less refined in terms of its user interface and its user facing features. The implemented infrastructure will then be evaluated and used to create another iteration of the prototype that also provides the refined user interface and additional user sided features. In order to allow the participants to explore the app at their own pace, the prototype is then going to be distributed to participants via the *Apple App Store*[2] as part of the *TestFlight* program and as a beta on the *Google Play Store*[3] alongside two surveys. Based on the resulting data the prototype is then going to be adapted once again in order to incorporate the received feedback. Additional user tests are going to be conducted with this final iteration of the prototype in a controlled environment. People who have participated in these tests are also going to be interviewed after the test concludes in order to gain deeper insight into their experience with the application and in order to gain additional information. The resulting data from these final methods will then be used to answer the research question and to suggest additional changes that could further improve the design of the *Alchemist* application.

1.4 Structure of the Work

The structure of the work is as follows: In chapter 2 the fundamental principles that guided the creation of this thesis are described together with related work from the fields of pervasive gaming, serious gaming and gamification in general. After the concepts of pervasive gaming, serious gaming and gamification are discussed the methodology of user centered design is introduced. Finally, the chapter provides a small introduction into the microbiome of the human digestive tract and, as well, provides an overview on different food additives, consequently giving context to the importance of the proposed research questions. Chapter 3 describes the methods applied in this thesis, beginning with design games and ranging from prototypes and questionnaires to interviews and usability testing. The actual implementation done during the course of this thesis will be described in chapter 4. In that chapter the creation of the design game and the actual design and technical implementation of the prototype and connected infrastructure are described in detail. Chapter 5 deals with the analysis of the different prototype evaluations in the form of two surveys, interviews and user testing. The results of each method are presented and analyzed there. Chapter 6 presents important outcomes and findings and highlights results and discussed issues. How the proposed research questions were addressed in this thesis is also explicitly discussed in that chapter. Finally, chapter 7 concludes the work by summarizing the most important aspects and by presenting limitations of the thesis and possible starting points for further development of the resulting application.

[2]https://www.apple.com/ios/app-store/, last accessed: 2020-03-30
[3]https://play.google.com/store/apps, last accessed: 2020-03-30

CHAPTER 2

Background and Fundamental Principles

This chapter describes the principles that were applied during the creation of the thesis and provides an overview of related work in the field of pervasive and serious gaming. In addition to the explanation of the concepts of pervasive gaming, serious gaming and gamification a small introduction into the related topics of food additives and the microbiome of the human digestive tract is provided. Although the goal of this thesis is to to create and evaluate a pervasive serious game and the concept of gamification is not directly applied, it is still explained, as the underlying principles and mechanics do still apply nevertheless. Finally, this chapter also describes the user centered design approach, which emphasizes the importance of user involvement in design processes in general. Related work from each respective field is also presented.

2.1 Serious Gaming

Serious games can be described as a subset of (digital) games that are used for other purposes than just entertainment. [13] [14] Michael and Chen define a serious game as "*...a game in which education (in its various forms) is the primary goal, rather than entertainment*". They stress however that the term "serious games" is not interchangeable with "edutainment" or other similar concepts. Edutainment, short for "education through entertainment" follows a similar goal, but is often used in the context of (video) games with overtly educational aims (often developed for children), wheres serious games can encompass all types of education and training for all ages in many different fields.[15] This falls in line with the definition provided by Zyda who argues that a key difference between serious games and conventional games lies in the addition of pedagogic activities that educate or train and thereby impart knowledge or skills onto their players. However Zyda

argues, that the pedagogic component must always be subordinate to the entertainment component of the game. [14] [16]

	Serious games	**Entertainment games**
Task vs. rich experience	Problem solving in focus	Rich experiences preferred
Focus	Important elements of learning	To have fun
Simulations	Assumptions necessary for workable simulations	Simplified simulation processes
Communication	Should reflect natural (i.e., non-perfect) communication	Communication is often perfect

Table 2.1: Notable differences in the design of entertainment games and serious games [[13],p.6]

Susi et al. further explored these differences by comparing how certain aspects of games are typically treated in entertainment games and serious games (see table 2.1). These aspects highlight the kind of design issues, that creators of serious games may face, and additional considerations that have to be made during the design of such games. One such example involves the concept of "fun" in the context of a serious game. In a survey that was conducted among researchers, educators and creators of serious games, more than 80% answered that they consider fun to be important or very important for design games. However, fun can clash with the intended goal of the game, as certain shortcuts, that are commonly used in entertainment focused games to steer players towards the "fun parts", would not be possible and some game mechanics therefore would need to be more elaborate or time consuming. Simplified processes, time compression or error-free communication are provided as examples for such mechanics or simplifications. [13]

As mentioned above serious games can be used in a wide variety of application areas and are not restricted to certain genres. Some notable games can, for example, be found in the areas of military games, art games, healthcare games, corporate or government games or educational games. [13][15]

Serious games in the healthcare sector can, for example, be utilized in a variety of ways. They can of course be used for educational or training purposes but they can also be used to improve motor skills in a rehabilitation setting and they even are applicable for therapeutic interventions. Bouchard et al. explored if a serious game could be used to treat arachnophobia, the fear of spiders, by creating a virtual environment where the patients would be exposed to gradual hierarchies of fearful stimuli in the form of various spiders in multiple situations. The trial encompassed eleven people that played the game for a total of 450 minutes each over a period of five weeks. Between the pre-game and

post-game results analysis a significant improvement on the behavioral avoidance test and perceived self-efficacy of the participants could be registered. [13] [17] [18] [19]

Traditionally, the military sector has incorporated games or simulations of some sort into their training regiments for a long time. A well-known example would be military exercises or maneuvers where troops would act out possible combat scenarios without live ammunition as a means of training and exercise. In 2002 the US military created the online tactic shooter "America's Army" and distributed it to the public. While the game offered missions and objectives similiar to other tactical shooters the ulterior motive of the game consisted of the engagement and even pre-training of possible recruits. A survey concluded that the game not only was as effective as other recruitment efforts at around 15% the cost, but also that drop-out rates of new recruits decreased because players already possessed an understanding of how the training would be conducted, therefore already dissuading some people from signing up. It has also been shown that new recruits that played the game before signing up, typically could traverse the training grounds faster and had a better understanding of its layout than those recruits who had not played the game, because a digital, explorable version of training grounds was included in the game. In the years following its release the game was expanded and modified and could also be used by soldiers on active duty as a means of preparing for real missions.[13] [20]

Serious Games can also be used be used in all branches and at every level of government, ranging from national scope all the way to a municipal one. The games are typically used for training and simulation purposes and deal with a broad range of topics. There are, for example, games that are used to train firefighters in forest fire techniques, games that provide ethics training, and games that train people in crisis management. But as stated above, serious games are not limited to the areas of training and education, they can also be used to create awareness about certain issues. In 2005, the United Nations World Food Programme (WFP) released the game *Food Force* in which the players join a team of UN experts and help them fight hunger on the fictional island of Sheylan in the Indian Ocean, which is suffering from both drought and civil war. [13][21]

The aim of the game is educate players about global hunger and the efforts to fight it and to convey what tasks and responsibilities WFP help workers have, how they work and what challenges they need to overcome. The game is structured into six missions, that provide an overarching narrative with every mission highlighting a different task or requiring the player to overcome a different obstacle.

In the first mission, the players need to pilot a helicopter in order to find people in need and the quickest way to get food to them. The second mission tasks the players with the creation of a balanced an nutritional diet on a tight budget of 30 cents per person per meal. In the next mission the resulting food packages must then be delivered via air-drop into the target areas. However the players need to make sure that the delivery via air does not endanger lives and that the recipients can reach the items. During mission four the goal is to facilitate and coordinate the shipment of purchased and donated food items from all around the world into the crisis area. In the penultimate mission these

Figure 2.1: In the game *Food Force* the players must take on various responsibilities of UN WFP workers.[22]

items must then be delivered to hungry people through a food convoy. On its way, the convoy has to overcome various obstacles, like land mines, fallen bridges and road blocks installed by local rebel forces. Finally, the last mission (see figure 2.1) deals with long term development challenges after an emergency where the goal is to rebuild. Over the course of ten years the players have to invest, on a tight budget, in the areas of nutrition, education, schooling and HIV-treatment. [13][21][22]

2.2 Gamification

Deterding et al. define the term *gamification* as "... the use of game design elements in non-game contexts".[23] Zichermann and Cunningham further clarify the possible uses of gamification with their definition of the term as "the process of game thinking and game mechanics to engage users and solve problems". They further state that gamification can be applied to any problem that can be solved by influencing human motivation and human behavior. [24] In turn game mechanics are defined as "*...constructs of rules and feedback loops intended to produce enjoyable gameplay. They are the building blocks that can be applied and combined to gamify any non-game context*".[25]

Nowadays a lot of such *gamified* applications exist in a variety of fields. The language learning application Duolingo[1] for example uses game elements like leaderboards, badges and points to motivate their students to continue learning and to do so at regular intervals. The math learning platform Khan Academy[2] also makes use of similar mechanics. A plethora of gamified applications also exist in the field of mobile health and fitness. A

[1]https://www.duolingo.com/, last accessed 2020-04-01
[2]https://www.khanacademy.org/, last accessed 2020-04-01

notable example in this sector is Fitbit[3], an application that uses external devices like wrist bands, to constantly record their users steps and allows them to compete for who has taken the most steps in a given time frame. In addition, other game elements like badges, that are awarded for fulfilling various milestones, like a total distance covered or an overall number of steps taken, are applied.

The mechanics that gamified applications utilize are are commonly seen in games and have been used by game designers for decades. The use of leaderboards for example has been a staple of some game genres since the early arcade days, where they were used to push players to spend money in order to compete over the top spots. [23]

Kumar and Herger provide an overview of commonly used gaming elements in their book "*Gamification at work: Designing engaging business software*"[[25],p.69]:

Points: Points are one way how a system can keep track of a players action in the overall gamification process regarding the targeted behavior, as they are a granular unit of measurement. They enable designers to provide instant feedback to the players. For some players the collection of points is a motivation in itself.

Leaderboards: Leaderboards are a way to spur competition among players. They typically work by listing players in descending order based on points or another context specific metric. A possible downside of such leaderboards is, that they can be demotivational for some new players by contrasting their achievements with those of long time players. An option to counteract this effect is using cross-situational leaderboards. Those leaderboards only show players that have a similar ranking as the currently logged-in player and therefore hide those players that are currently out of reach.

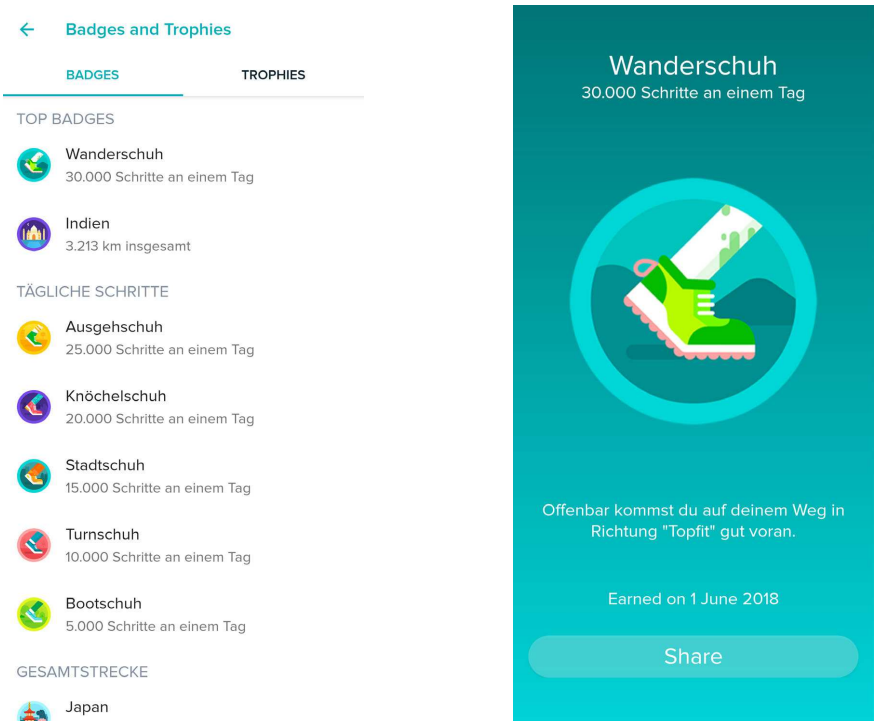
Narrative: Narratives can be used to draw players into stories within the game in order to encourage them to continue their journey. If players are invested in the provided narratives, they are more likely to continue the use of a product or beneficial behavior.[26]

Constraints: Constraints can also be used to motivate people, if they are combined with urgent optimism. Urgent optimism describes "*...the desire to act immediately to tackle an obstacle combined with the belief that we have reasonable hope of success* "[[25],p.79] An example for this mechanic would be time-limited event or a task that seems easy to achieve. To support this effect, larger goals should be divided into smaller, yet still meaningful, milestones, to provide players with a sense of near-completion that pushes them to take the final steps. [27]

[3]https://www.fitbit.com/, last accessed 2020-04-01

Badges: Badges are a way to provide positive reinforcement for the players. They are typically awarded after a certain number of points or another applicable metric has been reached or a specific task has been completed. Therefore, they can be used to reward players who have invested a certain amount of time and in turn have reached a specific milestone.

Fitbit for example awards badges based on the number of steps taken or the amount of distance travelled. Figure 2.2a shows an overview of collected Fitbit badges while figure 2.2b shows the detailed view of an awarded badge. It can be noted, that in addition to the badge details like the name, the unlock requirement, the accompanying icon and the description text, the player is also given the option to share the badge with other people.



(a) An overview of collected Fitbit badges. (b) Detail view of a badge.

Figure 2.2: Example of the badge system used by Fitbit.

Relationships: This mechanic works based on the motivational driver of connection. It has been shown that relationships have a powerful effect on the human psyche and on human behavior in general. They can reduce stress and act as positive motivators. People are for example more likely to recycle if a person they trust and respect does so as well. In addition, relationships can offer support and encouragement to people who try to quit bad habits such as smoking.

Challenge with meaning: Challenge can be a powerful game mechanic to motivate people into action. This is especially true if they believe that they work towards something meaningful or something bigger than themselves. A good example for this is the distributed computing project Folding@Home[4] which allows people to use the computational capabilities of their computers to run simulations of protein dynamics in order to find cures for various diseases. In exchange, they receive points for completed tasks which allow them to compete against one another. People can also pool their resources together and compete as teams. During the COVID-19 pandemic of 2020 the network exceeded a combined computational capability of 1,5 ExaFLOPS or 1,500,000,000,000,000,000 floating point operations per second which was around ten times faster than IBMs Summit[5], the worlds fastest supercomputer at the time. [28]

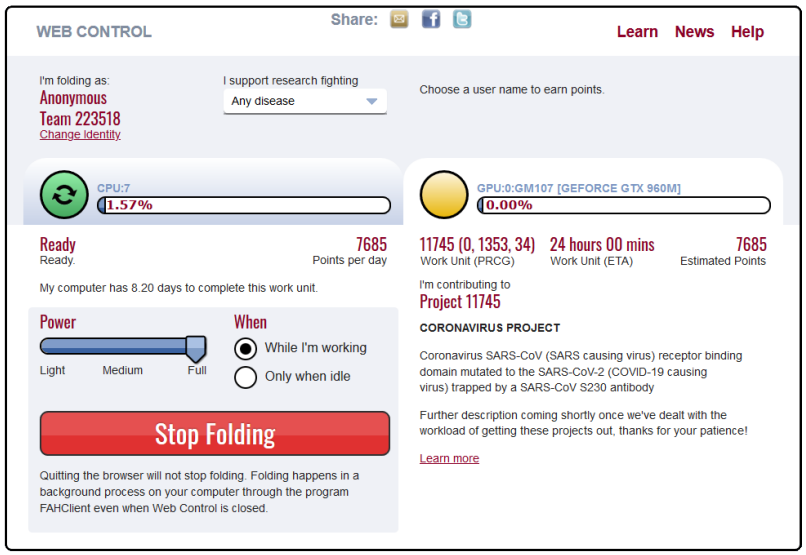


Figure 2.3: Web Interface of the Folding@Home application

Journey: This mechanic recognizes that players are on their personal journey and that good design should incorporate this aspect into their experiences. New players for example should be given an introduction into the features and functions of an application to help get them get started and to familiarize them with the program. Users should also be given feedback that visualizes their progress. Progress bars or experience levels could be used for the purpose of further encouraging a player to continue the journey towards their goal.

[4]https://foldingathome.org/, last accessed 2020-04-01
[5]https://www.ibm.com/thought-leadership/summit-supercomputer/, last accessed 2020-04-02

Emotion: Emotions play a powerful role in how humans perceive experiences or products. Therefore the field of emotional design has grown in the last years and has also received more attention. In his book *Emotional design: Why we love (or hate) everyday things* Don Norman states that there are numerous ways how the emotions of a person can be influenced while they use a product, but in the context of gamification some aspects are especially interesting. The visual design of the application should be pleasing and the software should be easy and pleasant to use. Also the tone that a software conveys plays an important role. Applications that convey a humorous or light-hearted feeling via text or images and therefore convey more positive emotions can be a better motivator than similar programs that take a more neutral stance in the way in which they communicate with the users. [29][30][31]

Although the authors note, that they do not provide a comprehensive list, the discussed mechanics nevertheless can be powerful tools to incorporate gamification into almost every type of application. However, the use of these methods needs to be considered carefully in order to be effective and not detrimental to the underlying goals. A common mistake made by developers and designers is to simply implement game mechanics without considering what they try to achieve through them. It is for example pointless to hand out badges to players or to provide them with tasks if they see no meaning behind them and therefore have no relation to the value that these mechanics should provide them with. Therefore it is questionable if such superficially added gamification layers can achieve the intended intrinsic motivational boost or behavioral change, be it short term or long term. Given the context Amy Jo Kim states that trying "*...to drive long-term engagement with extrinsic rewards is a fool's errand. If metrics and rewards are your main event, you've got a shallow and/or manipulative product that won't hold people's interest over time.*"[32] Thus it is vital for developers to understand the motivation and the intention of the users in order to be able to to use these mechanics to enrich the user experience in a meaningful way. [23] [25]

2.3 Pervasive Gaming

Games typically take place inside of a micro-world that is shared by everyone participating in the game, also known as the "*magic circle*", that implies certain systems and rules. This magic circle can be defined as a social structure that exists during the duration of the game and that the participants of the game as well as possible spectators are aware of, and know that the playful activity is taking place outside of the ordinary world.[32] [33] [34] An example for this is a typical game of basketball, as visualized by figure 2.4. Whereas the act of trying to toss a ball into a net can be an engaging activity in itself, inside the magic circle it also gains special meaning by implying that a successful attempt also means points for a competing team. [32]

In the past, games could only be played in the physical world under the restrictions of real-world properties, like for example physical objects or the human sense of space.

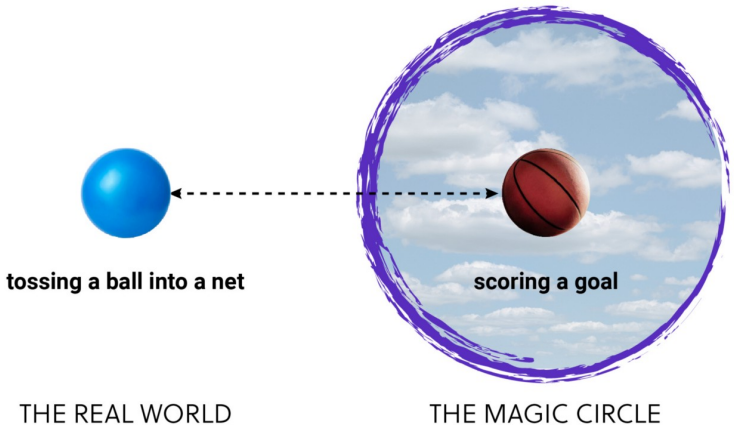


Figure 2.4: Visualization of the concept of the *magic circle*. The same action possesses additional meaning inside the game world. [32]

Therefore, the only two possible forms of interaction were human-to-human and human-to-physical world. The advent of computer games, pervasive technologies and mobile computing has lifted these restrictions and opened the door for new game concepts and new forms of interaction. Computer games possess some advantages that can make them more entertaining than traditional games: Through the use of graphics and sound they can immerse the players in an imaginative virtual world. Computer games typically also have more interactive goals, which strengthen the desire to win within the player. Finally, computer games can provoke the curiosity of the players by providing an adequate level of information complexity. Mobile computing allows the players to have a vast array of gaming experiences at their finger tips at any given moment. [35]

This is where the concept of pervasive gaming steps in as it tries to bridge the ordinary, physical world and the game world in some form by expanding or breaking the boundaries of the magic circle. According to to Markus Montola the limits of the magic circle can be expanded in in the *spatial*, *temporal* or *social* dimension. In contrast to traditional games that are typically restricted to a certain space, like chess which can only be played on a clearly defined game board with a fixed number of tiles, pervasive games can expand the spatial dimension of the magic circle by expanding the socially created location of the game in a way so that it is unclear or even unlimited. Therefore, there are some pervasive games which regard the entire world as their playing field. An example for such a game would be expansive alternate reality game *I love bees*[6] that engaged tens of thousands of players all around the world, requiring them to work together in order to collect clues and solve riddles. The game was later revealed to be part of a viral marketing campaign for the game *Halo 2*. [34][36][37]

Pervasive games can expand temporally by not providing explicit game sessions and as a result interlace with the everyday lives of the participants. This can be done to an

[6]http://www.ilovebees.co/, last accessed 2020-04-05

extreme where even the players are unaware if they are playing at a given moment or not or if an action that they perform in their everyday lives also constitutes a game action. For example, the game *Majestic* could alert players into playing at any given time, even after a longer period of dormancy, via a phone call, e-mail or instant message. The uncertainty of when life turns into game can be intriguing to players because *boring moments in life can be enchanted by any mobile game, but temporal expansion reaches even the moments of non-playing*, but it can also be problematic or off putting for the same reason as the call to action can also come at the worst possible times or generally take up to much time overall. [34] [38]

The expansion in the social dimension aims at obfuscating the boundary of playership and is considered by Montola to potentially be the most bountiful area of expansion but also the most controversial one as such games might include unwilling people or people unaware of the games existence as game elements or give them the option to influence the outcome. In the game *Prosopopeia* for example the organizers left messages and game artifacts with non-players and tasked the players with retrieving them through means of their choosing. The organizational aspect of *Prosopopeia* was also defined in the game world as a part of the game, blurring the line between organizer and player. [34][39]

Given these possibilities and the various states and formats that pervasive game can exist in, Montola argues that a clear strict definition that clearly distinguishes pervasive games from non-pervasive games is not possible or at least not feasible. Instead he proposes a more broad definition of a pervasive game as "*...a game that has one or more salient features that expand the contractual magic circle of play socially, spatially or temporally*". [34]

Although the field of pervasive gaming is often described as a subset of pervasive computing and therefore seen as technology affine or technology dependent, and while many games do in fact rely on pervasive or mobile technologies to function, whether a game uses some form of technology to craft its experience does not determine if it is considered pervasive or not. Based on Montolas definition of pervasive games above many sports or games that are traditionally not seen as pervasive fit the criteria as well. For example a game of football can be seen as an expansion of the social dimension as the the audience may have a tangible influence on the outcome though their support albeit the supposed role of a spectator. In addition, children's games like *Tag* or *Hide and Seek* are presented as examples for spatial expansion as the play area is often not clearly defined. [34] [35] [40] [41]

An example for a popular pervasive game that can be played without the use of technology would be the game "*Killer*"[7], also known as "*The Game of Assassination*". [42]

In their book "*Pervasive Games: Theory and Design*" Montola et al. describe a typical situation inside the game as follows: "*You are an undercover assassin. You're living your everyday life: Going to work, school, home, performing your day to day tasks, hiding in plain sight. But in secret, you are stalking a target, always keeping a hidden weapon at*

[7] http://www.sjgames.com/killer/, last accessed 2020-04-05

hand. You build bombs and prepare weapons while trying to scrounge as much information on your target as possible. Taking the perfect shot at him requires you to wait for hours in a stairwell, trying to hide from his cautious gaze. Maybe you get close enough to poison his coffee, trying to act normal while serving the deadly dosage. Yet you must look over your shoulder constantly; you are also somebody else's target. As the target, you are waiting for the dagger of another assassin, who might be your friend or someone you've never met before. You know there is someone out there intending to get you, and there is no way of telling how or when she will strike." [[37], p.3]

The rule set of the game is simple and allows many variations, explaining its longevity and popularity. At the start of the game each participant is given some basic information about another participant by the referees like their address, their phone number, their name or sometimes even just a photo of the person and is then tasked with eliminating them from the game. That means that during the duration of the game everyone is an assassin but also that every player is also the target of another player. The next step involves finding the target, a task that can take several days, and figuring out the best mode of assassination. An assassin might for example take the target out from long distance using a camera to snap a photo of them (as seen in figure 2.5) or from short range by using a banana as a pistol. They might also choose to go about their assassinations in a more sneaky way, for example by using citrus flavor to poison their targets drink or by putting a poisonous toy spider in their shoe. Of course they might just decide to blow the target up by letting an alarm clock go off next to them. As long as the referees or the target confirm the method or the kill, almost any means can be used, as long as it doesn't cause any actual harm to the target. The successful assassin is then tasked with taking out the victim's target. The game ends when only one assassin is left alive. [37] [42]

Figure 2.5: A *Killer* player waiting to take out his target from a distance by using a long lens camera as a sniper rifle. [[37], p.5]

Using Montolas definition on *Killer* clarifies that the game expands the magic circle in all three dimensions.

Based on the definition given above, Montola et al. describe eight different genres of pervasive games based on their features and properties, which they group in the two overspanning categories of *established* and *emerging* genres. They present *treasure hunts*, *assassination games*, *pervasive LARPs* and *alternate reality games* as established and *smart street sports*, *playful public performances*, *urban adventure games* and *reality games* as emerging genres. In addition, they also differentiate further between technology supported and technology sustained games. Technology sustained pervasive games would not be possible without their technical components whereas technology supported pervasive games would still be playable without them, albeit in a reduced format or scope. [37]

Treasure hunts are described as the oldest known genre of pervasive games as they can be traced back in their current form to the mid 19th century with their roots clearly laying in folk games. The goal for the players is to find certain objects or places inside of an often unlimited game space. Most of the time the prize or the object is not valuable in itself as the discovery of the object is seen as a form of reward as well. A modern variant of such treasure hunts is *geocaching*, where participants try to find caches hidden at specific GPS coordinates by other players. Sometimes riddles need to be solved or contextual clues need to be examined in order for the player to be able to find the exact location of the cache. An example of an assassination game is already given above with the game *Killer*. Pervasive LARP or live-action role-playing games are a variant of games that involve role-playing techniques that typically imply some sort of progression or that require the players to pretend to be their character for the duration of the game and act in the appropriate manner. Using this criteria *Killer* can also be seen as a role-playing game if the participants act like their imaginal assassin characters during the duration of the game. Finally, alternate reality games interweave everyday life with game narratives that can be publicly accessed around the clock. They typically also present the players with challenges or extremely sophisticated riddles that are too complex for a single person to solve and therefore encourage collaboration by requiring the collective intelligence of their player base. [43] Examples for such games are the already described games *I love bees* and *Majestic* above. [37]

The genre of *smart street sports* consists of games that can either be seen as physical versions of digital games or as technology-infused versions of physical games. An example for such a game would be the mixed-reality game "*Can you see me now?*", which lets two groups of players compete against one another with a ruleset similar to the game ”Catch”. The game however turns a twist on the concept by providing asynchronous gameplay through the use of technology. The group of the "*online runners*" move their avatars through a virtual representation of city streets while trying to evade the "*street runners*" who are out to catch them. But while the online runners play a computer game and move their caharacters through a virtual representation of the city, the street runners need to traverse the actual streets of the city in order to catch their virtual targets. Typically, a

group of fifteen online runners is pitted against four street runners. The players can see each other on a map and players within a group can communicate with one another with the other group being able to listen to them. [37] [44]

Playful Public Performances are similar to smart street sports but focus an another area of interest. Where smart street sports accentuate exercise and competition between the players public performances focus on creating a spectacle for the audience and fun for the participants. For example, *I love bees* incorporated some public performances, blurring the lines between the genres. [36] [37]

Urban Adventure Games typically function by designing their puzzles and narratives around city spaces. These games task their players with solving puzzles or finding specific locations all around the city and therefore in turn also teach them about a specific city and its history. Typically, a location or the solution to a puzzle contains a hint about the next puzzle, which makes these games somewhat comparable to scavenger hunts. Through the use technology players can for example be required to stand in a specific spot, to take a photograph of a specific object or to scan a bar code or a QR code placed in a specific location. *The Amazing City Game* by Wu et al. is an example for such a game that was played in the city of Trondheim. [37][45]

Finally, *Reality Games* try to consciously play with the concepts of real or reality by encouraging the players to experience their living spaces in new and different ways. They do however share strong connections to performance arts, raising the question if they can be considered games at all. [37]

Magerkurth et al. describe different genres of mostly technology dependent pervasive games, which highlight different aspects of the gaming experience. The researchers however again note that their categorizations of proposed genres are not definitive and not mutually exclusive. The proposed genres range from smart toys that augment traditional games with pervasive computing technology as a first step towards truly pervasive games, to location aware games and affective gaming to augmented tabletop games and augmented reality games. The already mentioned game "*Can you see me now?*" is a popular example for a location aware game. [44] Affective gaming is part of affective computing, which is described by Picard as"*computing that relates to arise from, or deliberately influences emotions*" [46] Affective gaming therefore aims to incorporate the users emotional state into the game experience by adapting their behavior based on collected data, like biofeedback or through the use of affective feedback. [35] [47] [48]

The genre of pervasive games that, through the advantages of mobile computational technology, is probably most well known to the general are augmented reality games(ARGs). Augmented reality means that context-sensitive computer-generated information is overlayed in real time onto the real world, therefore enriching the experience by providing additional or otherwise unobtainable information. Through these techniques the user perception of the real world can be enhanced or altered. Such AR applications can be used in a wide variety of ways. Through the use of AR historical sites can be experienced in a new way by digitally reconstructing already demolished buildings and placing them in their original locations by superimposing them onto the screen of a mobile device.

Such an application was for example developed for the historical site of Carnuntum in Austria, where digital reconstructions of already lost buildings can be experienced from every angle at the exact spots where they were located. [49] Other possible uses present themselves in the areas of education, art, commerce and of course in gaming, as it allows new game concepts and new game mechanics to be developed. [35] [50] [51]

An example for a technology sustained pervasive game that incorporates augmented reality is *Pokémon Go* [8]. The game can be seen as a mixing pot of pervasive game genres as is can be described as a location based mobile that incorporates augmented reality as well as elements from alternate reality games, treasure hunts and urban adventure games. The game was launched in the summer of 2016, which was quickly nicknamed "The Summer of Pokémon GO" as the game boasted more than 45 million daily users just two weeks after launch, with the game being omnipresent. [52] [53] [54]

Pokémon GO is a pervasive installment in the popular Pokémon game franchise developed for smartphones. In Pokémon the players act as pokémon trainers who aim to capture, collect, train and evolve creatures known as pokémon (short for pocket monsters) in order to compete against other trainers and their pokémon in battles. But where the players of the conventional console and handheld versions of the franchise would simply control an avatar in a digital game world via button presses, in Pokémon GO the location of the player in the game directly translates to the location of the player in the real world as the GPS coordinates of the phone are used to determine the players position (see figure 2.6a). Around the world various points of interest like PokéStops and arenas/gyms are located at landmarks in the real world, further strengthening the bond between the two worlds. PokéStops dispense useful items like PokéBalls that are needed to catch Pokémon, potions or even Pokémon eggs, while Gyms provide the players with in-game currency if their Pokémon manage to stay the champion there for a certain period of time. [53] [54] [55]

Players can acquire new pokémon in different ways. They can move around in the real world until they find the position of a pokémon and then try to capture it with a PokéBall. They can also trade pokémon with other trainers or they can hatch pokémon eggs in incubators. During capture encounters augmented reality is used to overlay the pokémon onto the real world viewed on the screen of the smartphone (figure 2.6b). In this case the pokémon can appear in a 360 degree radius around the player position and the player needs to turn in order to find the creature. This feature can optionally be turned off (figure 2.6c), making it easier to catch the pokémon since its position is fixed but decreasing the coupling of the real world and the game world. Pokémon appearances are dependent on real life conditions like time of day, the current weather or the time of year as some creatures only appear at night, during storms, or during a certain time frame. Ghost-type pokémon for example appear more often in the weeks leading up to Halloween. Other pokémon might only appear on certain continents while others are restricted the real life environments, like water-type which Pokémon predominantly appear near bodies of water. [53] [54] [55]

[8] https://pokemongolive.com/, last accessed 2020-04-07

(a) To move in the virtual world the players also need to move in the real world.

(b) Augmented reality is used to combine the real and the virtual world.

(c) Encounters can also be handled without AR, at the cost of reduced immersion.

Figure 2.6: The game design of Pokémon GO is enabled through the use of technologies like augmented reality and GPS.

As mentioned above players can come into the possession of eggs that pokémon will eventually hatch out of. These come in the variations of 2,5,7 and 10 kilometer eggs. The number indicates the distance that an egg needs to be carried in order for the pokémon inside to successfully hatch. So if a player wants to hatch a 10km egg, they need to walk ten kilometers in real life. This system in combination with the placement of pokéstops and gyms mean that the players need to get out of their way to get the most out of the gaming experience. They are for example encouraged to travel more on foot as distances that were covered on bike or in a car are not counted. Players are also encouraged to experience their environment in a new way and to explore their surroundings more in order to find new pokestops or pokemon. [53] [54]

Althoff et al. tried to study the effects of Pokémon GO on the physical activity of its user base. They found that over the study duration of 30 days the physical activity of the players increased significantly by up to 25%. The researchers also concluded that applications that combine physical activity with gameplay have the potential to reach and engage activity-poor populations, a user base with which conventional mobile health applications are struggling. Colley et al. used Pokémon GO to study the effects of location-based gaming on a large scale. Like Althoff et al. they also found that Pokémon

GO can drastically influence where people go and how they get there (ie increasing their physical activity), which is interesting given that, according to the researchers, humans rarely change their movement patterns without motivation. [56] [57]

Another example for a pervasive game, which tasks its players with the exploration of an open space is the game *REXplorer*, that was deployed in the German city of Regensburg by Ballagas et al. and was intended to be used by tourists. REXplorer lets the players assume the roles of researchers that try to unravel a number of paranormal activities and sightings placed at various locations inside the old town of Regensburg. The game uses this setting as a means to deliver a pervasive sightseeing experience that tasks its players with visiting various important landmarks of the city and allowing them to interact with notable figures and places from the cities rich history and therefore also tries to facilitate a fun learning experience, which places the game in the genre of urban adventure games. Before the start of the game players are given a *paranormal activity tracker*, which is actually a disguised mobile phone which houses the sensors (GPS, accelerometer,...) needed for the intended gaming experience. [37] [58] [59]

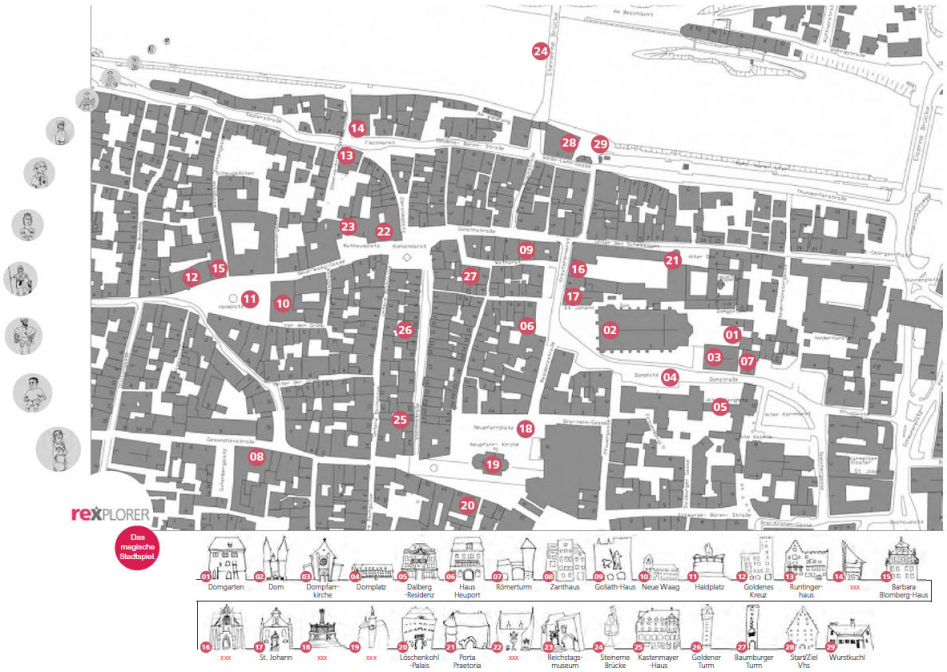


Figure 2.7: A map highlighting various points of interest inside the city of Regensburg for *REXplorer* players. [59]

The players can use this device to find spirits located at the twenty-nine historical locations all around the old town, which are depicted in figure 2.7. To do so the players traverse the city until the detector gives them a signal in form of a visual heartbeat on the screen, signaling that a spirit is close by. To summon the spirit the players need to cast a spell, by performing a certain gesture with the device. There are a number of

gestures to choose from and contextual clues often give a hint which one needs to be used in order to summon the spirit. As soon as the correct gesture is performed, the spirit appears on the screen of the device. These spirits represent people in different historical epochs which help to give the players insight into different important moments in the history of the city and portray different historical ways of life. Once uncovered, the spirits educate the players about life in their respective epoch and also task them with small quests that grant points and often involve spirits at other locations, therefore asking the players to bridge both place and time. One spirit for example instructs the player to deliver a love letter to his wife at a near church. A number of such short narratives also allow for non-linear gameplay because there is no fixed order in which the locations have to be visited. Because of that the players can accept up to three quests at the same time. The game is predominantly aimed at tourists and thus it was designed to be experienced in small groups of up to three people. On the other hand Solo players sometimes found the required gesturing with the paranormal activity detector in public to be awkward but the researchers found that the presence of even one other player would mitigate that feeling drastically. [37] [58] [59]

2.4 User Centered Design

The approach in this thesis encompasses methods commonly associated with the principle of user-centered design. Although no full-fledged user-centered design approach was applied, it was deemed important to explore the underlying principle of those utilized methods. User-Centered Design(UCD) is a subset of interaction design(ID) but with a much tighter focus. According to Abras et al. UCD is multidisciplinary whereas ID is mostly concerned with computer systems. [60] [61]

User-centered design is used to include human factors in the development of a system. Future and potential users are incorporated all throughout the design process to enable decision making based on conducted research. UCD methods are used to gather requirements and to maximize factors of acceptance and usability. [62] [63]

A concept that is often mentioned in combination to usability and design is *user experience*. But whereas the term usability can be clearly defined, the definition for user experience is much more elusive which is reinforced by the fact that some researchers use different definitions. [64]

The International Organization for Standardization(ISO) provides a definition for user experience in the ISO 9241-210:2019 standard, which defines it as *"user's perceptions and responses that result from the use and/or anticipated use of a system, product or service"* and is amended by two notes: [65]

1. *Users' perceptions and responses include the users' emotions, beliefs, preferences, perceptions, comfort, behaviours, and accomplishments that occur before, during and after use.*

2. *User experience is a consequence of brand image, presentation, functionality, system performance, interactive behaviour, and assistive capabilities of a system, product or service. It also results from the user's internal and physical state resulting from prior experiences, attitudes, skills, abilities and personality; and from the context of use.*

Usability on the other hand is defined as "*extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use*" and is also amended by two notes.[65]

1. *The "specified" users, goals and context of use refer to the particular combination of users, goals and context of use for which usability is being considered.*

2. *The word "usability" is also used as a qualifier to refer to the design knowledge, competencies, activities and design attributes that contribute to usability, such as usability expertise, usability professional, usability engineering, usability method, usability evaluation, usability heuristic.*

The ISO 9241-210:2019 standard is also mentioned in the book "User-centered agile method" by Deuff and Cosquer [62] where the researchers describe six key principles of UCD:

1. *"The design is based upon an explicit understanding of users, tasks and environments.*

2. *Users are involved throughout design and development.*

3. *The design is driven and refined by user-centered evaluation.*

4. *The process is iterative.*

5. *The design addresses the whole User eXperience.*

6. *The design team includes multidisciplinary skills and perspectives.* [[62], p. 15]

UCD is an iterative process, as clearly stated by the fourth principle. A visualization of this process can be seen in figure 2.8. This figure also shows that not every stage needs to be redone if the requirements are not met at the end of a design iteration. Depending on which stage of a design iteration is currently active different methods can be used to get an understanding of the users and the overall requirements. Deuff and Cisquer also emphasize four important methods in agile software development that are relevant to UCD: user analysis, prototypes, user evaluation and iterative design. [62] [64]

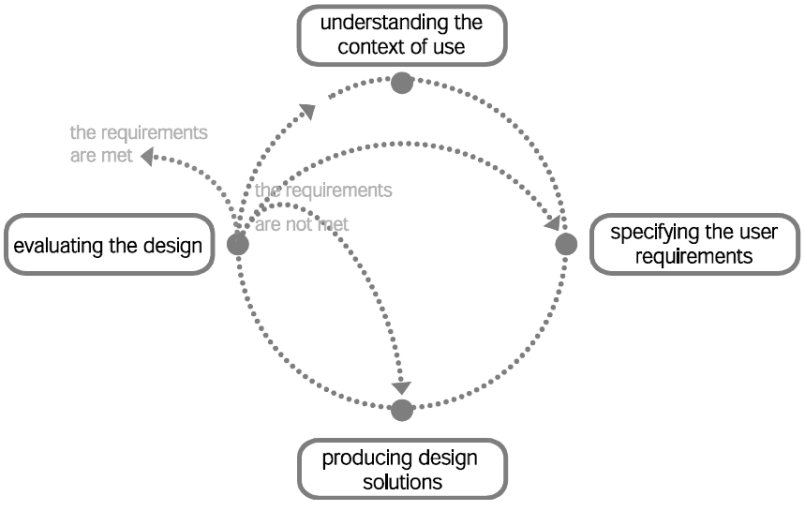


Figure 2.8: Visualization of the four stages of UCD based on the ISO standard. [[62], p. 15]

2.5 Microbiome of the digestive tract

The term microbiome is defined as the "*collection of microorganisms that include bacteria, protozoa, fungi, viruses and other one-celled organisms in and on the body.*"[12] Examples of occupied habitats include the oral cavity, the respiratory tract,the skin and the gastrointestinal system. The microbes that are present in the human gastrointestinal tract, that outnumber the cells of the human host by a factor of 10 to 1, are also referred to as the gut microbiome or the microbiome of the digestive tract.[66] [67] In recent history this microbiome has been the subject of extensive research that uncovered its involvement in various fields like metabolism, nutrition, physiology and various immune functions. [10] [11] [68] [69] [70]

2.5.1 Functions of the gut microbiome

The gut microbiome plays an important role in the context of metabolism and the immune system. There also exists a direct bidirectional communication system between the digestive system and the brain. [66] [67]

Metabolism: Similar to how the cells of the gut microbiome outnumber the hosts cells by 10:1, the encoded genes inside the bacteria outnumber the genes of the host system by the even larger factor of 100:1. This means that they can perform some metabolic functions which humans would be unable to or only in a limited form. Some of these functions include the ability to produce various vitamins and to synthesize all essential and nonessential amino acids. Additionally the gut bacteria provides the pathway to the metabolism of otherwise non digestible carbohydrates like pectins, cellulose, and gums, additional to previously unabsorbed sugars and

alcohols. The metabolism of carbohydrates in the colon is a major source of energy, which emphasizes the importance of the process. [66][67]

Host-protection and immune system development: Another important role of human microbiota is to provide colonization resistance to indigenous microbiota which leads to protection of the host against colonization of pathogenic invaders and prevention against overgrowth of pathogenic microbiota. They do this by producing antimicrobial compounds and by competing for nutrients and sites of attachment in the gut lining. [66] [67]

The intestinal microbiota can also affect the hosts immune system and its development in the early stages of life via continuous and dynamic interactions. A relationship between the gut microbiome and the development of allergies has been shown to exist, as infants and young children with allergies have been found to have a different composition of intestinal bacteria than those who do not develop allergies. It has been theorized that the microbiota stimulates the immune system and trains it to respond proportionately to antigens. Therefore, an immune system, that has not been exposed to these stimuli yet, due to an altered or inadequately developed intestinal microbiota, can overreact to certain antigens. [66][67]

The Gut-brain axis: The gut-brain axis is the term used to describe a bidirectional communication system between the gut and the brain that integrates neural, hormonal, and immunological signaling. This system allows the brain to control gastrointestinal and immune functions. In addition, antibiotic consumption, diet or psychological and physical stress can cause alterations in the habitat of the intestinal microbiota and promote changes in microbial composition or metabolism. [10] [11] [66] [67]

This can impair the function of the microbiota to maintain host wellbeing and in turn can lead to local or systemic diseases like inflammatory bowel disease, celiac disease or even to diseases of other organs. In recent years the gut microbiome has also been identifed as a possible contributor of obesity. [10] [66] [67]

2.6 Food Additives

A food additive can be defined as "*a substance or mixture of substances, other than a basic foodstuff, which is present in a food as a result of any aspect of production, processing, storage, or packaging.*" As already mentioned in chapter 1, food additives are used to create the processed food items which are nearly omnipresent in modern western nutrition. For example they are needed to preserve, colour and stabilise food during its production, packaging or storage, or to influence the smell or taste of food. Although every approved additive has been deemed as save to eat, sometimes the over provisioning of certain substances can still cause unwanted side effects and in turn facilitate some of the negative effects on the intestinal microbiome described in the previous section. Currently, more

than 2500 different additives are used around the world. In the European Union the E-system classifies additives by assigning each a unique three or four digit number with the initial letter "E". Food additives must always be included in the ingredient lists of the products in which they are used. 7 Labels must identify both the function of the additive in the finished food (e.g. colour, preservative) and the specific substance used either by referring to the appropriate E number or its name (e.g. E 415 or Xanthan gum). The E number system enables a more granular categorization of additives, as depicted in table 2.2. The Safety assessment and approval of newly developed additives are the responsibility of the European Food Safety Authority (EFSA). [71] [72]

Number range	**Food additive category**
E100-E199	Color additives
E200-E299	Preservatives
E300-E399	Antioxidants, acidity regulators
E400-E499	Thickeners, stabilizers, emulsifiers
E500-E599	Acidity regulators, anti-caking agents
E600-E699	Flavor enhancers
E700-E799	Antibiotics
E900-E999	Miscellaneous
E1000-E1599	Additional chemicals

Table 2.2: Categorization of various food additives under the European E number system as described by the EFSA. [72]

2.6.1 Different types of additives

Food additives can be divided into six major categories: *preservatives*, *nutritional additives*, *flavoring agents*, *coloring agents*, *texturizing agents*, and *miscellaneous additives*. In the E number system these categories are also represented by different number ranges. For example every coloring agent has an assigned number between E100 and E199. Therefore, any given three digit number in this range can be instantly recognized as a coloring agent without the need for further information about the substance itself. [71] [72]

Preservatives: Preservatives can be grouped in the three categories antimicrobials, antioxidants and antibrowning agents. Antimicrobials are used to extend the shelf-life of numerous convenience foods. Antioxidants are used to prevent lipid or vitamin oxidation in food products which would lead to the development of rancidity and off-flavor. They are especially useful to preserve dry and frozen foods over an extended period of time. Antioxidants range from synthetic chemicals to natural substances like vitamin C. Finally, anti-browning agents are used to preserve dried fruits and vegetables by preventing enzymatic and nonenzymatic browning. [71]

Nutritional Additives: Nutritional additives can be grouped into vitamins, minerals, amino acids and fiber additives. Vitamins like vitamin D and minerals like iron and iodine are added to restore or replace nutrients that were lost during the food processing or to enhance the overall nutritional value of food items. Although amino acids are not commonly used in foods, they are sometimes added to enhance protein quality or as texturizing agents. Fiber additives, like various cellulose, pectin and starch derivatives or naturally derived fiber from apples do not possess a direct nutritional value but they are added because they provide indirect value in the form of increased fiber intake. Sometimes they are also used to improve the texture of food items. Due to the increased interest in nutrition by consumers nutritional additives have increased in usage in the recent years. [71]

Coloring Agents: For the most part coloring agents are used to increase the overall attractiveness of food, by giving them intense and appealing coloring. In recent years there has been a shift towards the use of natural colorants although the vast majority of food coloring is still created synthetically. [71]

Flavoring Agents: Flavoring agents comprise the largest group of food additives with around 1700 different natural and synthetic substances used. They can be divided into the groups of sweeteners, flavor enhancers and natural and synthetic flavor agents. Substances like sucrose, glucose or fructose are the most popular sweeteners, but they are typically classified as foods and not as additives. The most popular sweeteners that are also classified as additives are aspartame and saccharin. Flavor agents are used to add different flavors to food either by artificially adding them or by restoring flavors that were lost or dulled in the food processing. Flavor enhancers on the other hand do not possess flavor on their own but they can be used to magnify or modify the inherent flavor of food. [71]

Texturizing Agents: Texturizing agents like emulsifiers, stabilizers or phosphates are used to add or modify the overall texture of food products. Emulsifiers allow flavors and oils to be dispersed evenly throughout a product. Stabilizers provide the texture of food items such as ice cream and are also used to prevent the deterioration or evaporation of volatile flavor oils. Phosphates can be used to modify the texture of food items containing protein or starch like dairy and meat products. [71]

Miscellaneous Additives: In addition to the already described additives, certain substances exist that are used for very specific purposes which would not justify their classifications in distinct categories. Examples for such additives are chelating agents, anti-foaming agents, surface finishing agents or catalysts. [71]

2.6.2 Benefits and Risks

Food additives obviously provide certain benefits that explain their widespread use. Preservatives and nutritional additives for example increase the safety and overall value

of food by preventing food poisoning due to various bacteria and molds. Antioxidants maintain the nutritional value of vitamins and lipids while also preventing the formation of autoxidation products, a form of oxidation that occurs in the presence of oxygen, which could potentially be toxic. Their usage also enables greater choice of foods for customers by allowing the production and the storing of otherwise out of season foods, import of exotic foods or the creation of novelty or convenience foods, like TV dinners, different kinds of breakfast cereal or the majority of microwavable products. Finally, it is argued that the use of food additives helps to keep the price of certain processed foods down by substituting much more expensive refrigeration solutions or new improved packaging, that would not be as cost effective. However, Branen et al. also argue that "*It is also important to realize that the assumption that food additives lower the price of foods is based on maintaining the same type and quality of foods that we currently have available. Without additives, we could still have an excellent food supply at a reasonable cost.*", therefore invalidating the previous statement to a certain extend. [71]

In recent years, the number of concerns regarding the potential risks of food additives, short term and long term, has been growing steadily. For example, whereas individual substances are tested for safety before their usage approval, although even then the data is not always conclusive or adequate, there exists little to no data on the health risks or joint effects of the combined cocktail of additives that are consumed on a daily basis. Food additives also enabled the widespread availability of junk food which typically possesses a high calorie density but a low density of nutrients, increasing health risks like obesity or under provisioning of important nutrients like vitamins or minerals. Some individuals also possess a hyperactive reaction to some additives like sulfites that can severely impact them even if the additive is used at a level that is deemed as safe. Of particular concern are the toxicological problems that could result from long-term consumption of certain additives, as those are not well documented yet. Finally, food additives can also have an impact on the gut microbacteria, which is concerning given the complex interplay of the microbiome and the hosts immune system as described in the previous section. [11] [67] [70] [71]

CHAPTER 3

Methods

This chapter outlines and describes the methods which are applied in this thesis. In addition to that, the steps which were performed to be able to answer the research questions are described. These descriptions offer explanations for readers who are unfamiliar with the topics or with the methods. This thesis made use of Design Games, Prototypes, Questionnaires, Usability Testing and Interviews. Therefore, those are described in this section.

3.1 Design Games

Design Games are a tool that allow designers to actively incorporate different stakeholders in a design process and to encourage participation in a playful manner. Salen and Zimmerman define a game as "*...a system in which players engage in an artificial conflict, defined by rules, that results in a quantifiable outcome.*" [[33],p.80] However, although the number of design projects which involve design games is rising, design games are not as clearly defined. In design games definitions based on certain aspects of a game are less meaningful because in design games appearance, form and style typically differ from game to game. Another aspect of design games that differentiates them from conventional games as described by Salen and Zimmerman above is that in a design game there is rarely competition among the participants as they are often encouraged to work together to reach a common goal. Instead, a number of different descriptions exist for design games that rely on the specific context and the aim of the game. Brandt for example highlights the exploratory aspects of typical workshop methods such as future workshops and acting out scenarios by describing them as *explorative design games.* [73] [74]

Vaajakallio and Mattelmäki identified four main purposes for which design games can be used: research, building design competence, user empowerment and engagement of multiple stakeholders. *Research* describes how design games can be used to study design action in a manipulable environment and to encourage situations akin to those in real

life. The researchers argue that in a game the player's actions are just as limited by principles, conventions and rules as they are in real life. *Building design competence* expresses how the creation and playing of and the reflecting on design games can be used to teach interaction design students how to facilitate a participatory design process between stakeholders. The ability to include people who are traditionally not part of a design process, but are still influenced by their outcomes by providing a common language between designers and users, is described by Vaajakallio and Mattelmäki as *empowering users*. This is also a way to involve stakeholders in discussions about existing and possible future alternatives of the proposed design solutions. Finally, the researchers state that design games possess the ability to *engage multiple stakeholders* into expressing, negotiating, and generating a shared understanding of users in early concept design. [74] [75]

Although design games are typically played in a specially organized setting, for example as part of a workshop, rules are still needed to clarify to the players what they can and can't do in the temporary game world. But unlike the rules in conventional games, in which the rules are typically absolute, the rules of design games are often open to reinterpretation or only vaguely defined. Brandt notes that those vague rules and the utilized game props can encourage players to explicitly describe how they understand and interpret the props and the elements of the game that they find meaningful within the topic. Reinterpretation of rules is also a tool that allows players to focus the game on elements or mechanics which they regard as meaningful. All these elements support the creation of a common language of the game which makes sense to all participants. [73] [74]

In chapter 4 of this thesis a design game is created in the early stages of the design process. This game is going to be used in a number of game sessions with multiple participants to explore how certain aspects of the thesis project should be designed in order to maximize the engagement of the users.

3.2 Prototypes

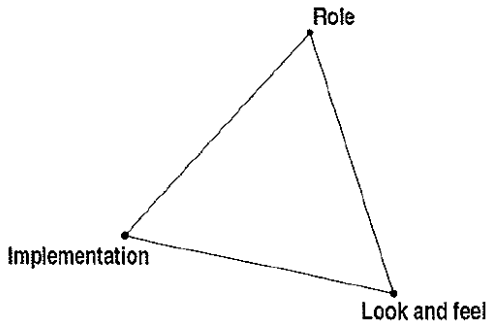
Prototypes are a tool that can be used to convey the intended product or design in total or in parts. They are a representation of a design idea. Houde and Hill go as far as to define a prototype as "*any representation of a design idea, regardless of medium.*"[76] This definition also includes pre-existing objects if they are used to answer design questions.[76] Holmquist on the other hand explicitly distinguishes between prototypes and mockups based on the view that mockups "*have the appearance but not the function*" with it being the other way around for prototypes. [77]

In order to be able to create effective prototypes the findings of previously applied methods need to be evaluated and used as input for the prototype development. Throughout a design process a number of prototypes that serve multiple purposes can be created. They can be used for user evaluation at different stages to reveal strengths and shortcomings

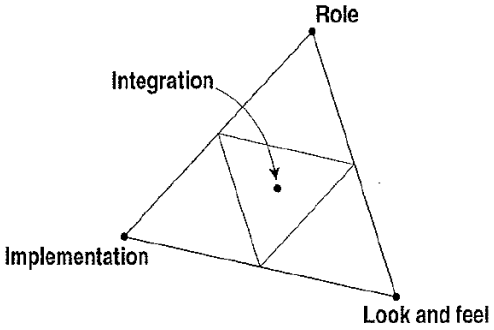
of the current design iteration. They can also be used to communicate the vision the designers have for the final product to the users. [62] [76] [78]

According to Beyer prototypes can also ensure that the correct functions and features are provided to the users. It is also mentioned that a prototype "*... represents the system as a whole, so it helps to keep the design coherent across the system.*" [79]

Houde and Hill state that a prototype contains various aspects that can be represented by a three-dimensional space with the dimensions "Role", "Look and Feel" and "Implementation" as seen in figure 3.1a. "Role" describes how the artifact is useful to the users, "Look and Feel" deals with what the users look at, feel and hear while using it while "Implementation" describes the techniques and components that make the prototype function. The two researchers argue that this model can be used to separate design issues into different categories, each with its own set of questions and methods, which in turn help to visualize the focus of the design exploration. [76]



(a) A model of what prototypes prototype.



(b) The four principal categories of prototypes.

Figure 3.1: The model of prototype categorization proposed by Houde and Hall [76]

Houde and Hill further state that this model can also be used to categorize different prototypes into four categories: The aforementioned "Role", "Look and Feel", and "Implementation" and the final category "Integration" (see figure 3.1b). The first three categories contain prototypes that have a strong emphasis towards one of the dimensions. A *role* prototype for example would primarily explore what an artifact could do for the target audience. In order for a prototype to be placed in the *integration* section it would be required that it explores a balanced number of questions in all three dimensions. [76]

Prototypes can range from fast and easy to produce low-fidelity prototypes to sophisticated high-fidelity prototypes. Whether a low-fidelity or a high-fidelity prototype should be created depends on various factors like the available resources, the designated time budget, what design issues the researchers want to address with the prototype, or how or in what setting it should be tested. [76] [79]

3.2.1 Low-Fidelity Prototypes

Low-Fidelity Prototypes are well suited for the early explorative phases of a design process because they are usually easy and cheap to create and fast to produce and to modify. Because aspects of technical implementation and potential cost do not need to be considered more time and energy can be spent on ideation. There are numerous ways on how a low-fidelity prototype can be created. They can for example be created digitally but there is also a vast array of materials to choose from including paper, clay or wood. [80]

A famous example of such a prototype is the wooden block which was used as a low-fidelity prototype of the Palm Pilot (see figure 3.2). With nothing more than a piece of wood in the intended size of the device, a stylus made out of a chopstick and various paper sleeves to simulate various functions like a calendar or a address book, the designer could pretend that the device was functional in order to get some insight into how it would be used. The collected data guided the further design process and was also enough to justify the investment to create a working prototype. [81] [82]

Figure 3.2: Wooden low-fidelity prototype of the PalmPilot created by Jeff Hawkins [81]

Another popular example of a tool for low-fidelity prototyping are storyboards. Storyboards consist of a number of sketches that describe a scenario in which the artifact is being used to solve a problem for the user. [79] [80]

Low-Fidelity prototypes usually are not interactive or only to a certain extent like how for example digital mockups can be interlinked to simulate interactivity. However, if further functionality is needed for testing purposes this functionality can be provided through a method called "Wizard of Oz". In such a scenario a researcher simulates the needed functionalities in a user testing environment. Often the participants do not know that the system which they are interacting with is not really interactive but that some parts are only a illusion, just like in the eponymous novel. [79] [83]

3.2.2 High-Fidelity Prototypes

High-Fidelity prototypes need more time and expertise to be created and are therefore more expensive, but they possess more functionality and their components are more sophisticated. Therefore, high-fidelity prototypes are usually found in the later stages of the design process. From a users perspective, a high-fidelity prototype should be comparable to the completed artifact in its form, aesthetics and function. But more complicated functions can still be mocked as long as the users are unaware of it. It is also not uncommon that certain features of a prototype are directly applied to the final artifact. [78]

During the process of this thesis a prototype of the Alchemist app is created to the point where it can offer a vertical slice of the experience the final version of the app would provide. That means that all major features are present but that they are reduced in scope. During the development phase the prototype is going to be evaluated after the completion of major development mile stones.

3.3 Questionnaires

Questionnaires consist of a fixed set of questions which need to be answered by the participants. The goal is to get input from as many participants as possible which makes them more of a quantitative than an qualitative research method. Because questionnaires can be distributed in various ways, for example on paper or online, and because the respondents often do not have contact to the researchers while filling them in and therefore can not ask them if they are for example not sure about the meaning of a question the choice of questions and their respective wording is essential. [84][85]

Kronsick and Presser provide some conventional advice on how to set up surveys and how to design their questions:

1. *Use simple, familiar words (avoid technical terms, jargon, and slang)*
2. *Use simple syntax*
3. *Avoid words with ambiguous meanings, i.e., aim for wording that all respondents will interpret in the same way*
4. *Strive for wording that is specific and concrete (as opposed to general and abstract)*
5. *Make response options exhaustive and mutually exclusive*
6. *Avoid leading or loaded questions that push respondents toward an answer*
7. *Ask about one thing at a time (avoid double-barreled questions)*
8. *Avoid questions with single or double negations.* [[84],p.2]

They also present further advice including the grouping of questions about the same topic. According to them early questions should explicitly address the research topic and that those early questions should also be easy and pleasant to answer with the more complex questions placed at the very end. [84]

For this thesis two questionnaires were be distributed online to determine the effects of the prototype. The first one was issued before the app was made accessible to the participants and dealt with their eating and cooking habits and their knowledge about food additives in general. The second survey was made available alongside the second iteration of the app prototype and dealt with the effects of the app and the reception of its overall design.

3.4 Interviews

Interviews can typically be described as conversations between between two people, in which one person tries to get information from the other one. The person seeking the information is known as the interviewer, while the other one is called interviewee. Although conversations between one interviewer and one interviewee are a commonly used form of interviews, interviews can also be conducted with multiple interviewers or multiple interviewees at the same time. [86] [87] [88] Interviews can be categorized into four types: unstructured, semi-structured, structured and group interviews or focus groups. Interviews are typically described as a qualitative research method. They can be structured in a way that they provide more quantitative data. In this regard structured interviews can be compared to questionnaires as both consist of a fixed set of questions that have to be answered by the interviewee. The terms structured, semi-structured and unstructured describe, how much control the interviewer has over the conversation and how much was decided on beforehand. The decision on which interview type is best suited for a given task depends on a multitude of factors including the research question, the study design or if a specific interview is conducted towards the beginning, the middle or the end of a study.[85] [88]

Group interviews, also known as *focus groups* are interviews with more than one interviewee at a time. Group interviews typically are conducted with a number of participants selected from the target group. Group interviews can be viewed as group discussions, where experiences about a topic are exchanged among the participants and with the researcher, who acts as a facilitator of the discussion. This interview method can profit greatly from group dynamics as the experiences of one participant can stimulate or encourage the other participants to share similar experiences as well. The number of recommended participants varies from source to source, but the limit seems to be ten participants. Focus groups typically contain a task which the participants need to solve or elaborate on. Although they can be used in various stages during a project, they are most commonly used during the ideation phase as ideas or approaches can be quickly discussed an then discarded. [85] [88] [89]

Unstructured Interviews: Unstructured interviews offer the highest degree of freedom

for both the interviewer and the interviewee. The interviewer may make use of an interview guide or they can come up with questions during the conversation. The questions are typically open-ended and broadly worded, which allows the interviewee to answer them in the manner they prefer and as elaborate as appropriate. This approach can reveal information or uncover a point of view which was not yet known to or considered by the interviewer. The format also allows the interviewer to react more flexible to these and to other interesting topics which come up during the interview by enabling them to steer the conversation in a certain direction. In turn, this flexibility results in data that is of a more qualitative nature.

Structured Interviews: Structured interviews provide the most control for the interviewer as all of the questions are prepared beforehand. Because the interviewer does not deviate from the question pool and some or all of the questions can be closed-ended, sometimes with a fixed amount of possible answers, structured interviews can reasonably be compared to questionnaires. The resulting data is of a more quantitative nature than the data gathered from unstructured or semi-structured interviews. Because of the predefined interview guide which is being followed without deviation, structured interviews can also be seen as standardized.

Semi-structured Interviews: Semi structured interviews are a combination between structured an unstructured interviews. A interview guide is used but the interviewer may choose to deviate from it at any point. However, a set of key questions should be covered in every interview.

In this thesis semi-structured interviews are conducted in order to evaluate the final iteration of the prototype. The interview guide will be built upon the results of the previously conducted questionnaires.

3.5 Usability Testing

Usability Testing as a method can be applied to detect strong and weak spots in a current design iteration and to find possibilities for further improvement. Depending on how the tests are conducted and what concrete methods are applied, the resulting data can be quantitative, like described by Preece et al, or qualitative, like stated by Lazar et al. [80] [90]

Preece et al. describe usability testing as a method which relies on measurable factors like for example number of errors, number of touches/keystrokes or the time needed to complete the task. [80] Lazar et al. on the other hand apply methods like observations and thinking aloud in their tests. During a *Thinking Aloud* session participants are encouraged to constantly communicate their actions and their thoughts. This helps the researchers to better understand how different users approach a situation and what aspects of the design are unclear or confusing. Observation as a research method is most

prominently used in the ethnographic research sector. But whereas ethnographers use them to understand people, and the context they work and life in better, in usability testing they are used to detect weak spots in a given design. Usability tests can be conducted as lab studies in controlled environments or as field studies. [90] Kallio et al. tested the usability of a mobile consumer application in both environments and realized that in both, the lab study and the field study, the same problems were found. Therefore, they advised that the decision if a field or a lab study or a combination of both should be conducted, should be made on a per-project basis, based on the respective factors. [91]

Depending on when usability tests are conducted during a design process they can either be formative or summative. Formative tests are usually conducted with low-fidelity prototypes in the early stages of the development process. Their goal is to gather exploratory insights which inform the further design process. Summative tests on the other hand are applied to test the effectiveness of the developed design. Therefore, they often require high-fidelity prototypes and are used in the later stages of the design process. [80] [90]

In this thesis a summative usability test consisting of a field and a lab test is going to be conducted at the end of the second and third prototyping stage. A prototype of the application is going to be distributed to the participants in order to allow them to explore the artifact at their own pace over a longer period of time. They report their experiences via a debriefing questionnaire. In addition, additional participants who have not yet received the prototype are going to be invited to interact with the application in a controlled environment. In this setting qualitative methods like thinking aloud and interviews are going to be used. Therefore, the usability tests should result in a combination of quantitative and qualitative data.

CHAPTER 4

Design and Development Process

This chapter describes the development process behind the thesis project in detail. A a pre-existing concept was adapted and a design game was created to test various assumptions about possible design elements. Based on the results, a technical proof of concept was created and internally evaluated. A second iteration of the prototype was then implemented, and evaluated via an ad libitum user test over a period of several weeks and an accompanying survey. The prototype was then once more adapted according to the feedback gained by the users and evaluated one last time using a usability test under controlled lab conditions in combination with exit interviews with the participants.

4.1 Concept

The concept for the pervasive "*Alchemist*" application is an adaptation of a concept that was created by students of the Technical University of Vienna as part of the courses "Explorative Design 1" and "Explorative Design 2", held by Prof. Purgathofer. The goal of these two courses was to create a game concept that would shed light on some often overlooked issues in everyday life. The "Alchemist" team decided to put emphasis on nutrition and in turn often overlooked additives and ingredients. To do so a concept that required the players to actively seek out specific ingredients and additives in food items was created. They hoped that this would cause players to reflect on their diet and maybe to make some changes or be more mindful in regards of their buying behavior. In the game concept that was proposed, the players had to take on the role of an alchemist, who needed to create various tonics and potions. The ingredients had to be gathered from various food items in the real world by scanning their product code, in turn creating a connection between the game world and the real world. So, if for example a recipe called for salt, the player had to find a food item that contained some form of salt and scan its bar code in order to collect or obtain the ingredient. This concept was used as the starting point for this thesis.

4.1.1 Brainstorming and Idea Finding

As a first design step a few brainstorming sessions were held during which the look of the concept in implemented form was discussed. Furthermore the questions of technology, services and information, which would be required to make it work and what kind of additional features and game mechanics could be added to enrich the experience or to provide additional value were addressed.

It was decided that these elements should be explored in the following design step as part of a design game.

One idea was to let the player choose between different alchemist specializations which would affect the value and the quality of some brewed potions. So, an alchemist who was specialized in poisonous concoctions would be able to create higher grade poisons and sell them for more gold, but in turn healing potions would be inferior to those of a player that specialized in healing.

Another discussed idea involved that in addition to the monetary compensation players would receive renown for their brewed potions. With a higher renown more lucrative or challenging potion orders would be offered to the players. But if the player would brew low-quality potions their renown in turn would decrease. The renown system would also incorporate an adept system, which would provide certain benefits to the player. Once a certain level of renown was reached the players would have been able to accept a maximum of two adepts to study under them. The players could task them with the gathering of missing ingredients or with the improvement of the quality of some potions. These adepts would have been NPCs(Non-Player-Characters) but a different approach revolved around the idea that these adepts could have also been other players. In this scenario the adepts and the master alchemist would have been able to share recipes or knowledge about ingredient effects and locations with one another. Additionally, if the master would receive renown for their potions the renown of the adepts would also increase by a small amount and vice versa.

During these sessions it was also discussed how a sense of progression could be communicated to the players. A possible solution was found by allowing the players to purchase higher grade equipment which would enable them to brew enhanced potions in greater quantity. So, if a player possesses the basic cauldron they would receive the base amount of any given brewed potion whereas a player with an enhanced cauldron could maybe receive double the amount.

Finally, ways to strengthen the connection between the real world and the game world were discussed. It was for example proposed that the context of a brewing process, like the time of day, the location of the player or the date should play an important role in the expected outcome. Important dates in alchemy, druidism or in folklore that possess special meanings like Walpurgis Night or Samhain (the precursor to Halloween) could be incorporated in the game by providing value boosts to potions that are brewed on those days. The inclusion of some recipes that could only be brewed successfully on certain dates, on specific locations, or during a specific time of day was also discussed but was

ultimately abandoned due to the scope of the required overhead. The application should also incorporate elements that are typically connected with alchemy, like an alchemists almanac.

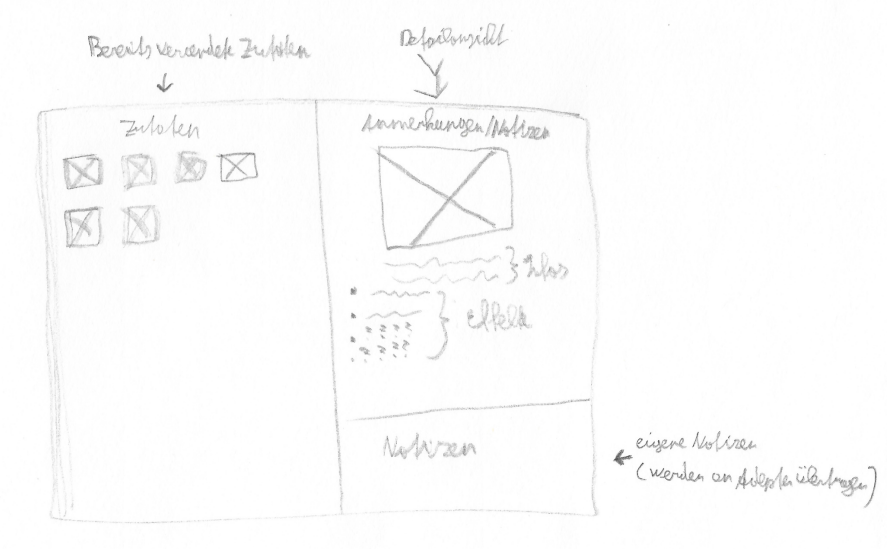


Figure 4.1: Early interface concept of a recipe screen that made use of the metaphor of an almanac.

An early interface sketch (see figure 4.1) used such an almanac as a metaphor for its main interface elements. Through a variety of means like providing backgrounds with a paper texture, screen transitions that mimic turning the page of a book or the use of a font that made the text look hand-written feeling should be conveyed that the "Alchemist" take on the role of ones personal almanac that can be personalized by the player in the course of the game. The player would have been able to flip through the almanac to find specific recipes or information about ingredients. On the left hand side, the ingredients required for the mixture are presented with the ones already collected being crossed out. The right hand side would be split into two parts: The upper section would contain various information about the potion like the name, an image of the potion and its effects while in the lower section the player would be able to place notes. These notes would also play into the adept system as they would be shared between master alchemist and adepts and vice versa.

In the end some of the ideas described above were discarded later on because they were either to expensive to implement, would expand the scope of the project in a way that is not relevant to the answering of the research questions, or the idea was reworked during the following design game.

4.1.2 Data Source

It was discovered very early on in the design process that such an application could only work as intended if a reasonable number of products are included. This circumstance made a sizable database of products and contained ingredients a necessity. But because the task of creating and maintaining such a database of various foods and their respective ingredients solely for the use in this project from scratch was deemed out of scope for this thesis, an already existing solution needed to be obtained.

As Hingle and Patrick point out in their article *There Are Thousands of Apps for That: Navigating Mobile Technology for Nutrition Education and Behavior* a multitude of applications in the area of mobile health exist that provide information about product ingredients, with almost all of them using proprietary databases that are not publicly accessible. They further state that *...in the area of nutrition tracking, apps use different databases for calculating caloric, macronutrient, and micronutrient information. Thus, it is often difficult to compare apps, and commercial entities are often unwilling or unable to share the proprietary information on which their apps are built, including nutrition databases.* [5]

Nevertheless, many providers of such applications were contacted about the possibility of a cooperation by giving limited access to their product database for scientific purposes but all of them were unwilling or unable to provide access to their information outside of their own offerings like Apps and paid APIs.

There also exist a number of dedicated databases that provide APIs for a multitude of products like toys, food, books and almost everything with a barcode. Am example for such a database, that is also completely accessible for free, would be the Open EAN/GTIN Database.[1] The problem with this solution is that it doesn't provide information about contained ingredients outside of meta information like whether a product is vegan or gluten-free, while other solutions that would provide ingredient information also were unwilling or unable to provide scientific access and again would charge for the use of their API.

Finally, a viable solution was discovered that ticked almost all necessary boxes: OpenFoodFacts.[2] OpenFoodFacts is a non-profit project that maintains an open database of over a million different food items and their ingredients that operates on the wiki principle known from other non-profit projects like Wikipedia. That means that everybody can add or modify information about products like their ingredients, additives or nutrient levels and that everybody can access the stored information for free. And because the data is provided under the Open Database License it can even be used for non-commercial or commercial projects. An example can be seen in figure 4.2 where a completed product entry for a chocolate bar is depicted. Various information about the product like the name and the barcode together with ingredient and allergen information is stored and is also accessible via an API.

[1] http://www.opengtindb.org, last accessed: 2020-05-10
[2] https://world.openfoodfacts.org/, last accessed: 2020-05-10

Figure 4.2: Completed OpenFoodFacts entries possess various information about a product including the data about contained ingredients and additives that is needed for the project.

Although at first glance this database seemed to be the perfect fit for the project some major shortcomings were uncovered upon closer inspection. The biggest one being that ingredients are not indexed and stored on a database-wide level. Instead the ingredients are only stored as part of the product entries where they are identified by their name. This means that the same ingredient in two different products will only be recognized as such if they are spelled exactly the same. Therefore, if some products contain ingredient entries like "*salted butter*", "*salted-butter*" and "*Salted butter*" and so on, the ingredients will not be recognized as the same. This problem is only exacerbated by the multinational and multilingual wiki nature of the project. Because the only identifier of an ingredient is its name, ingredients entered in different languages will also never be recognized as the same. For example the English "*salt*" would be a different ingredient than the German "*Salz*" which again would be a different ingredient than the French "*sel*" although they all describe the same one. Of course the same applies for different variants of an ingredient like for example "*table salt*", "*kosher salt*" or "*sea salt*" in the case of salt. Additionally each ingredient is denoted by a prefixed language tag like "en:" or "de:".

Another problem is the lack of proper input validation and sanitation. Because ingredients are only stored as part of a product no global list of ingredients exists. Therefore, anything that is added to a product entry as an ingredient will be accepted as such by the system.

This includes ingredients with spelling mistakes like "*koshe salt*", ingredients with improper capitalization like "*SAlt*" or ingredients that included additional information like "*salt (3,9%)*" which would all be recognized as valid and distinct ingredients.

Lastly, the wiki-like approach of the database means that the quality of product entries can vary greatly from entry to entry based on who entered and modified the data. So, for example the ingredient list of a product could only be partly entered or incorrect.

Nevertheless, the positive aspects of OpenFoodFacts greatly outweighed the negative ones so it was chosen as the data provider for *Alchemist*. The steps that had to be taken to correct the described flaws in order to make that database usable are described in section 4.3.

4.2 Design Game

Once the outline of the mechanics and the overall design were agreed upon, the next step was to create a design game in order to test some assumptions about how certain aspects of the game, like the inventory and brewing systems, should work and how the players would react to them. This game was then playtested in various game sessions with a number of people and the resulting data and insights were used to help create the first prototype of the app.

4.2.1 Intention and Assumptions

Although many aspects of the game were already discussed in detail during the brainstorming phase, they still needed to be tested with participants, whereas other aspects, such as the concrete way that the requisitioning and the handling of ingredients should work, could only be reasonably evaluated with user feedback. In order to get the players into the right mindset the proposed design game should also make use of the alchemy setting and incorporate elements and mechanics accordingly. The game was intended to test assumptions about several distinct game mechanics:

Cooperative play versus competitive play: The intended game mechanics, in regards to the multiplayer portion (i.e. the adept system), were largely of cooperative nature since the players could share notes or recipes with one another and they would also gain renown from the feats that their master or their adepts would perform. But the game could also be structured in a more competitive way. As mentioned before, the players could choose a specialization later on which would affect the quality of certain potions. This mechanic could be expanded by incorporating a narrative in which alchemists of different specializations or "schools" were at constant odds with one another and fought over brewing contracts and renown. The renown system would also be used for this aspect as the school would receive renown from its alchemists. By providing global potion contracts which were awarded to the school that delivered the largest amount of the requested

potions, the alchemists of the different schools were also be encouraged to focus on specific potions. The renown of the school could be used to receive discounts on equipment upgrades or on new recipes.

Requisition of ingredients: One of the core mechanics of *Alchemist* consists of the scanning of product codes in order to receive valuable ingredients. But within this mechanism a number of different approaches can be used. For example: If a product possesses the ingredients X, Y and Z. What would happen if the product code is scanned? Would the player receive every ingredient contained therein? If so, in what quantity? Or maybe they would need to choose between different ingredients as all of them would be unobtainable together? Additionally, some high value ingredient could maybe only be harvested with special equipment or once the player has reached a certain level of renown. As these decisions would have great impact on how the rest of the application would need to be designed the requisition of ingredients was defined as a central point of the design game.

Use of perishable ingredients: Once ingredients were acquired and put into the inventory the next step was to consider for how long they could be stored. The simplest solution would be to keep the ingredients in the inventory indefinitely until they are used for a potion. Although this approach would clash with the metaphor of an alchemist who needs to keep an eye on his inventory (ie. spoiled or expired ingredients) it would lead to a more tranquil game experience as the players could perform actions on their own terms. On the other hand: The inclusion of (certain) ingredients which could only be used in a certain time period after they were acquired would provide a sense of urgency. Should perishable ingredients be included, they could be handled in a number of ways. For example, they could simply be discarded from the inventory once they spoil. The more elaborate approach would be to allow the players to use those ingredients at the cost of lower grade and therefore lower value potions or potions which also have a poisonous side-effect. In regard to the renown system such potions would decrease the renown of the player. This could also be linked with the upgrade system of the alchemist tools as in that upgraded equipment would be able to mitigate or to cancel out those unwanted side effects.

Granularity of ingredients: Once products were scanned the contained ingredients could also be handled in different ways. The simplest approach would be to exclusively provide ingredients which are already suited for the brewing process and could be used without further processing. The more elaborate way would comprise resources that could not be used immediately and would need to be broken down into ingredients first through the use of equipment such as a mortar. In extension, certain resources maybe could be broken down into different ingredients depending on how they would be processed. The approach with tiered ingredients would

provide the players with a sense of agency. Therefore, this mechanic should also be part of the game in some form.

Duration of the brewing process: The brewing of various potions is one of the key features of *Alchemist* and therefore needs to be handled with careful deliberation. A number of possible factors which could influence the brewing process are presented in section 4.1.1, but one missing factor is the time that a brewing process takes to complete. The two possibilities are the following: the process would finish either instantaneously or a after a certain time period. The time needed could maybe also be decreased by using enhanced equipment.

Fixed recipes versus effect-based potions: The final assumption deals with the way the brewing system should work in regard to the potions themselves. The obvious way of implementing the brewing system would be to provide a number of fixed potion recipes. Consequently, once the player has acquired every ingredient the recipe demands they are able to brew the respective potion. The more elaborate approach would be to omit recipes altogether and instead give every ingredient a number of effects that the players would need to discover by themselves by mixing and matching ingredients and by looking at the resulting potions and their effects. So, if a player combines four ingredients and three of them have the "*healing*" effect, the resulting brew would be a healing potion. If they then repeat the process with four healing ingredients, the process would result in a higher grade healing potion. But if they, in turn, mix healing ingredients with poisonous ingredients the resulting potion would be unusable. The process of determining what kind of effects an ingredient possesses could be developed into a mechanic on its own. Maybe some effects only reveal themselves once certain ingredients are paired with one another, while others are revealed automatically once a certain level of renown or expertise is reached. This could also be used as part of the adept system, where discovered effects are shared between master and adepts. A combination of both approaches, where the effect system would still remain in place but recipes would also be included to provide aspiring novice alchemists with starting points would also be possible.

4.2.2 Creation of the Game

The design game should be created in a way which allowed it to answer multiple questions about the design of *Alchemist* by providing a basic game framework that could quickly be adapted to the relevant assumptions already laid out in the previous section. The game should also be portable and game rounds should last ideally between 15 and 30 minutes in order to accommodate more rounds in a game session as they were required to test the different assumptions. To keep the game portable it was designed as a card game without the need for a game board. To keep the rounds reasonably short the rule set was written accordingly. The game tries to emulate the mechanics of the full application to a certain

degree while still diverging from it where senseful. The deck consists of various different card types: potion cards, resource cards, ingredient cards and equipment cards. The resulting card deck can be seen in figure 4.3. Potion cards simply consist of the name of the potion together with a different colored potion image for each card. The three types *healing potion*,*sleeping potion* and *antidote* are provided but additional potions could be added during the game. Resource cards have a green frame and need to be broken down in order to get the ingredients. Such a relation is depicted in figure 4.4. To obtain the ingredients *egg*, *feather* or *liver* the resource *chicken* needs to be broken down. The final card type are the ingredient cards which are indicated by a blue frame. These are the cards that have to be used to brew potions. Some of them are provided to the players at the start of the game, while others need to be acquired by breaking down resources or by purchasing them.

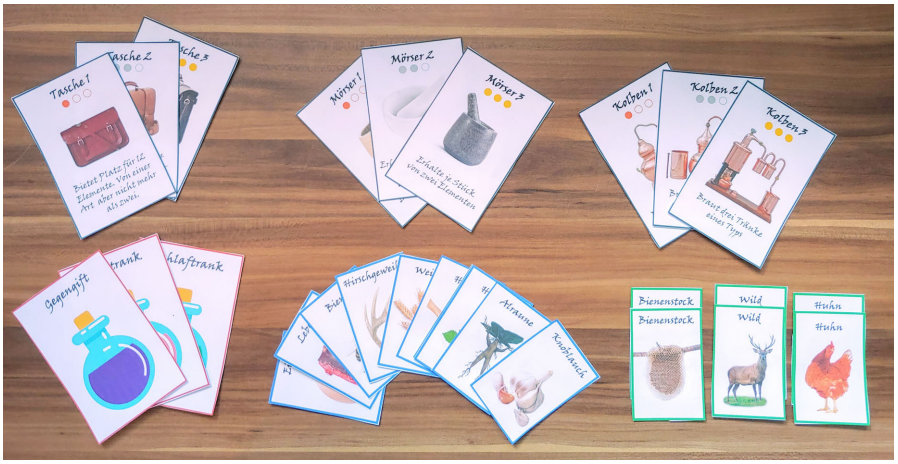


Figure 4.3: Overview of the game cards and the different card types.

Equipment cards are accentuated by a black frame and by the colored dots providing an indication of the equipment level. The level is also indicated by the suffix 1, 2 or 3 at the end of the card name, with 3 being the highest. The effect of the card is described by the text at the bottom. The equipment cards represent an alchemist satchel, a distillery and a mortar at one of three different levels (bronze, silver, gold). Each card serves a different purpose and each level provides a boost to the ability of the card. As an example the upgrade path for the satchel item is depicted in figure 4.5. To counteract ambiguity the upgraded items replace the lower tier items. Therefore, the players can only ever have three pieces of equipment in their possession.

The purpose and the ability of each of the equipment items are as follows:

Mortar: The mortar can be used to break down resources into usable ingredients. The level determines how many ingredients are received.

Bronze: The player receives one ingredient.

Silver: The player can choose between receiving two units of one ingredient or one unit each of two ingredients.

Gold: The player receives two units of two ingredients.

Distillery: The distillery determines the quantity of potions gained by a single brewing process.

Bronze: The player gains one instance of a potion.

Silver: The player gains two instances of a potion.

Gold: The player gains three instances of a potion.

Satchel: The satchel acts as the inventory of the game and limits how many items (resources, ingredients or potions) the player can possess at any given time. Once the limit is reached items need to be discarded before new items can be stored.

Bronze: The bronze level variant allows the storage of twelve elements. Additionally, only two items of the same kind can be stored at the same time.

Silver: At the silver level twenty-four items can be stored in the satchel. At the same time only three instances of an item can be stored at the same time.

Gold: At the highest level thirty-six items can be stored in the satchel simultaneously. The restriction regarding the storage of items of the same kind is removed.

The game itself is round-based and can be played by three to five people. One player takes on the role of a shopkeeper who provides the alchemists with ingredients and item upgrades and who also places the potion orders which the alchemists need to fulfill. The shopkeeper also acts as the game master and is tasked with setting the prices of equipment item upgrades, ingredients and potions within certain limitations. The player also sets the recipes for the different potions at the start of the game. It is up to the game master if they disclose the recipes to the alchemists or if they keep them a secret to encourage the exploration of different ingredient combinations. The other players act as alchemists, who, depending on the variation of the rule set, are either playing cooperatively with or competitively against one another. Before the start of the first game the shopkeeper is determined randomly among the players. The alchemists take turns in clock-wise direction beginning with the alchemist to the left of the shopkeeper. Each alchemist can perform three distinct actions before their turn ends. So, in any given turn the players can either perform the actions "Purchase resource from shop", "Break down resource" and "Brew potion" or they can perform the action "Buy ingredient" three times. Once a game is completed, the position of the shopkeeper also gets passed on to the next player in clock-wise direction.

Figure 4.4: The resource chicken can be broken down to get the ingredients feather, egg or liver. Depending on the available equipment not every ingredient may be obtainable.

At the beginning of the game each alchemist starts out with every equipment item at its base level and an amount of gold coins, which they can use to purchase goods from the store. These gold coins can be represented by poker chips, game tokens or they can simply be written down on a piece of paper. The win condition for the game can be set depending on what rule set variation is in use during a game. So, for a cooperative game the goal could be to collectively brew a certain amount of potions in a given round limit while the goal in the competitive game could be to upgrade every piece of equipment to the highest level or to amass the largest amount of gold in a given round limit. It can also be noted that although the alchemists have to work together in cooperative scenarios they can't directly interact with one another during the game in competitive situations as they can only interact with the shopkeeper. Because of that restriction alchemists are not able to trade with one another.

4.2.3 Playtesting

The play testing of the design game occurred during the week of August 20th 2018. A total of five game sessions were conducted with nine different people aged from 17 to 37 participating for a total of 22 alchemists and shop keepers who completed 19 games. A scene from one of the sessions can be seen in figure 4.6. During the sessions, different rule sets were used to account for the different assumptions described previously in section 4.2.1, like gameplay of competitive nature versus cooperative play or the use of resources

Figure 4.5: Each equipment item can be upgraded multiple times. Enhanced items provide more storage or improve the amount of brewed potions.

that needed to be broken down into ingredients first.

Although the rules sometimes needed to be adapted during a game the prepared rulesets were kept unchanged for the most part and allowed for interesting game scenarios. One area where changes were needed, were the powers of the shopkeeper as they were originally given too much leeway in how they set the prices for different items. This change was necessary because depending on the set prices and the cards received at the start of the round an alchemist could have been severely limited in their actions because they would not be able to afford the needed ingredients. After the change, each item had to be priced within a predefined price range.

The aspired time window of 15 to 30 minutes per round was also achieved, with most rounds taking between 15 and 20 minutes after the players got accustomed to the rules. The first few rounds in a game session typically took longer than 30 minutes as the players where unfamiliar with the rules or certain mechanics, like the way the breaking down of resources worked and what resources were eligible for them based on their equipment.

4.2.4 Results

During the game session notes were taken and after every game the participants were questioned about how they've liked the rules. At the end of each game session the players were questioned about how they liked the game in general, and in which areas they would see potential for improvement.

Figure 4.6: The design game was tested in a number of game sessions with a total of nine different people.

The results are going to be presented broken down in the same manner as the assumptions in section 4.2.1:

Cooperative play versus competitive play: Most participants stated that they found the competitive version of the game more fun to play than the cooperative version. This assessment could be caused by a number of factors. Because the alchemists effectively act as one team and the only "opponent" is the round limit, the level of excitement at the moment of winning is probably not as high in the cooperative game. Maybe, to combat this, the player limit could be increased so that in the cooperative version two or three teams of three alchemists each compete against each other. Another possible factor could be the way the alchemist equipment was utilized in these circumstances. Since the alchemists could share their equipment in a lot of rounds each alchemist specialized on a different piece of equipment. That means that one player only upgraded their distillery while another only upgraded the satchel to safe money. This approach worked quite well in games with three alchemists as each one could focus on a different item but in games with four alchemists the fourth one didn't really have anything to do. In this case the solution also would be to limit the number of players or to replace the personal items with an item pool that is shared between the team members.

The input for the thesis project gained from this assumption is that the multiplayer portion of the application should be the focused on competitive play. But since

multiplayer was discarded from the prototype in the end this rule set delivered input for possible future work (found in section 7.2) in this area.

Requisition of ingredients: The requisition of ingredients was tested via the restriction imposed by the mortar, where, in its base form, players would need to choose which ingredient they would like to get from a resource. In addition to the cards received at the start of the game the other source of ingredients and resources was the item shop as the scanning mechanic was not translatable in card game form in a satisfying manner or in a way that fit the setting. The players opinions were divided on this topic with roughly half of them liking the agency of choosing the ingredient while the other half disliked it. A player stated that "*Most of the time I needed all of them anyway, so the game only took longer.*" with others sharing the resentment. Alchemists would sometimes indeed require multiple ingredients gained from the same resource for a specific potion. For example, many healing potions required a combination of *Liver*, *Egg* and *Honey*, with the former two only being obtainable via the *Chicken* resource. So, with the starting equipment the players would need to purchase twice the amount of chickens to gather the necessary ingredients.

This insight was used in the prototype by removing the mortar ability from the game. When players scan a product in the app they will receive one instance of of every contained ingredient. This was the logical step to take because without actively hindering the progress of the players (e.g. a cooldown between each product scan) they would have been able to quickly scan the same product consecutively and choose different ingredients to receive them all. So this change can actually be seen as a quality-of-life improvement because the players can now expect the same results with less effort on their part.

Use of perishable ingredients: To test this assumption some appropriate ingredients, like eggs and and liver were given a turn limit, while others like honey or lavender were not. This means that once an ingredient with a turn limit was acquired it needed to be used within that limit or it would perish otherwise. This mechanic was almost universally disliked by the players. Some stated that this mechanic made for a more stressful game as their actions were dictated by which ingredient would perish next, effectively removing agency. Another player stated that the required planning and ingredient management turned the game boring and tedious as each round was stretched out. Finally, some players were unable to brew certain potions as they were unable to possess all required ingredients at the same time. Some players on the other hand circumvented this restriction by upgrading their satchel and then purchasing a number of resources first, which they then broke down into perishable ingredients in quick succession. This means that the players who did not use this strategy always had to buy the same ingredients over and over again and therefore spent money at the shop without being able to sell potions, effectively running out of money in the process. Although ingredients would not be needed to be purchased and therefore this would not be a problem in the mobile

application, most of the complaints, especially those in regard to the inventory management, would still carry over.

As a result ingredients in the mobile application do not spoil once they are collected, therefore minimizing the effort needed for item management.

Granularity of ingredients: The introduction of resources that need to be processed and broken down before their ingredients could be used was received differently by the players depending on what additional rules were in effect. In combination with perishable ingredients the mechanic was received well by the players who used resources as a way to circumvent the spoilage of ingredients while it was often criticized by those who did not. Some of those players stated that the mechanic in combination with the action limit per turn would make it quite hard to brew more elaborate potions or any potions at all depending on the recipes the shopkeeper had defined. In games where perishable ingredients were not used the mechanic was almost universally received in a more positive way by the players. This could be the case because without the limit imposed by spoilage the otherwise needed strategies do not need to be considered and therefore the resource system is received as just another mean of acquiring ingredients.

Although the resource mechanic was received positively by the players, ultimately it was decided not to include it in the prototype as ingredients on food products already had to be listed as granular as possible. So, to use this mechanic these ingredients would need to be broken down even further and therefore possibly collide with the goal of informing the players about the various ingredients and additives in their food products.

Duration of the brewing process: To test this assumption in some games the brewing process would be instantaneous while in others it would take one round to complete. Almost every player preferred the instantaneous version over the other one. One player stated that once that they collected all necessary ingredients the brewing should finish immediately. On inquiry, the player further explained that they saw the resulting potion as the reward for the collection of the ingredients and not as the product of a brewing process. Another player stated that due to the time the brewing process took to complete, the number of potions that could be brewed was severely limited. With the brewing process which finishes immediately the number of potions that the players could produce were only constrained by their ingredient stockpile and the action limit per turn, while in the other variant they could only brew one potion per turn. This proved to be especially cumbersome when combined with perishable ingredients.

As a result, it was decided that brewing of potions in the prototype should be instantaneous. However, the inclusion of a brewing duration was seen as an interesting aspect that could potentially be explored as part of further development.

Fixed recipes versus effect-based potions: Overall most of the players preferred the fixed recipes over the effect-based ones. This could very well be caused by the fact that in only two games the shopkeeper opted to keep the recipes a secret, openly providing them in the other instances. Therefore the two systems seemed almost identical to the players because from their point of view it didn't make a difference whether they collected ingredients simply because the recipe called for them or because the ingredients possessed the desired effects. One of the two games were the recipes were kept secret was also a cooperative game and the alchemists quickly developed strategies to increase their chances to discover ingredient effects. In this game each alchemist used a different ingredient combination until a working recipe was found. After the game they reported that they liked the effect-based system better than the other one as it added a sense of mystery and discovery to the game. On the other hand some players reported that fixed recipes could make the game unbalanced and boring if one alchemist happens to be able to brew a potion from the get go because they received the right combination of starting ingredients, therefore gaining an unassailable advantage over the other players.

Due to the received feedback and the shortcomings of the chosen product database already described in section 4.1.2 it was decided to use fixed recipes for the prototype. Nevertheless effect-based recipes still still remain an interesting concept that could be explored further once a suitable number of ingredients are added to the system.

Overall the design game was well received by the game testers and led to some important insights that were used to create the prototypes of the application.

4.3 Server

As was already laid out in section 4.1.2 the OpenFoodFacts database could not directly be used for this thesis project but instead needed to be adapted in order to overcome some of its shortcomings like the lacking ingredient matching. This could have been done in one of two different ways: The first approach would have been to clone the entire database, perform the necessary changes on the data set and then to use the resulting database as the data source for the application. But not only would this approach have required considerable time and effort for the intended outcome, but the database would have also been unable to be updated with entries unless the changes were performed on the new entries as well, making it very hard to maintain. The second approach, which was also the one agreed upon, was to create a second database that acted as a intermediary between the OpenFoodFacts database and the mobile application and which could provide the required ingredient matching functionality. This would also require a certain effort to implement but it would provide the advantages that new entries in OpenFoodFacts are available immediately for the use in Alchemist and that the system will be easier to maintain. But one aspect that would need to be updated on a regular basis is the mapping of ingredients onto each other as this functionality would be very hard to automate.

Another functionality that the server should provide is the maintaining of lists for potion recipes and ingredients usable in the application. Lastly, the provided information needs to be accessible in the mobile application, which means that the server also needs to provide an API.

To sum up, the server component needed to fulfill three distinct functions:

1. Provide the required matching functionality for ingredients
2. Maintain a list of usable ingredients and potion recipes
3. Provide an API through which the stored data can be accessed by the mobile application.

The development and the considerations that went into each of these functions will be described and explained in depth in the following sections. The server component itself was developed using Java and made use of H2 for the database and Apache Tomcat for the server functionality.

4.3.1 Ingredients

As was mentioned above, the matching of ingredients would need to be performed manually and for each ingredient individually. Therefore, the first step was to identify those ingredients that would make the most sense to include in the database either because of the number of their appearances or because they were especially suitable for usage in potions. It would make no sense to spend time and effort to include ingredients that are only present in a small number of products and therefore would be very hard to find for the players. But it also would go against the idea of the project to only include ingredients that are very common but are not interesting from a gameplay perspective. An example for such an ingredient would be water, which is logically one of the most used ingredients but its use in every potion is already implied and therefore an inclusion in each recipe would be repetitive in nature and tedious for the players. But because the records of ingredients were only stored locally inside of products there also was no easy way to determine the number of each individual ingredient right away. Instead, this list had to be produced first. As a first step, the entire OpenFoodFacts database was downloaded onto a local machine and extracted. Then a simple Java program was written which crawled the entire database and extracted the ingredient tags from every product. The occurrence of each tag was then counted and put into a list. The resulting output of the program was a simple text file that contained an entry for every ingredient in the database ranked by the number of respective occurrences. This process unearthed around 773.000 unique ingredients present in the database of which roughly 92.5% had less than four occurrences and therefore were not considered after that point. The main causes like spelling mistakes or differences in capitalization for this high percentage of ingredients that are hardly used are already explained in section 4.1.2.

The remaining 7.5% of the list was then searched for ingredients that fit the criteria. It was then decided to include the following 40 ingredients in the system for usage as part of the potion recipes:

- Caffeine
- Cranberries
- E 100 - Curcumine
- E 150 - Caramel Color
- E 160 - Carotin
- E 211 - Sodium Benzoate
- E 235 - Natamycin
- E 250 - Sodium Nitrite
- E 260 - Acetic Acid
- E 270 - Lactic Acid
- E 290 - Carbon dioxide
- E 300 - Ascorbic Acid
- E 304 - Ascorbyl palmitate
- E 320 - BHA
- E 321 - BHT
- E 322 - Lecithin
- E 330 - Citric Acid
- E 338 - Phosphoric Acid
- E 385 - EDTA
- E 406 - Agar Agar
- E 407 - Carrageenan
- E 410 - Carob Bean Gum
- E 412 - Guar Gum
- E 415 - Xanthan gum
- E 428 - Gelatine
- E 440 - Pectin
- E 450 - Diphosphates
- E 471 - Mono- and diglicerides of fatty acids
- E 500 - Sodium carbonate
- E 950 - Acesulfame potassium
- E 951 - Aspartam
- E 1400 - Dextrin
- Garlic
- Palm Oil
- Salt
- Sugar
- Sunflower Oil
- Vitamin A
- Wheat
- Yeast

Each of those ingredients represents a multitude of different entries in the OpenFoodFacts database. So in order to be able to, for example, successfully identify and recognize cranberries over 50 different cranberry ingredient variants like "*dried cranberries*" or "*sweetened dried cranberries*" were added to the matching table. In total, over 620 ingredient entries were needed to ensure the correct matching of the 40 selected ingredients.

The selected ingredients were given an unique ID, together with a short description of the substance in the languages English and German. The system was also designed in a way that additional languages could be quickly added without the need to adapt the database schema.

The checking for ingredient matches itself works as a three step process. The process starts once a product is scanned via the code scanner embedded in the mobile application. If a valid product barcode is found, a request is sent to the OFF API with the recognized barcode as a parameter. The API request can be answered in two different ways. If

the code is not present in the database the API return the transmitted code together with the status code "0" with the meaning "product not found". However, if the product is found the API returns all stored information about the product, including a list of every ingredient. These ingredients are then sent to the Alchemist server where they are matched against the database to identify the related ingredients. The server then strips the resulting ingredient list of repeated entries and sends the result back to the mobile application where the information can be processed further. This behavior can be seen in the API request shown in figure 4.8.

4.3.2 Potions

Once the usable ingredients were selected the creation of the potion recipes as the next step could begin. The different potions should be created with alternating difficulty levels either through the number of ingredients needed or through the rarity of the ingredients that the recipe calls for. Also, not every ingredient should be included as part of the test run, with their use being reserved for additional recipes. To start out, the following ten recipes were created:

- Agility Tonic
  - *Provides an agility boost.*
  - Ingredients:
    - Caffeine
    - E 1400 - Dextrin
    - Sugar
- Black Powder
  - *A quite explosive substance.*
  - Ingredients:
    - E150 - Caramel color
    - E250 - Sodium nitrite
    - E304 - Ascorbyl palmitate
    - E406 - Agar Agar
    - E500 - Sodium carbonate
    - E950 - Acesulfame potassium
    - Salt
- Garlic Juice
  - *Some garlic dissolved in water.*
  - Ingredients:
    - Garlic
    - Salt
- Health Potion
  - *A potion that restores health.*
  - Ingredients:
    - Cranberries
    - Milk
    - Vitamin A
- Invisibility Serum
  - *Provides a brief window of complete transparency.*
  - Ingredients:
    - E 100 - Curcumine
    - E 320 - BHA
    - E 410 - Carob Bean Gum
    - E 412 - Guar Gum
    - E 951 - Aspartam
- Potion of Braveness
  - *This serum will increase the braveness until the effect gradually wears out.*

  - Ingredients:
    - E 951 - Aspartam
    - Palm Oil
    - Sunflower Oil
    - Wheat

- Potion of Forgetting
  - *This tonic will impair the ability to ...do something. I don't quite remember.*
  - Ingredients:
    - E150 - Caramel color
    - E322 - Lecithin
    - E330 - Citric Acid
    - Yeast

- Potion of Survival
  - *This potion will increase the odds of surviving the next winter.*
  - Ingredients:
    - E471 - Mono- and diglycerides of fatty acids
    - Milk
    - Palm Oil
    - Sugar
    - Wheat

- Rat Poison
  - *A poisonous brew intended for rats.*
  - Ingredients:
    - E211 - Sodium Benzoate
    - E321 - BHT
    - E385 - EDTA
    - Salt

- Stress Reducer
  - *This potion will reduce the stress level by some degree.*
  - Ingredients
    - E304 - Ascorbyl palmitate
    - E471 - Mono- and diglycerides of fatty acids
    - E500 - Sodium carbonate
    - E 951 - Aspartam

Those recipes were chosen as examples for a spectrum of different kinds of potions that are more or less realistic. One the one end of the spectrum is "*Garlic Juice*", a quite literal interpretation of the recipe that just asked for some garlic dissolved in water. On the other end are fantastical potions like the "*Invisibility Serum*" that asks the users to suspend their disbelief and to immerse themselves in the setting of the game. Then there are substances like "*Black Powder*" that was actually discovered through alchemical efforts or the "*Potion of Survival*" which works by just putting together of a lot of fattening ingredients. Another interesting potion is the "*Rat Poison*", as it is the only really concoction that can be brewed with the sole intention of harming someone. Maybe the players react well to the idea of creating poisons from ingredients they collect from their foods or maybe they do not like the idea of a potion that erases ones memories.

Potions were again translated into English and German and they also have parameters for the perceived difficulty of the recipe (ranging from 1 to 5) and the value of the potion in its base form. This value is then multiplied with the boni gained from equipment or other modifiers during the brewing process to get the final value of the brewed potion.

4.3.3 API

This section provides a brief overview of the different requests that are supported by the API. In order to be able to create a simple and fast interface that fits all of the needed criteria, it was decided to create a RESTful API to be used for the communication between the server and the mobile clients. Since the server is only needed to perform SQL-queries and it therefore does not need to perform complex computations, the server was deployed on a Raspberry Pi 3. Also, since no data on the server needs to be modifiable via the API, only "get"-requests are needed (see figure 4.7).

The functions of the API can be divided into parts for the ingredients received from OpenFoodFacts ("off_ingredient"), the ingredients used inside of *Alchemist* ("ma_ingredient"), and for the different potions. Some notable examples are provided below.

get **/ma_ingredients/all/**

Get a list of all ingredients.

Response application/json

200 ok

```
[
    {
        "id": 1,
        "name" : "Cranberries",
        "translations" : [...]
    },
    {
        "id": 2,
        "name" : "Milk",
        "translations" : [...]
    },
    ...
]
```

Figure 4.7: API request that returns a list of all internal ingredients.

The entirety of the API documentation can be found in Appendix A.

Once the server component was deployed and the API was in place, the development work on the prototype of the mobile application could begin.

get **/ma_ingredients/getbyOFFIngredient/**

Get a list of ingredients based on OpenFoodFacts ingredients.

Body application/json

```
[
    {
        "tag": "en:Nonfat milk",
    },
    {
        "tag": "de:pasteurisierte _Milch_",
    },
    {
        "tag": "en:aspartam",
    }
]
```

Response application/json

200 ok

```
[
    {
        "id": 2,
        "name" : "Milk",
        "translations" : [...]
    },
    {
        "id": 6,
        "name" : "E951 - Aspartam",
        "translations" : [...]
    }

]
```

Figure 4.8: If multiple ingredients match onto the same one, the respective ingredient is only returned once by the API.

4.4 Mobile Application

The development of the mobile application was a core focus of the project, as it would be the only part of *Alchemist* that the users would actively interact with. In order to be able to develop an application which would be received positively, the users were integrated into the entirety of the development process. Three iterations of the prototype were developed, with the first one being used as a technical proof of concept that was only

evaluated internally while the other two were evaluated using usability tests, interviews and questionnaires.

4.4.1 First Prototype

In this section the functionalities of the first prototype are explained. The first iteration of the application was developed as an Android-only application using Java as the main programming language and Android Studio as the development environment. The main goal for this iteration was to get a feeling of how individual functions of the application, like the technical implementation of the scanning functionality, should work and how different parts could and should interact in order to enable the intended functionality. So, in this early development stage not much effort went into the design of the user-facing elements of the application. The lack of a cohesive design language in this step is also the reason why the some parts of the interface look very rough and unpolished.

The app is navigated via a menu placed at the bottom of the screen, which divides the application into five areas: *Start*, *Scan History*, *Almanac*, *Brewing* and *Shop*.

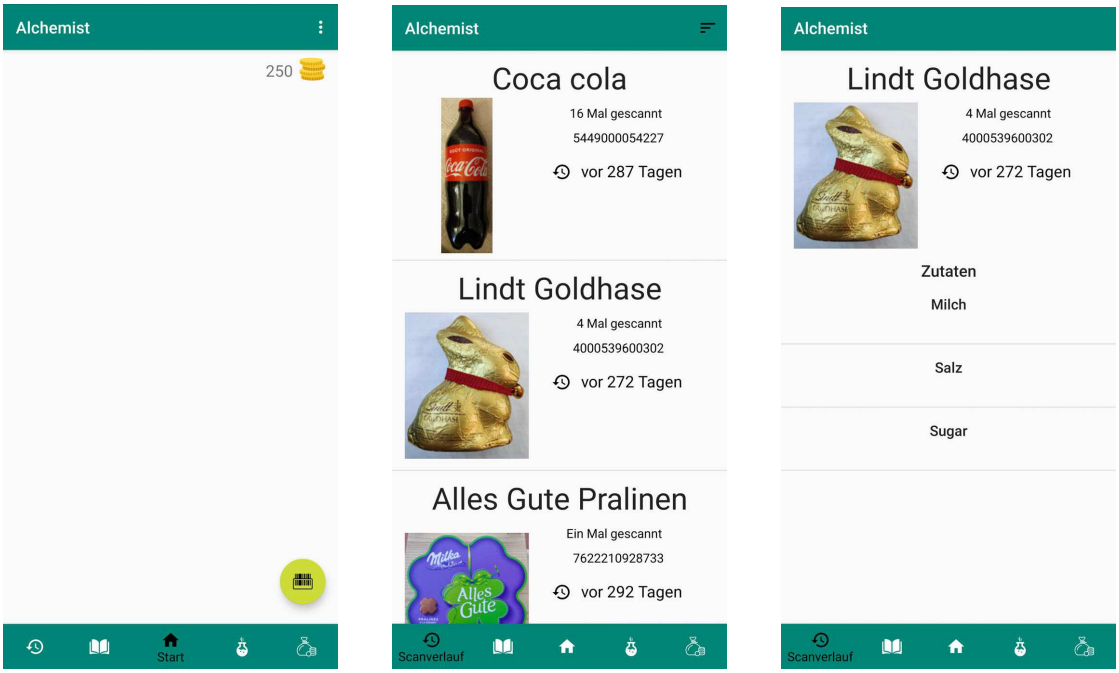
When the app is launched it opens the "*Start*" screen (see figure 4.9a). This screen is largely meant as a placeholder. It only holds the button to start the scan process (lower right corner) and information about how much gold coins the player currently owns.

The scan history screen (see figure 4.9b) lists all the products that the player has scanned. Via the button in the upper right corner the entries can be sorted either alphabetically by their name, the number of times an item was scanned or by date the item was last scanned. The product entries themselves are presented in a list. Each entry can be identified through its name, an image of the product and its barcode. In addition, the player can see how often the item has already been scanned and when it was last scanned.

If the player selects an entry on this list they are taken to the detailed view of the product (see figure 4.9c). On this screen the same information is accessible together with a list of contained ingredients. These ingredients are the ones used internally by Alchemist and not the complete list of ingredients that are present in the product.

While some information like the ingredient list is checked on every scan, other data like the product image and product name are pulled from the OpenFoodFacts server on the initial scan and stored locally. That means, even if the product image or the product name changes, these changes are never reflected in the app.

If a scanned barcode is recognized the detailed view of the product will open. If however a product is not already entered into the database, the player is asked whether they want to contribute to the OpenFoodFacts project via a prompt. If they want to contribute and choose "Yes" they are redirected to the entry of the OpenFoodFacts app in the Google Play store, or, if they've already installed the app, the app will open directly. Via this app the players can add products to the database and make changes to already existing entries.



(a) The start screen is only sparsely populated and only used to start product scans.

(b) Already scanned items are presented as a list in the scan history screen.

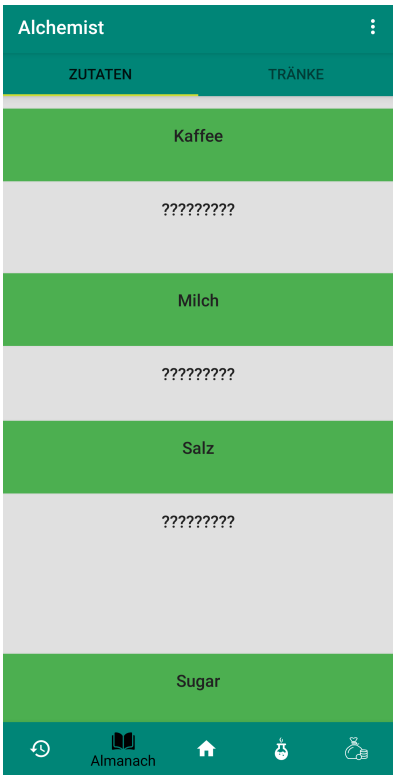
(c) The detail view also lists the usable ingredients of the product.

Figure 4.9: Screenshots of the Start and Scan History screens of the first iteration.

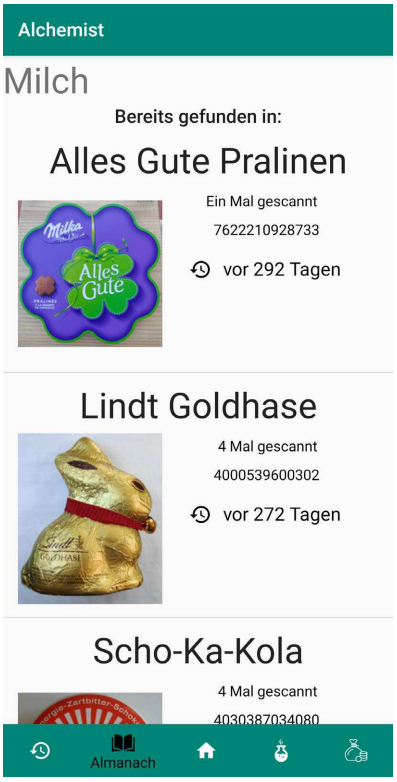
The next entry on the bottom menu is the almanac section. In it all information about ingredients and potions is stored. In the "*Ingredient*" part of the almanac every ingredient can be found, but the ones that are yet to be discovered are grayed out and their names are replaced with question marks (see figure 4.10a). Ingredients that are already discovered are highlighted by a green background color. If the players click on such an ingredient they are taken to the ingredient detail screen (see figure 4.10b), where they can see in which products the ingredient has been found already. This way they can also see which products share the same ingredients.

The part of the almanac which houses the potion recipes works in a similar way (see figure 4.11a). Potions that have already been brewed in the past are written in clear text, while the names of undiscovered potions are hidden again. Discovered potions can again be clicked on to open the potion detail view, seen in figure 4.11b). Here the name of the potion together with the required ingredient list, a short description and the perceived difficulty level via a range from one to five stars can be found.

On the potion brewing screen (figure 4.11c) the players can see which potion they are currently preparing. Already discovered ingredients are highlighted by a green background, while ingredients that have not already been collected or discovered are highlighted in red. That way the players can quickly see which ingredients they are missing in order



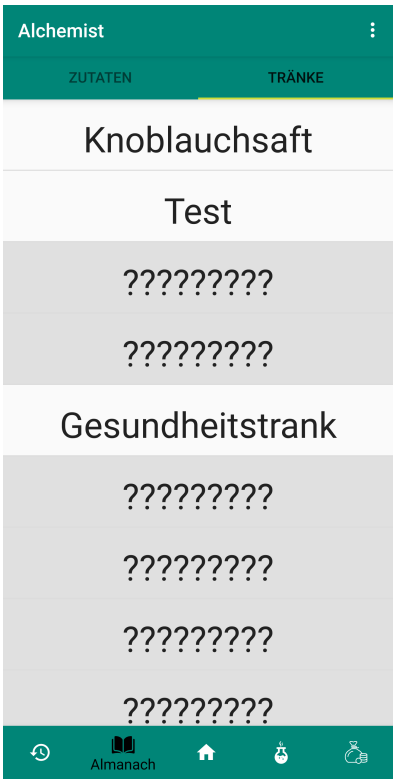
(a) Undiscovered ingredients have to be found by the players.



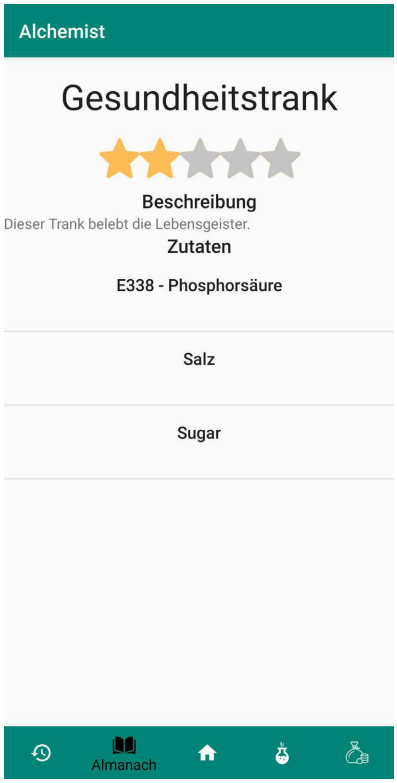
(b) The app keeps track where each ingredient has already been found.

Figure 4.10: The almanac stores various information about already discovered ingredients.

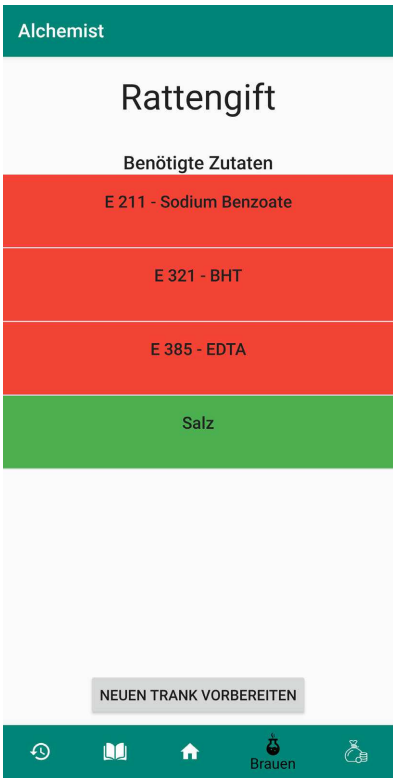
to finish the current potion. Once all ingredients have been collected the button at the bottom changes from "Next potion" to "Brew". If the players click on this button they receive the gold coins for successfully brewing the potion and a new potion is selected for preparation. In this early version of the application an ingredient inventory has not been implemented and because of that ingredients could only be tracked on a per-potion basis. That means that if the player wanted to switch potions before all ingredients were collected the collected ingredients would have been dismissed altogether even if the following recipes called for some of the same ingredients.



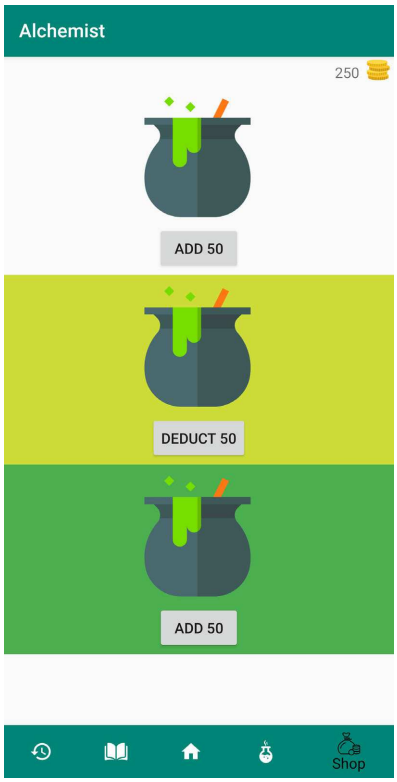
(a) Potions are hidden by default and need to be discovered.



(b) In the almanac the players can look up the ingredients and the difficulty for each potion.



(c) Once all ingredients are collected the potion can be brewed.



(d) The equipment system was not yet implemented in this version.

Figure 4.11: In this early version interface design was not really being considered.

The players are informed about this behavior when they click on the button. Regardless whether they brew a potion or just change the one that is currently being prepared, the next potion will be randomly selected from the entirety of the potion list.

The final screen implemented in this prototype and the final entry in the main menu is the shop. But because the equipment system was not implemented in this early prototype the places where the individual pieces of equipment should be, are filled with placeholders which allow to change the amount of gold coins by increments or decrements of 50 coins.

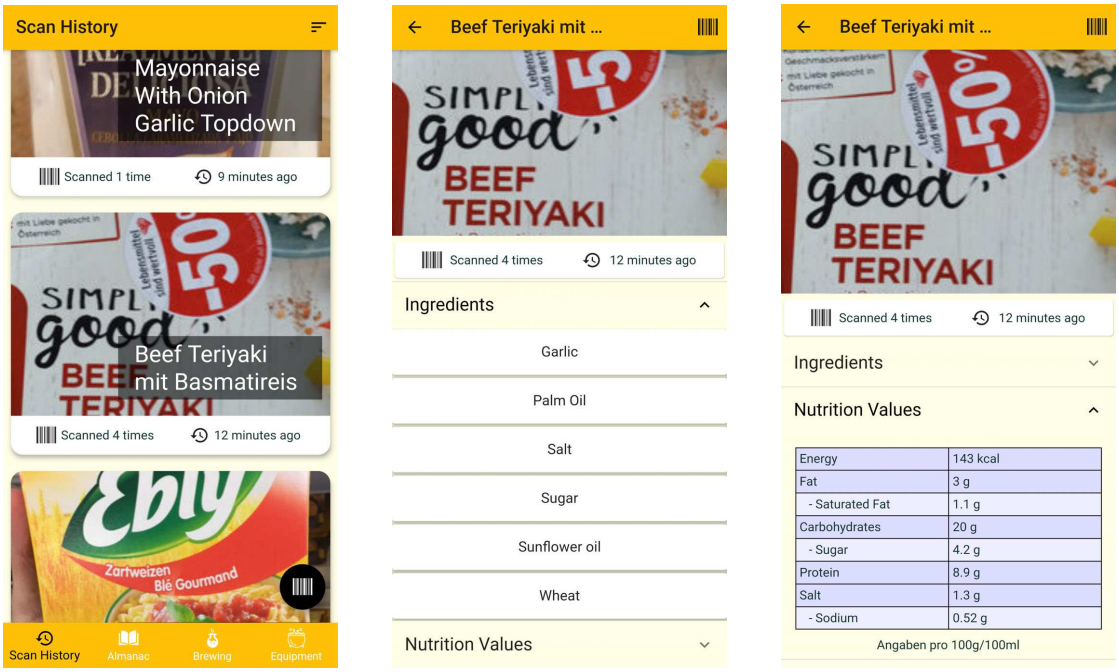
4.4.2 Second Prototype

The second iteration of the prototype was developed new from the ground up using the Flutter interface framework. This framework utilizes the Dart programming language and allows for the creation of applications for multiple platforms (Android, iOS, Web Browsers,...) from the same code base. This was important because the application should be able to be deployed on both Android and iOS devices for the planned usability tests and evaluations and because the development of two separate applications would have been to expansive for the project. For the development of this prototype the insights that were gained from the previous iteration were used to be able to build upon the parts that worked while removing the parts that did not work or which caused confusion.

Figure 4.12: The icon highlights the connection between real world products and the potion brewing mechanic.

The overall color schema was switched from a dark turquoise to a strong yellow. Also, because of the planned store release of the application, a suitable logo for *Alchemist* needed to be designed. After some consideration, it was decided that the app icon should convey both, the mechanic of potion brewing and the inclusion of real world products, immediately to the users. To achieve this, the icon should highlight the connection between the two elements. The result can be seen in figure 4.12. The barcode inside of the depicted flask represents the products that are used to brew the potions. An earlier concept of the icon saw a number of barcodes inside the bottle but due to the small size of the icon the barcodes would become unrecognizable, so instead a single barcode was chosen.

The home screen found in figure 4.9a was removed because it was not needed anymore. Originally it was intended to act as an information hub where players could quickly see



(a) Scanned products are given more space in the second iteration.

(b) Contained ingredients can be found in the product detail view.

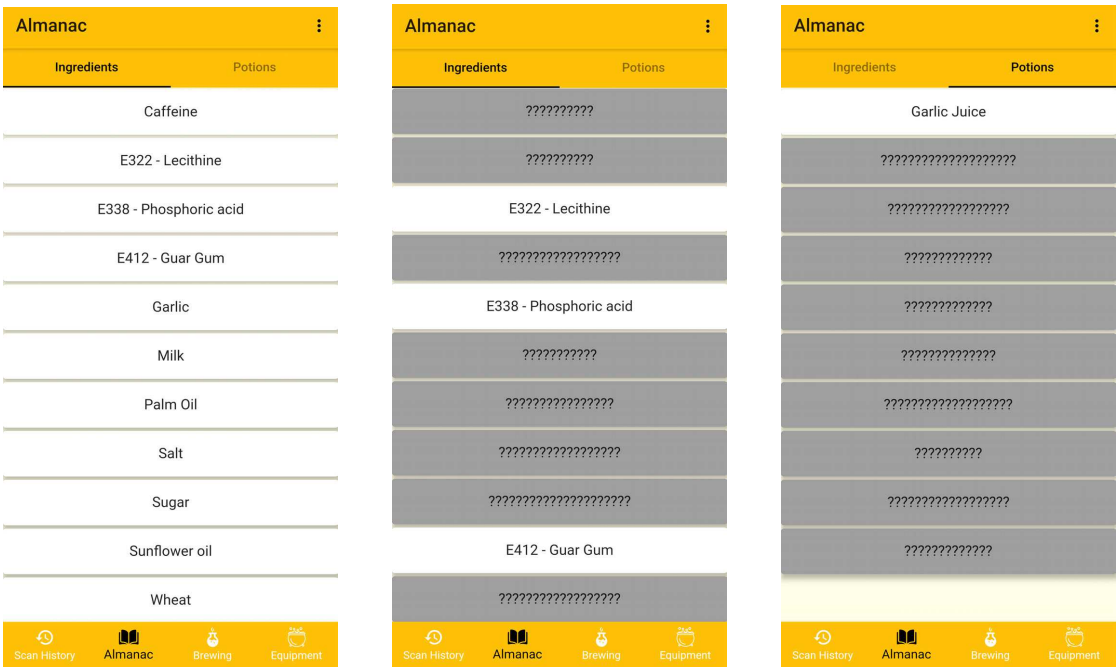
(c) Nutritional information of the product can also be accessed if available.

Figure 4.13: The second iteration of Alchemist was built from the ground up.

various information like their renown or their brewing history but these features were discarded after the first iteration. Instead opening the app now launches directly into the scan history seen in figure 4.13a. Each scanned product is presented as a card with a prominently placed image with the product name right on top. Additional information like the number of times the item was scanned and when the last scan happened can be seen at the bottom of the card. The action button to initiate a product scan can be found in the bottom right corner. Finally, the entries can be sorted by their name, the number of time they were scanned overall, or by the date when they were scanned (first or last) via the filter in the top right corner. Scanned entries can also be deleted by swiping either left or right on the card. This feature was added because it was discovered during the evaluation of the first prototype that some products would match incorrectly due to a faulty entry in the database and that those false entries would make it impossible to fix the entry in the application, therefore losing the ingredients of the product.

Once the player selects a scanned product they are taken to the product detail view, where they can find additional information. This detailed view can be seen in figure 4.13b and figure 4.13c. Just like in the previous iteration the contained ingredients are presented in this view but unlike the first iteration the ingredients now link to the ingredient detail view (see figure 4.15a). In order to provide some additional information

about the scanned products the nutritional value table is now also shown for products that have this information entered into the OpenFoodFacts database. The final interface element consists of the barcode icon in the top right corner of the screen. If the player taps on that icon a small pop up view with the barcode of the product appears (see figure 4.20b). This feature was added in order to support cooperative play. By using this feature players can "share ingredients" with one another by allowing other players access to their product and in turn their ingredient libraries via the respective product barcode that the other players can scan directly instead of having to find the actual product first.



(a) Ingredients are sorted alphabetically.

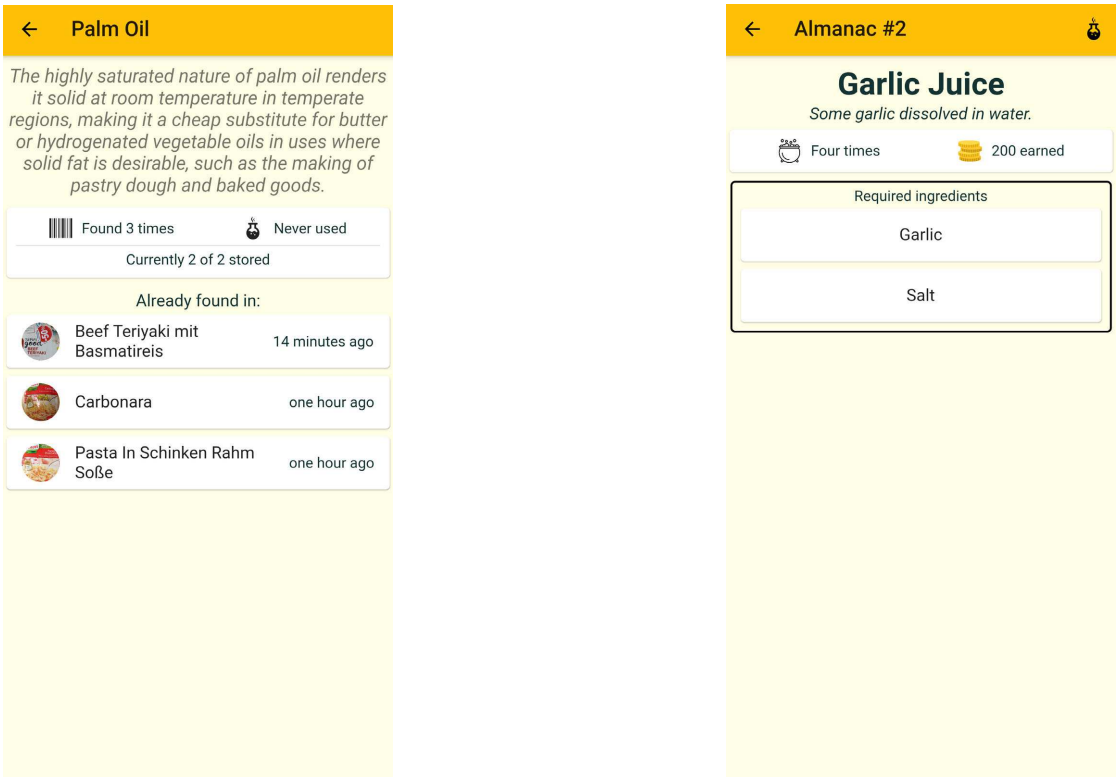
(b) The number of question marks depends on the length of the name.

(c) Undiscovered entries are hidden by default.

Figure 4.14: The almanac functions largely the same as in the previous version.

The Almanac section depicted in figure 4.14, which holds the ingredient and potion information, remained virtually unchanged and functions identically to the one in the previous iteration. Ingredients are presented alphabetically, while undiscovered ingredients or potions can either be shown or hidden via a toggle in the menu in the upper right corner. Discovered entries are no longer given a green background and instead are presented in a neutral white, while undiscovered entries are marked with a slightly darker gray. Should the players choose to show these entries the names of the undiscovered elements will be swapped with question marks, with the number of question marks correlating with the length of the name of the entry. This behavior can be seen in 4.14b and 4.14c.

If the player taps on a discovered entry in the almanac they are taken to the respective



(a) The ingredient view provides additional information.

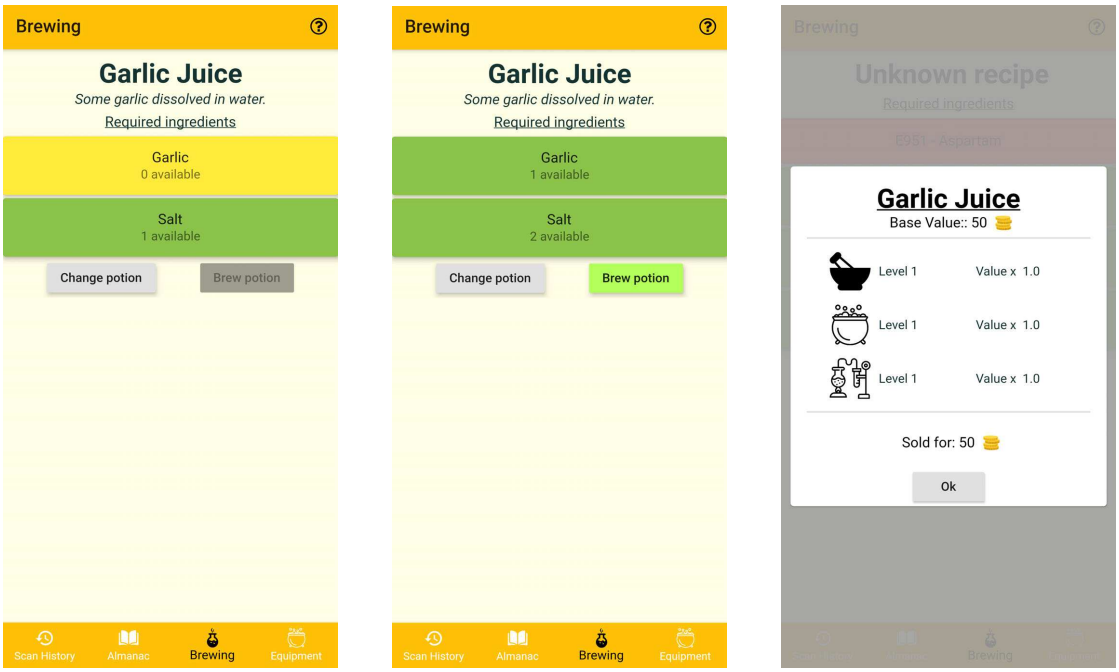
(b) The potion view also allows additional insight.

Figure 4.15: The detail views for ingredients and potions were completely redesigned.

detail view. The ingredient detail view as seen in figure 4.15a has been completely reworked from the previous iteration (found in figure 4.10b). First, the name of the ingredient was moved to the title bar in order to have more space for the content. The space that was occupied by the ingredient name in the first iteration is now used for a description of the ingredient that provides various information about the substance like possible uses or how the item is procured. It was attempted to word these descriptions in a way that makes sense for the setting and that the provided information therefore would also be useful for alchemists. Below the description some statistical information is provided. The player can see how often a specific ingredient was found and how often they have used it to create potions. And finally, they can see how many quantities of an ingredient they have currently in storage and how many quantities the could store at the same time. Below the statistical information the products are listed in which the respective item has already been found. These items take up much less space than in the previous iteration while also providing the player with the additional information about when each product was scanned last.

The potion detail view depicted in figure 4.15b has only received comparatively small

changes from the original version (see figure 4.11b). The star rating was removed, because the perceived difficulty was a static property of the potion and therefore could not take contextual factors like the existing equipment or the currently available ingredients into account. Statistical information about how often a potion has been brewed and how much money was earned by doing so was added to provide the players with some additional insight and the ingredient list now links to the respective ingredients. Finally, a potion icon was added in the upper right corner of the screen. Via this icon the potion recipe can be prepared for brewing and replaces the currently selected recipe.



(a) Collected ingredients are no longer tied to the current potion.

(b) Even if all ingredients are collected, the players can now choose to not brew a potion.

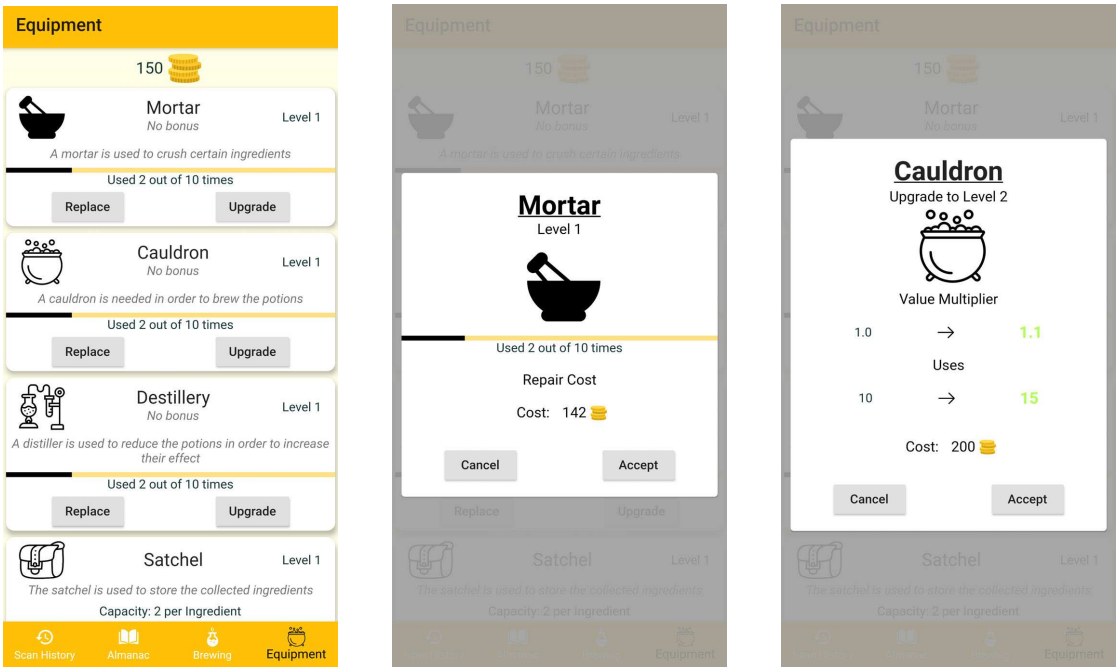
(c) An overlay informs the player about the earnings.

Figure 4.16: The brewing system has been reworked as well.

The brewing system has also received some substantial upgrades. The most important one being that ingredients are no longer tied to the currently selected potion but instead are tracked on a per ingredient basis. This means that already collected ingredients no longer get discarded when the currently prepared potion is changed. In extension, this also means that the state of any given ingredient is no longer divided into "Collected" and "Not collected" but that now multiple quantities of the same ingredient can be stored. The exact number is depending on the level of the satchel equipment item but between two and ten units of any given ingredient can be stored simultaneously. The available quantity of an ingredient can either be seen on the ingredient detail page (see figure 4.15a) or directly on the brewing screen as depicted in figure 4.16a. Ingredients that are

currently available are given a green background, while ingredients that have already been discovered but are not currently stored have a yellow background. In addition, the currently stored quantity is visible below the ingredient name, so that color is not the only source of information in that case. If the player taps on one of these tiles they are again transferred to the ingredient detail screen where they can see in which products the ingredient can be found. Undiscovered ingredients are again given a red background and the information about the available stock is omitted.

Once all ingredients have been collected the player can choose to brew the potion via the green right button (see figure 4.16b) or they can see if they can use these ingredients for any other potions by clicking the left button. Once they brew a potion an overlay (see figure 4.16c) appears that informs the players about how many coins they received from the potion as the action of brewing a potion also constitutes its selling. In the overlay the base price is depicted and the player can see how each individual equipment item influences the final price of the potion.



(a) Alchemists have access to four different tools.

(b) Equipment needs to be serviced or it will break.

(c) Upgrades make the equipment more powerful.

Figure 4.17: The Shop section has been replaced by the Equipment overview.

The shop section that has been used as a placeholder in the first prototype (see figure 4.11d) has been replaced with an overview of the alchemists equipment items depicted in figure 4.17a. In this section the players can see the amount of gold coins that they currently possess together with a list of their current tools. The items *cauldron*,*distillery* and *mortar* provide a value boost to the brewed potions, while the *satchel* determines the

amount of an ingredient that can be stored at the same time. The players can see a short description, the current level, the provided bonus and the status for each item. The items that increase the potion value degrade over time with usage and need to be serviced or they will break. In order to brew potions all items need to be operational, which means that the players need to keep an eye on the status of their equipment. The repair screen is depicted in figure 4.17b. The cost to repair or to replace an item is determined by its degradation and its level. Each item can be upgraded multiple times and each upgrade increases the provided value bonus and the amount of usages before an item needs to be serviced or replaced. A complete list of the item upgrades and the provided bonuses can be found in table 4.1.

The upgrade screen can bee seen in figure 4.17c. Here the players can see the amount of gold that they need to spend on the upgrade together with a side-by-side view of the value multiplier and usages of the current item and the values for the upgraded version.

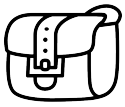
Equipment Item	Image	Level	Uses	Upgrade Cost	Effect
Cauldron		1	10	N.A.	Potion Value x 1.00
		2	15	200	Potion Value x 1.10
		3	25	400	Potion Value x 1.25
		4	40	600	Potion Value x 1.50
		5	50	1200	Potion Value x 2.00
Mortar		1	10	N.A.	Potion Value x 1.00
		2	15	200	Potion Value x 1.10
		3	25	400	Potion Value x 1.25
		4	40	600	Potion Value x 1.50
		5	50	1200	Potion Value x 2.00
Distillery		1	10	N.A.	Potion Value x 1.00
		2	15	200	Potion Value x 1.10
		3	25	400	Potion Value x 1.25
		4	40	600	Potion Value x 1.50
		5	50	1200	Potion Value x 2.00
Satchel		1	Unlimited	N.A.	Two ingredients of a type
		2		200	Four ingredients of a type
		3		400	Six ingredients of a type
		4		600	Eight ingredients of a type
		5		1200	Ten ingredients of a type

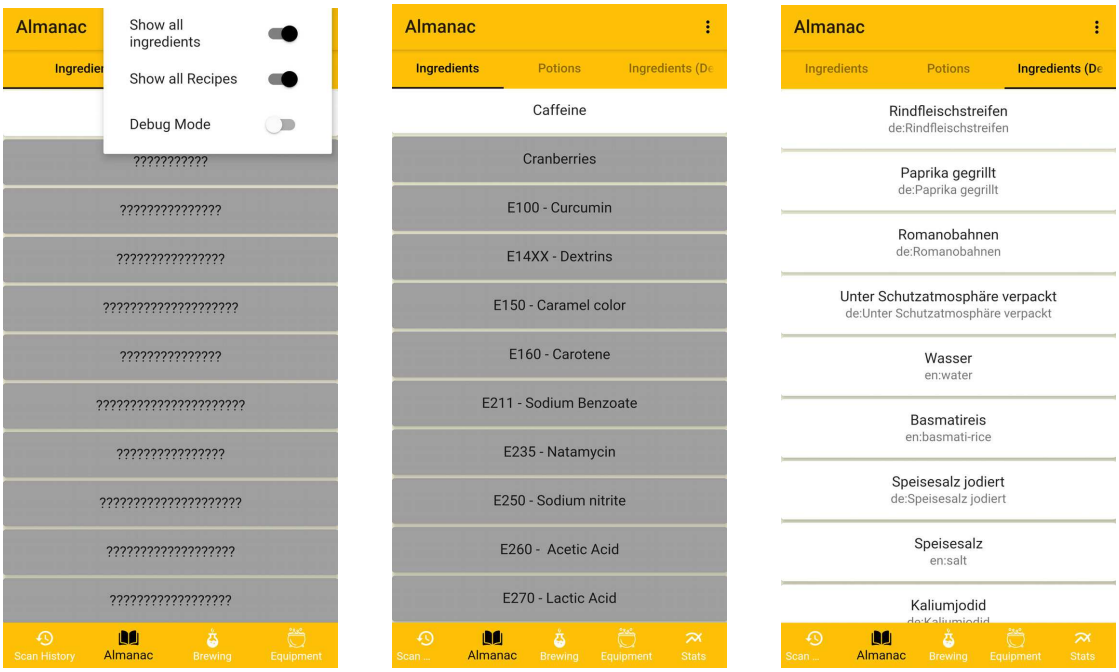
Table 4.1: Overview of the different equipment items, their effects and their upgrades.

Debug Mode

Since *Alchemist* needed to be distributed to people that participated in the study and since the successful collection of ingredients is highly dependent on the ingredient matching

provided by the server, a solution for products whose ingredients are not recognized correctly needed to be found. For the first iteration and during the development of the second iteration of the application these problems could be investigated and solved using the tools provided by the development environment. But this approach would not be possible for the distributed testing of the application so another approach needed to be pursued.

The implemented solution consisted of the implementation of an unlockable "debug mode" into the application that provided additional information to the players which could then be used to quickly fix incorrect or unsuccessful ingredient matches. This opportunity was also used to implement some additional features into the application that were deemed as too powerful for conventional play or that could be useful for the evaluation phase.



(a) The mode can be toggled on and off in the almanac menu.

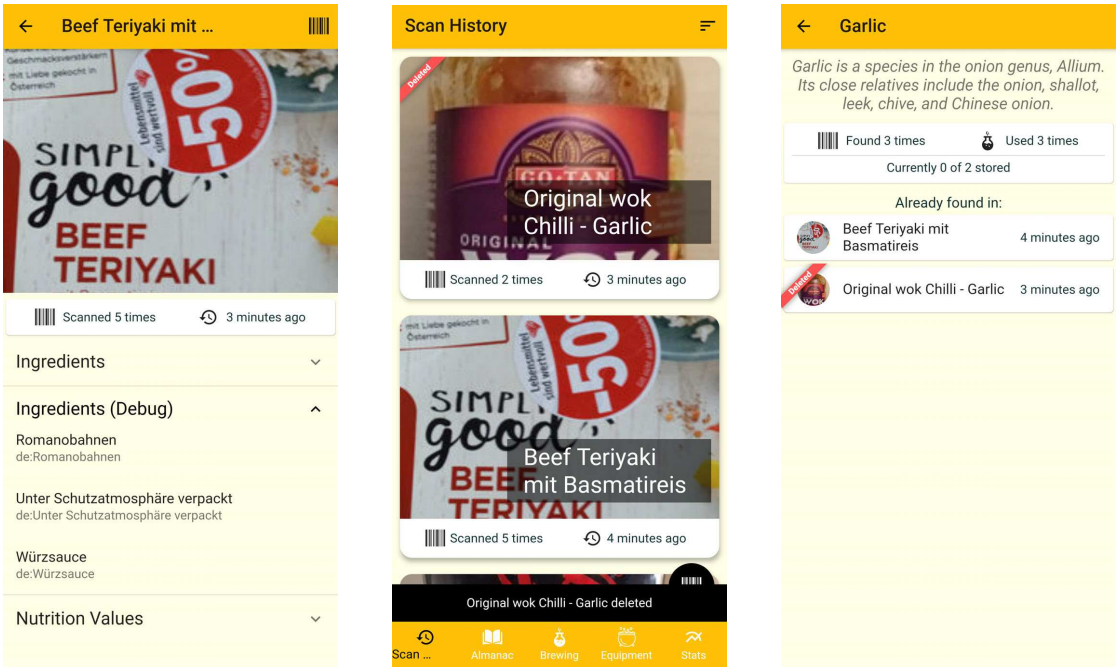
(b) The debug mode shows undiscovered elements.

(c) While the debug mode is active, players have access to additional information.

Figure 4.18: The activation of the debug mode affects the entire application.

In order to activate the debug mode it first needs to be unlocked. To do so the player needs to tap ten times on the almanac item in the bottom menu bar. After a short message confirms the successful unlocking the debug mode can be turned off and on at any time using the switch inside of the almanac menu (see figure 4.18a). The activation of the mode has ramifications all throughout the application. The first change, which can be seen in figure 4.18b, is that undiscovered ingredients and potions are no longer hidden to the players. They are still highlighted with the gray background that indicates

their status, but they can now be used as a guide for players who want to complete their ingredient collection. This feature was implemented because, although all ingredients are visible on the brewing screen, not every ingredient is used in a recipe to allow for the fast inclusion of further potions. So without this feature players would have no indication as to what ingredients they can still discover. Another effect is the inclusion of a third section into the almanac that lists the ingredients received from the scanning process. This list (see figure 4.18c) can be used to get an overview over what kind of information gets falsely labeled as ingredients (e.g. "Unter Schutzatmosphäre verpackt").



(a) The actual product ingredients can be seen.

(b) Deleted products are shown in the scan history...

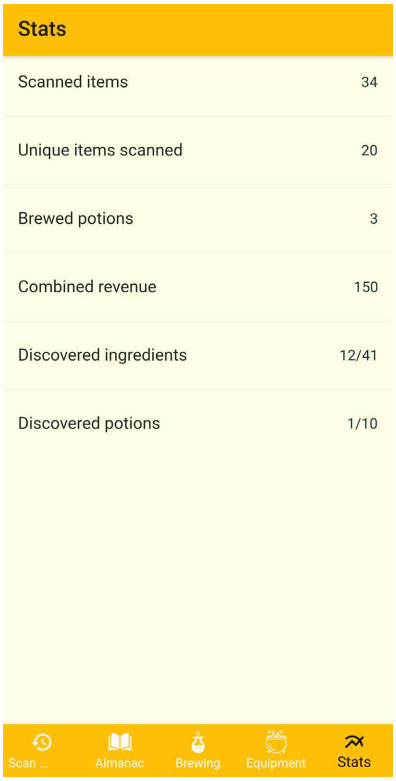
(c) ... and in the ingredient detail screen.

Figure 4.19: The activation of the debug mode affects the entire application.

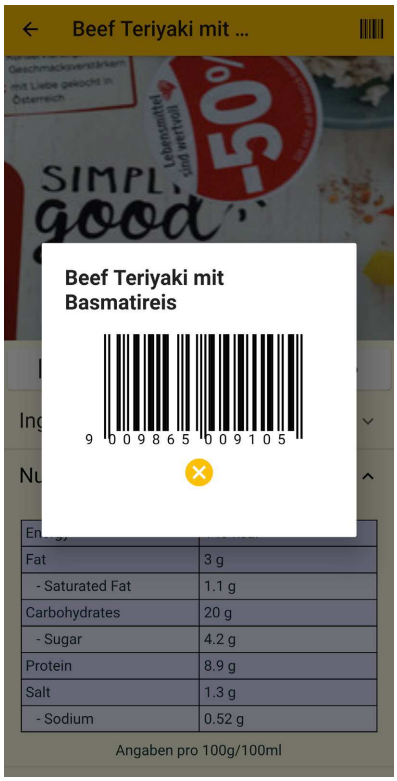
The feature that provided the inspiration for the debug mode can be found in the product detail page (see figure 4.19a). While the debug mode is active the players are also presented with the ingredients that are stored for this product on the OpenFoodFacts database and that are sent to the Alchemist server to retrieve the matching ingredients. Using this information it can be quickly pointed out why some ingredients were not successfully recognized by the system. If players would confer this information the ingredient could be quickly added to the matching database, resulting in both a better matching system and a better experience for the users.

The players are also given access to the products that they have deleted previously. For reasons of data consistency scanned products actually cannot be deleted and are simply marked as deleted, which would normally hide them from the players. These entries are

highlighted with ribbons that indicate their status as deleted, as can be seen in figures 4.19b and 4.19c.



(a) The ingredient view provides additional information.



(b) The potion view also allows additional insight.

Figure 4.20: The detail views for ingredients and potions were completely redesigned.

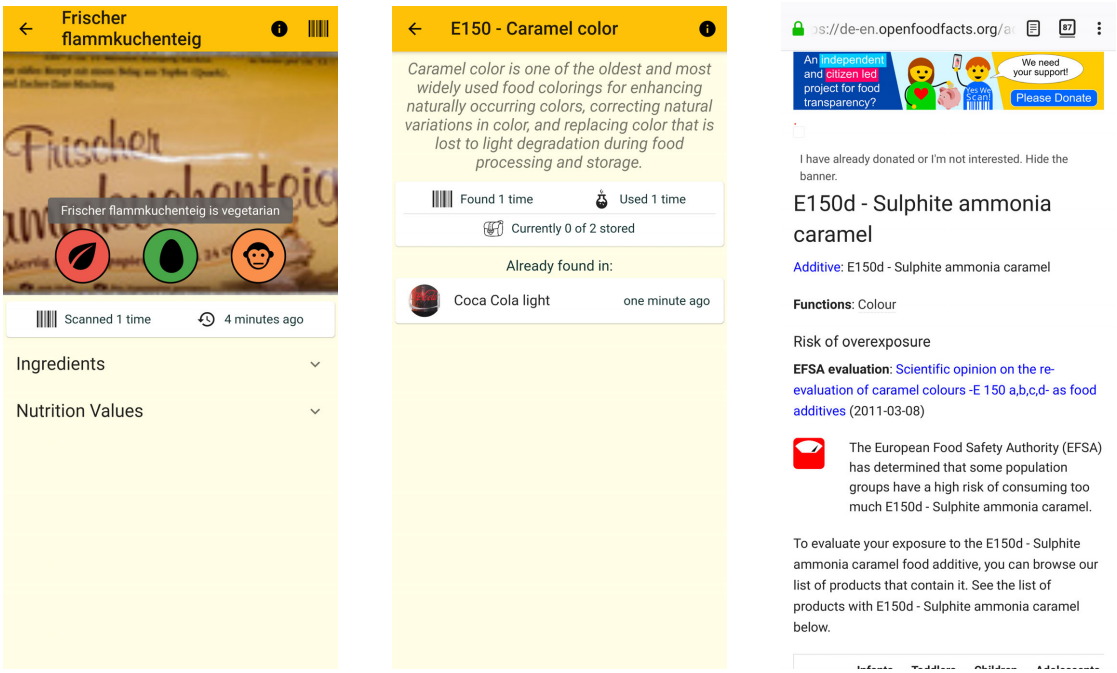
The debug mode also adds a fifth entry to the bottom menu, which holds statistical information (see figure 4.20a). On this screen the users can see how many scans they have performed in total and how many unique products they have captured by doing so. They can also see how many potions they have brewed and how much money they have earned by doing so. Finally, they also get a list of how many ingredients and recipes they have discovered. This screen is important because it holds important information which can be used for the evaluation of the prototype. Of course the data is not transferred automatically but instead the players can choose to include it into their evaluation questionnaire if they want to.

The final feature is hidden inside the view of the product barcode. The feature to display the barcode of a product, as depicted in figure 4.20b, has already been mentioned before as a way to share products between players. But if the debug mode is activated and the player taps and holds the barcode, the related product will be scanned again instantly, effectively removing the need to physically scan it ever again. Because this shortcut to

retrieve ingredients would almost certainly completely break the pacing and the premise of the game, it is only accessible in debug mode.

4.4.3 Final Prototype

The final version of the prototype was developed with the goal to improve certain aspects of the second iteration and by adding some specific features or mechanics. These aspects and features were determined through the analysis of the data gathered through the second questionnaire, which can be found in section 5.2, as well as through some additional discussions. The implemented changes were intended to address some of the points that were brought up through either of those methods.



(a) Product pages now indicate whether an item is vegan, vegetarian or if palm oil is used.

(b) An icon was added to the top of product and ingredient detail screens...

(c) ...that links directly to the items detail page on OpenFoodFacts.

Figure 4.21: The final prototype enables the users to receive additional information about products and ingredients.

Some testers of the second prototype iteration for example expressed the desire to be able to get access to more information about a specific product or a specific ingredient. In order to address this, two features were implemented which tried to enable this wish. As depicted in figure 4.21a, three icons were added to the product detail screen that indicate whether the respective product is vegetarian, vegan or if it contains palm oil. These icons were intended to be minimalistic and therefore contain no textual information. Instead

the information is represented through a combination of images and colors. The icon that depicts the leaf represents the vegan status, the icon with the egg represents the vegetarian status and the icon with the monkey represents the products use of palm oil. Each icon is then colored with either red, green or orange to indicate the use. A green icon means that a product is vegan, vegetarian or free of palm oil while a red icon indicates the opposite. If an icon is colored orange the status could not be clearly determined, either due to a lack of information about the ingredients or because some provided data about the ingredients is contradicting. Finally, if no data can be provided about a product at all, the icon is hidden from the user to avoid confusion. Should a user be unclear about what a specific icon means, for example if they see the icons for the first time or if they suffer from a form of red-green color blindness or achromatopsia, a tap on an icon reveals a tooltip that contains the information in textual form.

In addition, an icon has been added to the top of the screen next to the barcode icon that directly links to the product's detail page on the OpenFoodFacts website. There, a number of additional information about the product which is not present in *Alchemist*, like for example the brand of the product, the kind of packaging used or an evaluation of the used ingredients, can be found.

Some participants also expressed desire to gain access to more information about the included food additives like for example what purpose they serve, or in what kinds of products they can be found. While the ingredients that are used inside of the application all possess short descriptions about their uses and effects in the form of one to two paragraphs, there is only so much information as can be included in these descriptions. Since the overall goal of the application is to get the users to actively engage themselves with food additives, providing quick and easy access to further information could be another viable step in achieving this goal. As has already been described in section 4.1.2 the lack of a universal ingredient tagging system was one of the major disadvantages of OpenFoodFacts which in turn required the creation of an API that could turn the ingredient information provided by the OpenFoodFacts API into data that the mobile application could interpret and use. And because the concrete ingredients are therefore known inside *Alchemist*, a solution could be easily implemented. In addition to information about food products, the OpenFoodFacts project also collects and provides information about various ingredients, including all ingredients with a dedicated E-number. So, the same icon which has already been added to the product's detail page, was added to the pages of ingredients that OpenFoodFacts collects data for(see figure 4.21b). When a user clicks on that icon they are, again, directly taken to the respective ingredient page (see figure 4.21b). While this solution receives acceptable results in terms of ease of use, some intended changes to the OpenFoodFacts ingredient database will be presented in chapter 7.2 that would increase the efficiency of this system as well as providing substantial overall value for the project as a whole.

One mechanic that also received some critique was the scanning procedure. Some participants stated that they found the need to repeatedly scan products in order to collect a larger amount of the same ingredients repetitive and monotonous. The inclusion

of the product scanning mechanic as the only way to collect ingredients was a conscious design choice that was intended to strengthen the link between the real world and the game world and therefore the introduction of alternative ways to gather ingredients (e.g. through the shop) would be detrimental to the concept. However, since a fully upgraded alchemist's satchel would allow a player to carry ten ingredients of the same type, the restriction of only gaining one item of each ingredient per scan could be lifted.

As a solution, a new equipment item was added to the game: the sickle. The sickle is used as a representation of the gathering and collecting of ingredients that the alchemist would need to perform and determines the ingredient quantity that is acquired per scan. A detailed overview of the item is provided in table 4.2.

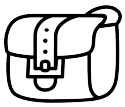
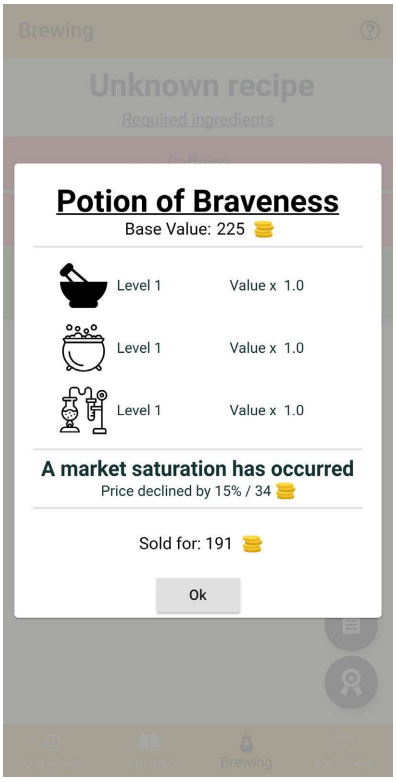
Equipment Item	Image	Level	Upgrade Cost	Effect
Satchel		1	N.A.	Carry two ingredients of a type
		2	400	Carry four ingredients of a type
		3	800	Carry six ingredients of a type
		4	1200	Carry eight ingredients of a type
		5	2400	Carry ten ingredients of a type
Sickle		1	N.A.	Gain one ingredients of a type per scan
		2	600	Gain two ingredients of a type per scan
		3	1000	Gain three ingredients of a type per scan
		4	1800	Gain four ingredients of a type per scan
		5	2600	Gain five ingredients of a type per scan

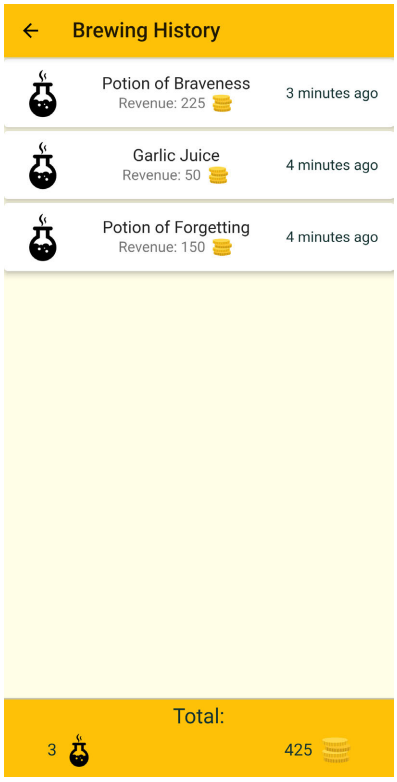
Table 4.2: Overview of the sickle item and the increased pricing for the satchel.

The sickle allows for up to five units of an ingredient to be collected at once, drastically reducing the number of times that a product needs to be scanned in order to fill the satchel. Because the sickle is a very powerful item the upgrade prices are rather high, ranging from 600 coins for the first to 2800 coins for the final upgrade. In turn the prices of the upgrades for the satchel were also doubled, because the ability to gather ingredients faster also increased the value of the storage space.

Another part of the application that was adapted was the potion brewing mechanic. The statistical usage data that was provided by some participants revealed that most of them only ever discovered a small amount of recipes while still brewing a sizable amount of potions. This behavior could be an indicator that, once they discovered sources for all required ingredients, some players stuck to the same recipes instead of trying out new ones that would require the discovery of additional ingredients. So in order to encourage the players to try and find as many recipes as possible the mechanic of *market saturation* was added. Once a specific potion is brewed too often in succession its value decreases based on the number of identical potions. The provided reasoning behind this mechanic in the application is that an over production of a potion leads to a value decrease based on supply and demand.



(a) If brewed too often in succession potions now decrease in value.



(b) The players were also given access to their brewing history.

Figure 4.22: Potion brewing received some tweaks in the form of a market saturation mechanic.

Number of recently brewed identical potions	Value Decrease
1	0%
2	10%
3	15%
4	20%
5	25%

Table 4.3: Overview of the value modifier applied during potion brewing.

The message displayed to the player can be seen in figure 4.22a while the degree of the value multiplier in proportion to the brewing history is depicted in table 4.3. The mechanic takes the last five brewed potions into account and decreases the value of the newly brewed potion by up to 25%. That means, if a player would exclusively produce one type of potion, they would only receive 75% of the coins they would earn otherwise. This also means that a market saturation can occur for multiple potions at the same

time, for example -15% for one potion type and -10% for another one.

Because this mechanic also needed a record of the previously brewed potions in order to work, entries of brewed potions are now stored permanently. This information is also provided to the players in the form of a brewing history screen (see figure 4.22b), which can be accessed from the brewing screen. On this screen the players can see their previously brewed potions together with the resulting revenue as well as some statistical information in the form of their overall revenue and the their total number of brewed potions. Because the players can access this information at any time, an upfront warning about a possible market saturation has not been included in order to let the players discover this mechanic themselves to require them to make an informed decision about what potion they should brew next. This means that the first time the players will be made aware about the existence of this mechanic once they are affected by it. They are then left on their own to discover what triggered the value decrease and how they can avoid it in the future.

The final feature that was added to this version of the prototype was again influenced by the results of the evaluation questionnaire. Based on the received feedback, an achievement system has been implemented into the game with the goal to supply the players with a number of trackable short term goals in order to keep them engaged. While a possible way to implement and to integrate this mechanic into the game will also be presented in section 5.2.3, the system implemented in the application does not directly influence the other areas of the game (e.g the ability to upgrade certain pieces of equipment).

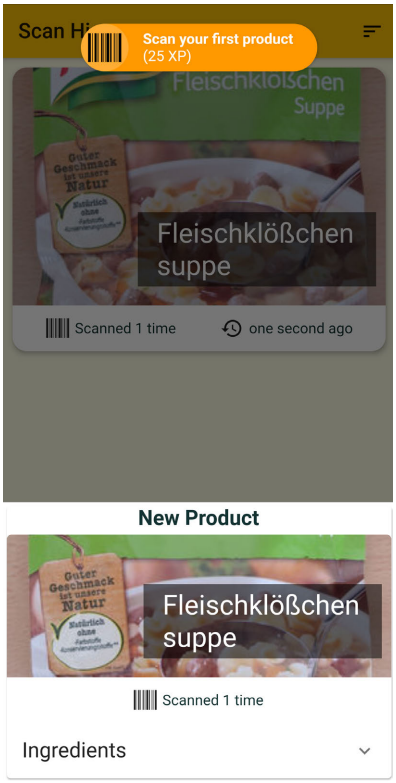
The players can earn achievements for performing various tasks, like scanning products, discovering new ingredients or for brewing potions. Once a player earns an achievement they are informed about it by a notification in the upper section of the screen (see figure 4.23a), containing the icon of the achievement, its name and the amount of gained experience. Each achievement can possess a number of requirements that need to be fulfilled at the same time in order to unlock it. These requirements are determined through the use of a number of enumerations/enums (see table 4.4) where each one allows for a different metric to be tracked.

Enum Name	Fulfillment Condition
AWARDED_ACHIEVEMENT	The player has earned a specific achievement
BREW_POTION_DISTINCT	The player has brewed a set number of different potions
BREW_POTION_TOTAL	The player a brewed a set number of potions overall
SCAN_INGREDIENT_DISTINCT	The player has found a set number of different ingredients
SCAN_INGREDIENT_TOTAL	The player has found a set number of ingredients overall
SCAN_PRODUCT_DISTINCT	The player has scanned a set number of different products
SCAN_PRODUCT_TOTAL	The player has scanned a set number of products overall
REVENUE_TOTAL	The play has earned a set amount of gold coins overall

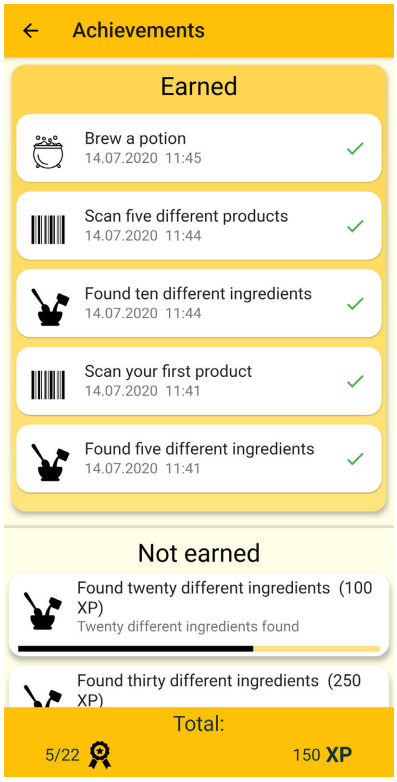
Table 4.4: Listing of the different enumeration types that can be used to create achievements.

This system allows for a large amount of customization and flexibility with an easy way to expand it in order to track additional metrics or events inside the application (e.g. the upgrade of a specific piece of equipment). Nevertheless, currently not all of the available enums are utilized and each of implemented the achievements only possesses one requirement in order to keep them simple and easy to unlock. A listing of every achievement currently obtainable in *Alchemist* is provided in table 4.5.

The players can keep track of their obtained achievements and their progress towards obtaining the remaining ones on the achievement detail page depicted in figure 4.23b. This page can be divided into three distinct parts: a list of earned achievements, a list of non awarded achievements and statistical overview of the total achievement progress and the amount of earned experience points. Once a player has obtained every achievement, or if they have not yet earned one the respective section of the screen is hidden. While each achievement provides the player with an experience reward, currently these experience points are not tied to any game mechanics like a levelling system. Instead the value simply indicates the amount of effort that is required to earn the achievement.



(a) Players can earn achievements for performing various tasks.



(b) A list of all achievements has also been added.

Figure 4.23: An achievement system was implemented in order to provide the players with additional short term goals.

Both awarded and non-awarded achievements are displayed with an icon which hints at the type of the achievement together with its name. But whereas earned achievements also show the time at which the achievement was obtained together with a small green check mark, unearned achievements display an additional achievement description as well as a progress indicator.

Icon	Title	Reward	Utilized Enum
	Found five different ingredients	25 XP	SCAN_INGREDIENT_DISTINCT
	Found ten different ingredients	50 XP	
	Found twenty different ingredients	100 XP	
	Found thirty different ingredients	250 XP	
	Scan your first product	25 XP	SCAN_PRODUCT_TOTAL
	Scan ten products	50 XP	
	Scan twenty-five products	100 XP	
	Scan fifty products	250 XP	
	Brew a potion	25 XP	BREW_POTION_TOTAL
	Brew five potions	50 XP	
	Brew twenty potions	100 XP	
	Brew fifty potions	250 XP	
	Scan five different products	25 XP	SCAN_PRODUCT_DISTINCT
	Scan ten different products	50 XP	
	Scan twenty different products	100 XP	
	Scan forty different products	250 XP	
	Small beginnings (Earn 250 coins)	25 XP	REVENUE_TOTAL
	First steps (Earn 500 coins)	50 XP	
	First successes (Earn 1000 coins)	100 XP	
	Big successes (Earn 2500 coins)	250 XP	
	Brew five different potions	100 XP	BREW_POTION_DISTINCT
	Brew ten different potions	250 XP	

Table 4.5: List of the currently implemented achievements.

CHAPTER 5

Study

To explore whether a pervasive game could be a suitable measure to create awareness about food ingredients and food additives, the different iterations of the prototype needed to be tested and evaluated with outside users. As was mentioned before, the first iteration of the application was never intended to be deployed to and tested by outside users due to its status as a technical proof-of-concept, and therefore the evaluation was performed internally without direct involvement of external people. Nevertheless, some informal feedback was gathered from friends and colleagues during the development and evaluation phases of that first iteration. The second iteration of *Alchemist* was then evaluated with the involvement of outside participants utilizing ad libitum testing of *Alchemist* over a longer time period and an accompanying followup questionnaire. This approach allowed the participants to spend as much or as little time with the application as they wished and in addition, it allowed to check whether the duration of the app usage also had an effect on how aware the participants were about different kinds of additives.

The followup questionnaire distributed alongside with access to the prototype tried to collect data on two major areas: First it was used to gather data on whether the usage of the application changed the users views, their knowledge, awareness and their opinions about the use of food additives. The questionnaire was also used to gather feedback about the application itself, like for example if the players thought that it was interesting, monotonous, boring or exciting to use or if they faced any technical problems during their usage. The gathered data was then evaluated in order to use it to shape the final iteration of the prototype by highlighting features or mechanics that should be altered or added in order to enhance the usage experience. This final prototype iteration was then again tested via a usability test with five participants, but this time the app was not tested over a prolonged time period using an ad libitum testing method like the previous version, but in a controlled environment confined in a single session.

Two of the participants of this test also had access to the second iteration while the other three had no former involvement in the study and therefore had not seen or heard of

the application before. After the test concluded each participant was interviewed about their experiences with *Alchemist*, their opinion and their perceived knowledge about food additives and their overall feeling towards the research field. The interviews were conducted in a semi-structured manner, which allowed the exploration of interesting remarks made by the participants during the interviews.

Before the aforementioned questionnaire, which was only distributed to the people who also took part in the usability test, was released, a second questionnaire was also distributed. This questionnaire was intended to, among other things, gather information about how food ingredients and food additives, their declaration, and further information are known to the general public and how these substances are perceived. Unlike the evaluation questionnaire this one was intended to reach as many people as possible.

5.1 Questionnaire about food additives

The first questionnaire served two distinct purposes: First it was designed to determine how well the participants thought they were informed about food additives and their uses, and how attentive they were about their diet in general. By answering these questions the participants would create a baseline of how widespread the knowledge about different additives is in the general public. This baseline could then be consulted during the evaluation phase of the prototype in order to evaluate the effects of the use of the application, and whether this usage has led to the creation of awareness for this topic. The second purpose of the questionnaire was to find participants that were willing to take part in the testing process of the application. Because the questionnaire was not targeted at a specific user group it was intended to reach as many people as possible. To do so the questionnaire was distributed using a variety of channels, like distribution in various online forums, the promotion of the questionnaire in some lectures held at the Technical University of Vienna as well as being promoted through the word of mouth.

The questions are presented in German, as it was assumed that the vast majority of the people reached by the questionnaire would have German as their native language or at least would be capable of it. In the following section the included questions will be presented in an English translation while the original German version can be found in Appendix B. Questions that use circles to mark their answer options are single-choice questions while questions where the answer options are marked with squares indicate multiple choice questions.

5.1.1 Questionnaire Design

The first two questions of the questionnaire, which are depicted in figure B1, intend to gather some personal information about the participants like their age and their gender. Although the collection of this information was not really the goal of the questionnaire it could have been quite valuable during the evaluation process because it would have allowed to make comparisons between different participant groups, like for example based on their respective ages or dietary choices.

1. **What is your age?** _____

2. **What is your gender?**
   - ○ male
   - ○ female
   - ○ Other: _____

The third question(see figure B2) deals with how much attention the participants pay to their diets and in which ways this behavior manifests itself. Some examples are provided, which are intended to help the participants decide and include measures like the amount of food that they eat, the ingredients which are contained within or whether they care about a balanced diet. This information is also valuable because through this, the answers of people who care very much about their diet can be compared to those of people who do not. It also allows to explore if and how the knowledge about food additives differs between these different groups.

3. **In terms of balance, ingredients and quantity, I focus on my nutrition...**
   - ○ very extensively
   - ○ extensively
   - ○ not very extensive
   - ○ almost never
   - ○ never

The fourth question, which can be seen in B3 is the most complex question in the entire questionnaire because it asks the participants to provide information about how they would rank the importance of different aspects of food products, like for example their price, their packaging or the ingredients used therein. This question allows to investigate whether the self-proclaimed knowledge about food additives and diet in general causes differences in what aspects get prioritized by different participants.

4. **While shopping for groceries I pay attention to...**

the brand / the producer	very much □—□—□—□ none
the packaging	very much □—□—□—□ none
the best-before date	very much □—□—□—□ none
the price	very much □—□—□—□ none

the point of origin very much □—□—□—□ none

the ingredients very much □—□—□—□ none

nutritional information very much □—□—□—□ none

additional information very much □—□—□—□ none

The next question asks the participants to share their opinions about whether they think that the existing declaration of food additives on food packaging, like for example through the use of the European E-number system, is sufficient or not. Should a participant not believe that the current system suffices, they can explain their position and their opinion in an optional follow-up question (see figure B4).

5. **I think that the declaration of food additives(eg: "E-numbers") on product packaging is...**
   - ○ sufficient
   - ○ not sufficient

6. **If you've answered "Not sufficient" on the previous question: Why not?**

   _____

As was already described in section 2.6, the E-number system encompasses a multitude of different kinds of food additives, categorized by their type and their respective uses. Question 7 (see figure B5) asks the participants to estimate the knowledge that they possess about food additives. This question somewhat expands on question 3, which asked participants about their dietary behavior in general, but this question focused on food additives in particular.

7. **I would classify my knowledge about food additives to be..**
   - ○ very good
   - ○ good
   - ○ average
   - ○ below average
   - ○ bad

Another important aspect of the E-Number declaration system, in addition to how well it can be utilized to categorize and describe food additives, is how well it can be used by itself to convey this information to the consumers. As described in section 2.6, food additives can be categorized into several major categories like for example nutritional

additives, texturing agents or flavoring agents, with the first digit of the number indicating into which category a certain additive belongs. To explore how well this property of the system, among numerous other ones, are known to the public, question 8 (see figure B6) asks the participants to classify their perceived knowledge about the functions of food additives.

8. I feel that I am informed about the function(s) of food additives:

- ○ very good
- ○ good
- ○ sufficient
- ○ bad
- ○ not at all

As was already mentioned in section 4.1.2, a number of different applications with proprietary nutritional databases exist, with some of them being used by multiple million users. The questionnaire offered the opportunity to explore how widespread the knowledge about the existence of these applications is and what percentage of the participants make use of the services that these applications provide. Question 9 therefore asks the participants to select the solutions that are known to them or that they use or have used in the past. The default options provided for this question, as depicted in figure B7, are some of the most prominent solutions in this field, as well as OpenFoodFacts which was included because it is used as part of this thesis project.

9. Which of these food databases do you know?

- ☐ OpenFoodFacts
- ☐ CodeCheck
- ☐ MyFoodData
- ☐ MyFoodDiary
- ☐ None of the above
- ☐ Other: _____

The final questions, as depicted in figure B8, try to address to what extent the participants incorporate convenience foods into their diet and what their stance about such products is in general.

10. Whenever I cook I use convenience products:

- ○ always
- ○ often
- ○ sometimes
- ○ rarely

○ never

11. In regard to the previous question: What is your stance on convenience products?

At the end of the questionnaire the participants were informed about the existence of the *Alchemist* project and were given the opportunity to take part in the testing and the evaluation of the prototype.

5.1.2 Results

The survey was running from the end of November 2019 to the beginning of June 2020 with a total of 38 people participating. This long duration was required because, although the questionnaire was heavily advertised, the number of submissions stayed below the intended target for a long time.

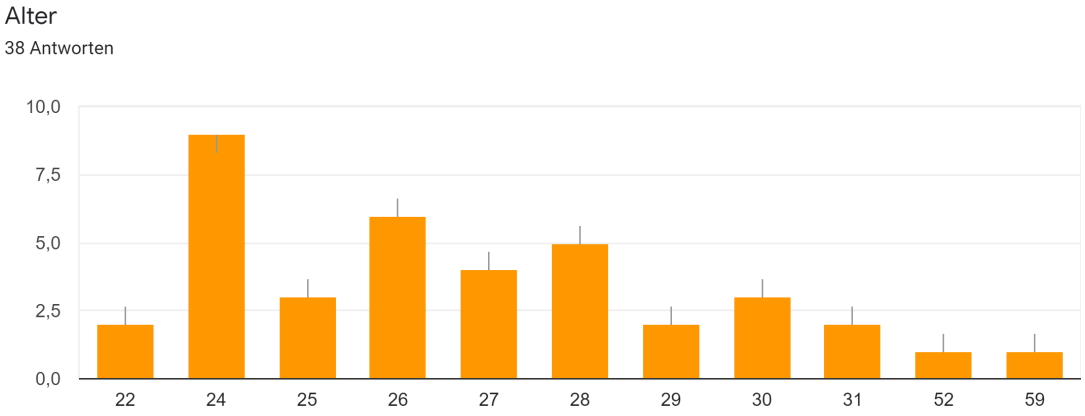


Figure 5.1: Results for question 1, which asked the participants to state their age.

As can be seen in figure 5.1 the age of the participants ranges from 22 to 59 years with the average being 28 years and the most common age among the participants being 24 years. When asked about their gender (see figure 5.2) 24 people stated to be male while the other 14 participants stated to be female. Other gender options where not chosen.

When asked about how much the participants concern themselves with their diet, 18 participants (47,4%) chose "extensive", 11 participants (28,9%) chose "not very extensive", 5 participants(13,2%) answered "hardly at all" and 4 participants(10,5%) stated that they do concern themselves with the topic very extensively. As can be seen in figure 5.3 the final option "Not at all" was chosen by none of the participants.

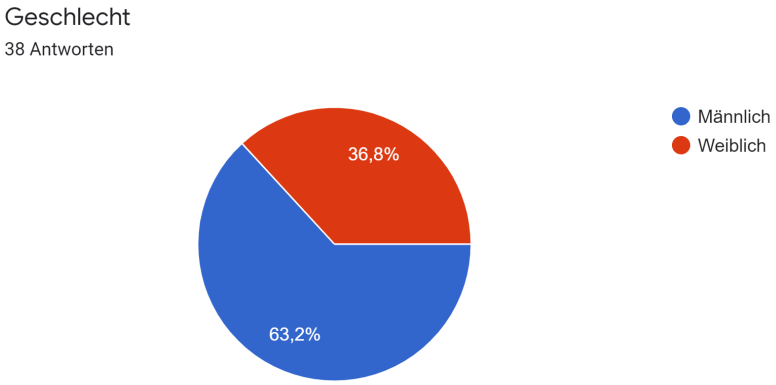


Figure 5.2: A majority of the study participants stated to be male.

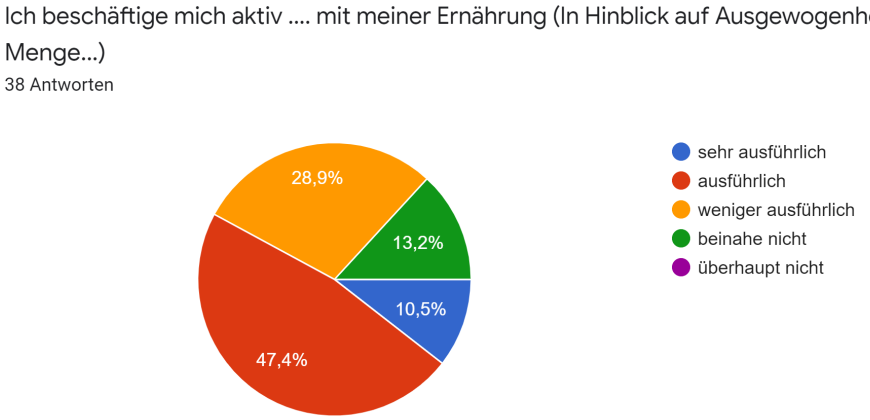


Figure 5.3: Results for question 3 regarding how much attention the participants pay to their nutrition.

Question 4 asked the participants to state how much attention they pay to different aspects of a product, like the price, the brand, or the used ingredients, when they are shopping for groceries, and how much these aspects influence their buying behavior. They were provided with eight different categories and could either answer "Very much", "Some", "Almost no attention" or "Not at all" for each of those. The final option "Prefer not to say" was also presented to the participants but was not chosen once and will be omitted from the presentation of the results.

For the category *brand/manufacturer* 18 participants chose "Very much", 16 participants answered "Some" and 4 participants chose "Almost no attention". For this category the

answer option "Not at all" was not selected by any of the participants.

When asked about the importance of *product packaging* and related aspects like the apparent build quality, the product design or the used materials 14 people stated "Very much", 14 people selected the option "Some", 9 people answered "Almost no attention" and one person chose the option "Not at all".

For the category *best-before date* 19 people selected "Very much", 11 participants chose "Some", 6 people answered "Almost no attention" and 2 people selected the answer option "Not at all".

When asked about how much attention they pay to the *price* of a product 11 participants answered "Very much", 21 participants answered "Some" and 6 participants stated "Almost no attention". The answer option "Not at all" was again not selected by any of the participants for this category.

The category *point of origin* caused 22 participants to answer "Very much", 10 participants to answer "Some" and 6 participants to answer "Almost no attention". Once again no participant chose the answer option "Not at all".

While the results for the first five categories are interesting on their own accord, the final three categories *ingredients*, *nutritional information* and *additional information* are of particular interest for the project because they directly relate to the discussion of second the research question.

The category *ingredients* prompted 9 people to answer "Very much", 19 participants to answer "Some attention" and 10 participants to answer "Almost no attention". The answer option "Not at all" was selected by none of the participants.

When asked about how much attention they pay to the provided *nutritional information*, 9 participants answered "Very much", 11 participants answered "Some", 15 people stated "Almost no attention" and 3 participants answered "Not at all".

Finally the question about the importance of additional information about the product, for example whether it is vegan or vegetarian or if it can be considered to be organic, prompted 14 people to answer "Very much", 10 participants to answer "Some", 11 participants to state "Almost no attention" and 3 people to choose the option "Not at all".

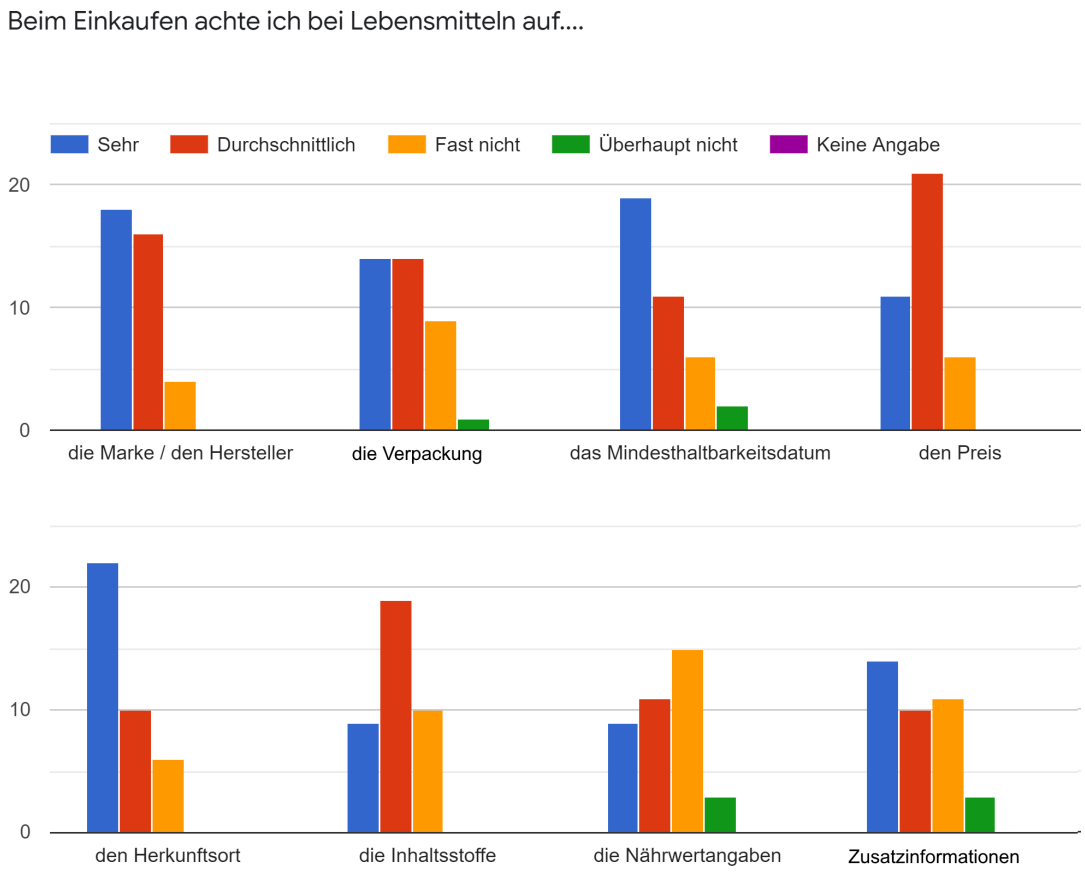


Figure 5.4: Results for question 4, which asked the participants to state the importance that different aspects of a product have for them.

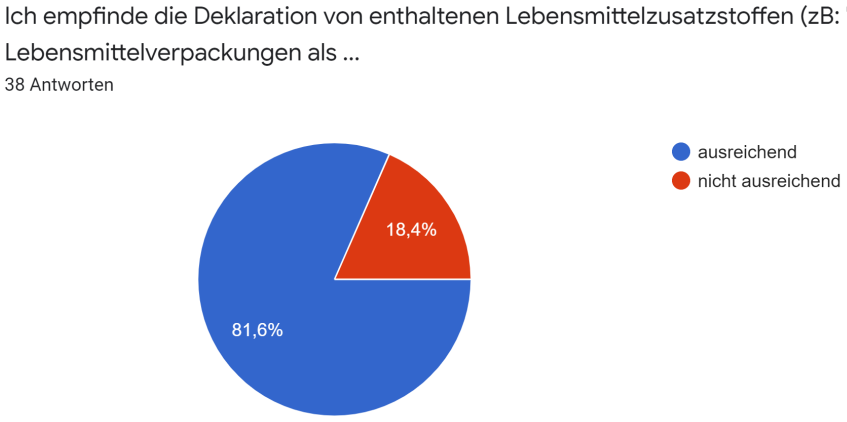


Figure 5.5: Results for question 5

When asked whether they considered the current declaration system as sufficient or not, 31 participants(81,6%) answered that they did, while the remaining 7 people(18,4%) stated that they did not (see figure 5.5). The 7 participants that chose the second option where then given the opportunity to further elaborate on their answer using the follow-up question, of which 6 people made use of.

One participant stated that they didn't know what an "E-number" was or what the system entailed or what it was used for. The other five people complained that the system was not very transparent and not very understandable. One person further explained that they are not very content with the system because there is no indication if a specific additive was sourced from plants or from animals. Another person stated that they had a background in food economics, and that in their experience the labeling of nutritional information and used ingredients can be confusing or cryptic to people who are unfamiliar with it, partly due to inconsistent placement of the information or small font sizes.

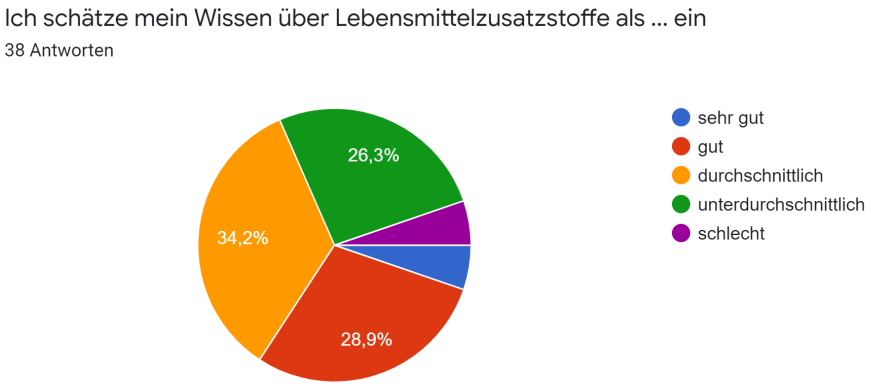


Figure 5.6: Results for question 6 which asked the participants to self-report their perceived knowledge about food additives.

Question 6 (see figure 5.6) tasked the participants with providing a self-assessment about their perceived knowledge about food additives. Two people(5,3%) reported that they perceived their knowledge to be "very good" and eleven people(28,9%) claimed that their knowledge about food additives was "good". Thirteen participants(34,2%) reported their knowledge to be "average", while ten participants(26,3%) chose "below average". Finally two participants(5,3%) categorized their knowledge level as "bad".

For question 7 (see figure 5.7) one participant(2,6%) stated that they feel "very well" informed about the function of food additives, nine participants(23,7%) answered "good" and again nine participants(23,7%) reported to be sufficiently informed. Fifteen participants(39,5%) reported to be badly informed and the final four participants(10,5%) answered that they don't feel informed about the various functions of food additives at all.

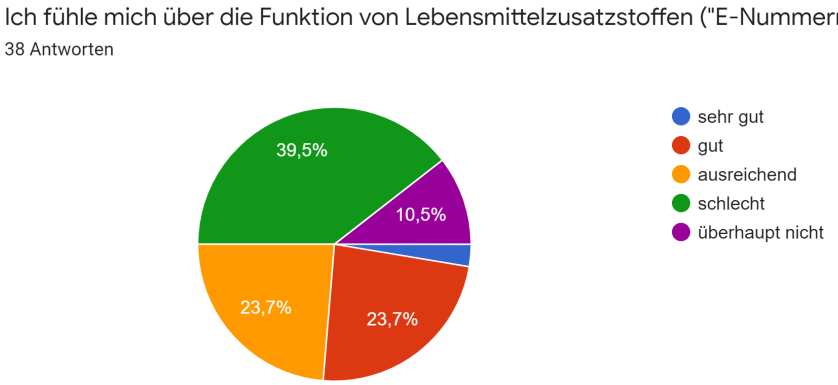


Figure 5.7: Results for question 7

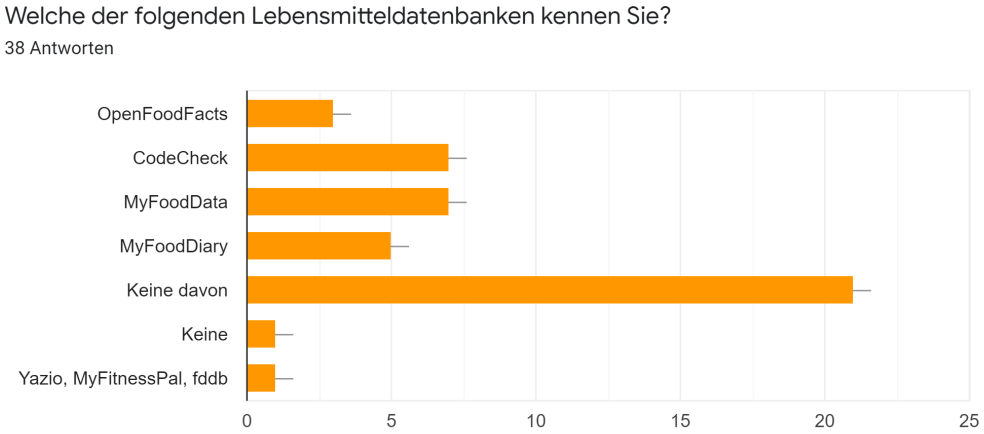


Figure 5.8: Results for question 8 which asked the participants to select (or add) food databases that they know or use.

Question 8 tasked the participants with selecting the food databases that they use, have used or that they have heard of. They were also given the option to add new entries if they knew of an additional solution (see figure 5.8). 22 out of 38 participants stated that they are not familiar with any of the presented solutions as well as any additional ones. The two solutions that were most well known among the questionnaire participants were *CodeCheck* and *MyFoodData* with seven notions each. *MyFoodDiary* was recognized or used by five participants and *OpenFoodFacts* was known by three participants. Only one participant had knowledge about additional solutions in this field and with their answer "Yazio, MyFitnessPal, fddb" added three new solutions to the list.

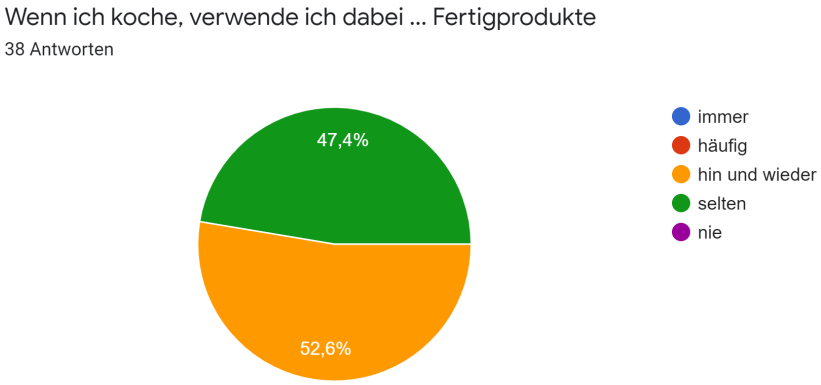


Figure 5.9: Results for question 9 which asked about how often the participants make use of ready meals.

When asked about how often they make use of ready meals in their diet in question 9, 20 participants (52,6%) answered "Sometimes" while the other 18 participants answered "Rarely". The remaining options "Always", "Often" and "Never" were left unused.

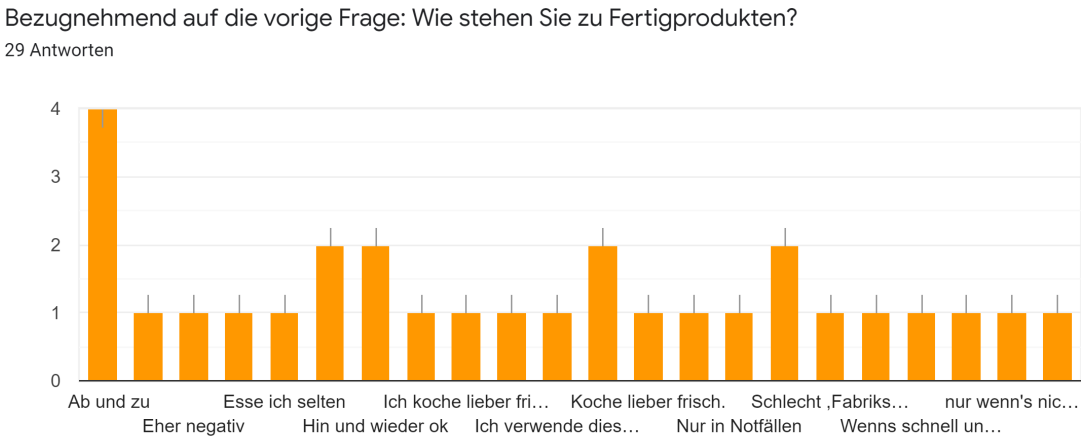


Figure 5.10: Results of question 10 regarding the stances of the participants on ready meals.

The final question allowed the participants to further explain their stance on ready meals. Because this question was optional instead of mandatory like the previous questions, only 29 out of 38 total participants chose to provide an answer. As can be seen in figure 5.10 a magnitude of different explanations were given so in order in keep the presentation

concise most of the answers will be grouped together and discussed that way.

The majority of the participants disapproved of ready meals to some degree and viewed them as without alternative in certain situations for example when no other viable option exists. Some of the provided examples included the use of ready meals due to time constraints or because the person would have been unable to prepare a proper meal due to other reasons. In the remaining answers ready meals where described as a viable alternative to traditional cooking. But even in the responses that highlighted the positive aspects of ready meals some participants noted that the usage of ready meals should be the exception from the norm and if possible not a regular occurrence. One participant for example responded with "*Ich koche meistens lieber selbst, aber veganer Fleischersatz geht anders schwer*", highlighting the possible use as a source for vegan meat substitutes as an upside of these products for vegans. Another participant wrote "*Chemie ist ohnehin überall - bezüglich Ingredients oft viel Fehlinformation, natürlich heißt nicht besser. Qualität und Geschmack sind eher ein Problem, ebenso die Herkunft der verarbeiteten Lebensmittel.*", indicating a more pragmatic stance on the issue. Finally, one participant added "*Fertigprodukte sind leicht und schnell zubereitet und müssen nicht unbedingt ungesund sein.*", highlighting once again the easy and fast-to-use nature of these products.

5.1.3 Discussion

Only seven of the 38 participants stated their age to be 30 years or older which means that the chosen ways to advertise the questionnaire (e.g. university lectures, posts in health and food related online communities and the use of word of mouth) reached largely younger people, which was expected to some degree. This also means that the resulting data in general or regarding utilized technological solutions in particular could also be partly biased towards that particular age group, since it can be argued that younger generations are more prone to use such solutions like nutritional databases or ingredient tracking applications to keep track of their nutrition or diet than older generations or that they at least have heard of one. This claim can also be supported by the gathered data, because out of the 16 participants that stated that they either knew of or used such a solution only two were over the age of 30. If the participants are split into two groups based on their age, with one group containing people aged 30 or over and the other group containing participants younger than 30, those two participants represent roughly 28,6% of the seven people belonging to that group, while 14 out of the 31 participants in the other group or roughly 45% were familiar with at least one technological solution.

All participants stated that they concern themselves with their diet to at least a certain degree, with 57,9% percent choosing either the option "very extensive" or "extensive" and and the remaining 42,1% choosing either "not very extensive" or "hardly at all" on question 3. Another interesting finding based on the results is that, once overall distribution between male (24/63.2%) and female(14/36.8%) participants is factored in, the genders of the people that belong to the first group are almost evenly distributed, with a total of fourteen men and eight women choosing one of these two options. On the other

hand a divide between male and female participants for the other two remaining answer options seems to exist. Out of the eleven people who chose "not very extensive" nine were male while four out of the five participants that chose "hardly at all" were female. Based on the resulting data for this question no link between the age of a participant and their probability to choose a specific answer could be found.

The data gathered through question 4 (see figure 5.4) suggests that among the participants the brand of a product, its best-before date and its point of origin are the most important aspects, based on the number of participants that chose the option "Very much". On the other end of the spectrum, with the highest percentage of "Almost no attention" and "None" answers, are the three aspects ingredients, nutritional information and additional information. Here, some possible correlations between the selected answer option and the answer provided for question 3 can be found once the results from that question are factored in. Each of the nine participants who selected "Very much" for the ingredient aspect either chose the option "very extensively" (six answers) or "extensively" (three answers) when asked how much they concern themselves with their diet, suggesting that the knowledge about which ingredients are used within a certain product are of greater importance to people that try to have a balanced diet. To a lesser degree the same observation can also be made for the aspect of nutritional information. Out of the nine participants that chose "Very much" on this aspect only two did not chose "very extensively" or "extensively" on question 3. In addition, six out of the nine participants also chose "Very extensively" in regard to the ingredient aspect, providing a slight indication that these aspects could be linked. Finally, out of the fourteen participants who answered "Very much" for the aspect of additional information thirteen chose "extensively" and and only one participant chose "not very extensive". But in regards to the previous two aspects these participants overwhelmingly chose "Some", suggesting a weaker link between these aspects. But in order for these possible connections to be explored the questionnaire design would have been needed to be changed in a way that could potentially have been detrimental to the exploration of the research questions.

Another possible correlation between data points seems to exist in regard to the participants self-assessed knowledge of food additives, how well they feel informed about the respective functions of these additives and whether they use or know any nutritional databases. Out of the thirteen people that assessed their knowledge about food additives to be either "good" or "very good" only one didn't know or use any nutritional databases. All ten participants who reported to feel well informed about the various functions of food additives are also part of this participant group of thirteen people. So the data could support a theory that suggests a link between the knowledge about food additives and the usage of nutritional databases or similar solutions. This would also strengthen the intention of "*Alchemist*" to create awareness about food additives in people who are not part of the traditional core target group of such applications.

Interestingly, most of the participants provided differentiated views on convenience products regardless of their answers on previous questions, so awareness about the side effects of excessive use of such products like an over- or under provisioning of certain

substances or the typically high calorie density seems to be present already.

5.2 Prototype Evaluation Questionnaire

Contrary to the first questionnaire that was made publicly available and was widely and freely distributed, the second questionnaire was only distributed to those people that also took part in the study. There, it was made available to them alongside with access to the second iteration of the prototype on either Apples App Store or Googles Play Store. For Android devices a direct download of the application file was also possible, and was also the approach preferred by most testers on that platform. The participants were also told that they could explore and use the app for as much or as little as they wished before they fill out the form. This was done in order to simulate how the app would probably be used in in natural circumstances over longer time periods. This information was also shared with the participants when they joined the prototype test as well as in a disclaimer at the beginning of the survey. The participants were also heavily encouraged to reach out via e-mail if they had any further questions or if they encountered problems while using the application.

5.2.1 Questionnaire Design

The questionnaire itself tried to gather data on whether the use of the application made an impact on how or if the participants perceived food additives as well as how the app itself was received by the testers. In order to be able to do this the questionnaire consisted of two parts with thirteen questions in total of which seven were mandatory to answer. The first part consisted of seven questions and regarded the impression that the application made to the participants as well as the possible impact in regard to food additives. The second part consisted only of optional questions and allowed the participants to share more detailed information about their app usage collected by the app itself. The functionality of this *debug mode* and the information that was made accessible was already discussed in section 4.4.2.

In the following paragraphs the individual questions and the considerations that went into them will be described. Just like the previous questionnaire, this one was also distributed in German and the figures included in Appendix C therefore again will show the original German version of the questions, while English translations of the questions will be provided in text form.

1. **I have tested *Alchemist* for...**
   - ○ one day
   - ○ a few days
   - ○ a week
   - ○ a couple of weeks
   - ○ Other: _____

2. During the testing phase I have used *Alchemist*...

- ○ regularly
- ○ often
- ○ sometimes
- ○ rarely
- ○ almost never
- ○ never
- ○ Other: _____

Figure C1 depicts the first two questions of the questionnaire. These questions ask the participants about the duration in which the application was tested, as well as the frequency of the actual application uses. This information is useful because it allows for comparisons between answers of participants who rarely used the application with answers of those who did so more frequently.

3. I think that the concept of *Alchemist* - the tackling of food items and their ingredients in a playful manner is...

- ○ very good
- ○ good
- ○ somewhat good
- ○ not good
- ○ Other: _____

4. I think that the application *Alchemist* itself is...

- ☐ playful
- ☐ exciting
- ☐ interesting
- ☐ educational
- ☐ boring
- ☐ monotonous
- ☐ misleading
- ☐ complicated
- ☐ Other: _____

The third question, which is depicted in figure C2, deals with how the concept was received by the participants. As was already mentioned in chapter 4, some people could have certain issues with how ingredients gathered from food items can be used to create potentially harmful concoctions, although for certain ingredients this effect could also

be put to use willingly. It is however assumed that most participants would take no offense over this, but should the results show that a majority of the participants dislike this approach, some design choices would need to be reconsidered in terms of potion recipes. The fourth question asks the participants to select adjectives that they associate with their experiences while using the *Alchemist* application. The provided answers were chosen to provide a balanced selection between positive and negative options for the participants to choose from. Should none of the provided answers seems fitting, the participants could also add additional ones. The way in which testers would describe the application is also important for the evaluation process because some people could like the concept but dislike the implementation or vice versa.

5. I think that *Alchemist* has led to an increase of my knowledge.

○ Yes

○ No

6. If "Yes": In what area(s)? If "No": Why not?

_____

7. On which areas/features should the development of the next version be focused on in particular?

□ Multiplayer (Joint potion brewing with other alchemists, Leaderboards)

□ Uses for the potions (eg: Raids, Fights against monsters,...)

□ Graphical Presentation

□ Research Breakthroughs (eg: Discovery of a new ingredient)

□ Other: _____

Questions 5 and 6 on the questionnaire (see figure C3) deal with the perceived effect that the usage of the application during the testing period had on the participants. Since the goal of the application was to create awareness about food additives the participants are further asked to expand upon their answer by providing further information. If a participant thinks that the usage of the app has led to an increase in their knowledge or helped to create awareness they are tasked with listing the perceived affected areas. However, if they stated that no change occurred they are asked to share their thoughts about the possible reasoning. Because all possible effects of the application could only be self-reported in this setting, this approach seemed to be the most logical one.

The final question on the questionnaire allows the participants to state what they think the focus points for the further development of the application should be. The default options, except the graphical presentation, are features that have already been discussed during the concept stage, but were not implemented due to various reasons. Due to the fact that the final version of *Alchemist* is supposed to contain full-fledged game elements, at some point the graphical presentation also needs to be addressed but for the development of the prototype the underlying systems were prioritized.

Most of the questions were also accompanied by optional text fields which allowed the participants to share additional information, like for example the reasoning behind their answers, or some further explanation that could not be captured by the question itself. At the end of the question section the participants were also given the option to share any remarks, suggestions or critiques that they might have had and that they were unable to share in any of the previous questions (see figure C4).

The second part of the questionnaire allowed the participants to share their usage statistics of the application if they wished to. In order to do that the section starts with an introduction and an explanation of the debug mode, followed by fields for each individual tracked statistic, as depicted by figure C5. What this debug mode is, what options it enables and how it can be activated has already been described in section 4.4.2 while the collected statistical information is depicted in figure 4.20a. The fields provided by the questionnaire and the declaration of the collected data inside of the application are identical so that participants could fill them in quickly and without much hassle.

5.2.2 Results

Out of the 38 people that filled in the first questionnaire in total ten also opted to test the application and out of those ten participants five people also answered the second questionnaire. That means that effectively only 50% of eligible people fully completed the study. Because the communication with the participants of the study could only be done via e-mail, and those participants also did not respond to the initial mail, in which they received their access to the prototype and the questionnaire, the reasoning behind their dropping out could not be determined. It is therefore also unknown if those people even installed and tested the application to a certain degree or not.

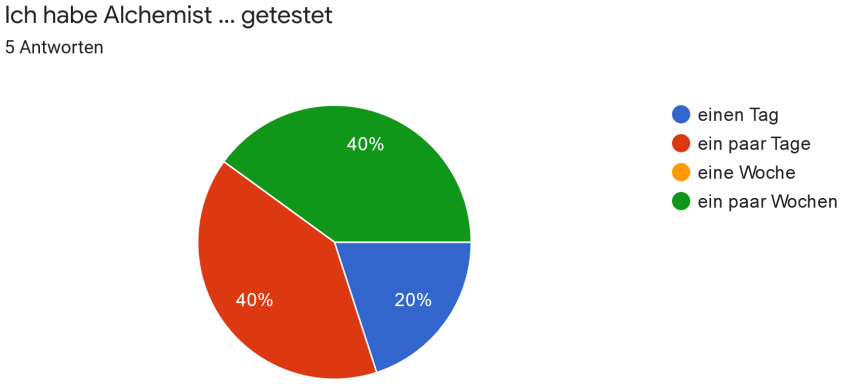


Figure 5.11: Results for the first question regarding the duration of the application usage.

In terms of the duration of the testing phase only one participant chose to test the

application for the duration of only one day, with the other 80% being equally distributed between the options "a few days" and "a few weeks" (see figure 5.11). In regard to how often the application was actually used, all participants reported that they used the app sporadically, for example while shopping for groceries or to scan food products already present in their homes, as was reported by one user. The extreme cases of heavy or non-existent app usages where not reported, as can be seen in figure 5.12. Some users also chose to further explain the reasoning behind their app usage. One user for example reported, that they would have liked to use the app more often, but did not do so due to the fact that almost none of their scanned products were found in the database, which dulled the experience and led to them having to scan the same few detected products over and over again.

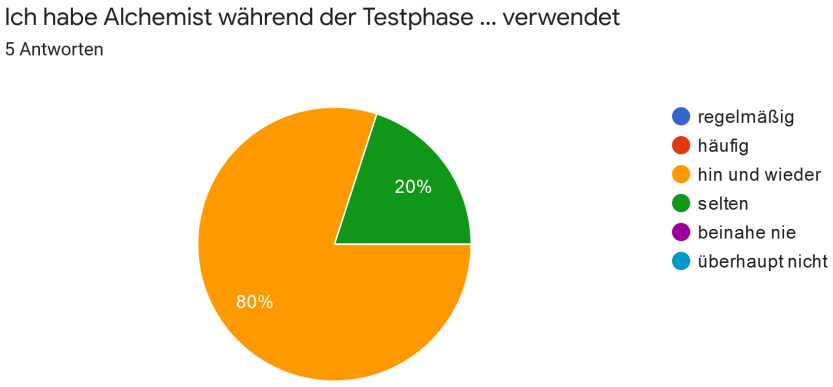


Figure 5.12: Results for the second question regarding the frequency of the application usage.

In regard to how the underlying concept of the application is received, all participants reported that they liked it, with 60% answering "Good" and 40% answering "Very good", as can be seen in figure 5.13. One participant who answered the latter, further expanded on their answer by stating that they did not pay much attention to food ingredients before using the application but that they actively engaged themselves with the topic during the study period.

When asked which adjectives seem fitting to them to describe the application the participants chose mostly positive ones. Only one participant found the app to be "monotonous". One person answered that they experienced app as "exciting", while two found it "informative". Finally, every participant stated that they found *Alchemist* "interesting". The complete list of results can be seen in figure 5.14.

Out of the five total answers four participants reported that the use of the application caused an increase in their knowledge either directly or indirectly. Three people further stated that they learned something about ingredients and food additives through the use

Figure 5.13: Results for question 3 which asked the participants to state their opinions about the underlying concept.

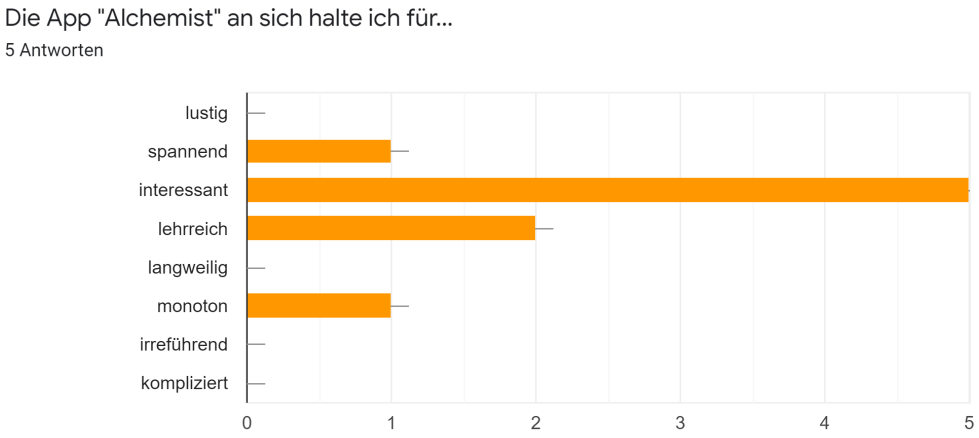


Figure 5.14: Results for question 4 which asked the participants to choose adjectives that express how they feel about the application itself.

of the application. One participant also stated the app caused them to actively research ingredients that they had not collected in order to have an idea in which products to look for them. Only one participant stated that the use of the application did not cause and tangible or perceivable change, as can be seen in figure 5.15.

Figure 5.16 shows the result for question 7 which asked the participants about what features or areas should be prioritized in the further development process of the application. With three total answers the inclusion of some form of multiplayer aspect, for example the

Figure 5.15: Result for question 5 regarding the self-reported increase of knowledge.

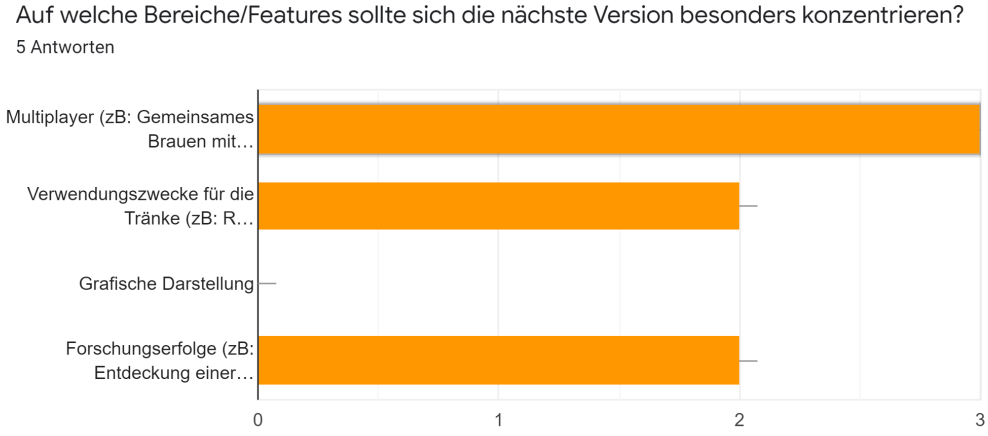


Figure 5.16: Results for question 7, which asked the participants about their opinions about what features should be prioritized for the further development.

joint brewing with other players, was the most requested feature. The inclusion of actual uses for the potions was an important feature for two participants. Just like the uses for potions, the introduction of a research system was also selected by two participants as an important subject for the further development of *Alchemist*.

The inclusion of additional graphical elements or actual graphics for the game however was not seen as particularly important as it was selected by none of the participants. Also no additional features were requested by the participants through the use of the provided "Other" field.

5.2.3 Discussion

Although the small number of completed surveys(n=5) does not allow to extrapolate some form of statistical significance, the gathered results and collected data could still be seen as an indication that there is enough potential for further research into this specific topic. The broad approval of the underlying concept and the mostly positive adjectives chosen by the participants could act as further arguments for this claim. The assumption that the inclusion of recipes for poisons or concoctions that are harmful in some way would irritate some people proved to be wrong. But this could very well be because of other reasons. As was stated before the participants could also share some statistical data about their app usage with most participants also making use of this opportunity. But while four participants chose to provide numbers for scanned products overall (between 15 and 167) and different scanned products (between 15 and 89) were quite high, only one participant submitted the number of different potions that they were able to brew. According to them they could only discover the ingredients to brew two types of potions. This means that this person only saw the names of the two potions that they managed to brew because although the required ingredients are visible on the potion brewing screen at all times (see figure 4.16), only the names and descriptions of already brewed potions are also visible, whereas the names of undiscovered potions are replaced by "*Unknown recipe*" and the description text being omitted altogether.

In terms of the actual app usage behavior during the study period most people reported that they used the app sporadically over longer time period, ranging from a few days to a few weeks. This was actually the expected way of using the application, because it was designed in a way that allowed for the quick and fast scanning of products and brewing of potions. It also allowed the minds of the participants to be occupied with the subject matter over longer time periods as well. It is assumed that a longer exposure to the subject matter could positively affect the awareness gained for the topic.

Throughout the survey the participants were given the opportunity to further expand upon their answers in textual form. Alongside some points and explanations that are already provided in the previous section some people used these fields to communicate their disappointment that a large portion of their scanned products were either not recognized correctly by the application or not at all.

Missing products in the database and the incorrect or incomplete matching of ingredients were actually the problems that caused the most correspondence between the participants and the study author. Although a screen-filling welcome message on the first launch of the application informed the participants about the project's background and the utilization of the OpenFoodFacts project therein which also invited them to contribute to the project, by adding or completing product entries, if they wanted to, some participants opted to report missing products via mail. Two other participants frequently pointed out that some ingredients were correctly recognized by the OpenFoodFacts application but not by Alchemist, which led to an expansion and improvement of the matching algorithm. Using this approach a total of 25 ingredient entries were added to the matching table over the duration of the study. The existing organizational structures of the underlying

OpenFoodFacts database, which is responsible for these problems, are already discussed in section 4.1.2. During the evaluation of the prototype OpenFoodFacts announced some upcoming changes to their platform which could be greatly utilized by *Alchemist*. These changes will be discussed in section 7.2.

In regard to the direction in which the further development of the application should head the participants answered multiplayer support with three votes and usages for brewed potions together with research tasks with two votes each.

Plans for a possible multiplayer component were already laid out in section 4.1.1, in which, among other things, the adept system was presented as a way to introduce multiplayer in a way that fits the setting of *Alchemist*. But these concepts were discarded from this prototype because they were either deemed out of scope for the project or because they didn't seem to provide any value for being able to answer the research questions. However the apparent demand for these features were noted for any possible future work on this subject.

Another demand dealt with uses for the created potions. In the current version of the application potions are instantly sold to an unnamed party once they are brewed. Therefore, further expansion of this mechanic in future versions would make sense. A possible way of going about this would for example be the introduction of a barter system, which would allow the player to haggle with specific customers, which may be inclined to pay higher prices for specific concoctions. Another possible use could be that the potions have actual uses inside the game, for example to restore health of companions while out on an adventure. But again both of these concepts exceeded the current scope of the prototype and are subject of future development.

The final demand focused on the introduction of a research system. But although the "discovery of a new ingredient" was provided as an example, this mechanic actually would bend the concept of the application, because through this, ingredients could no longer be gathered exclusively through scanning of food products as intended by the concept. Instead, this feature could also be included in a way that fits the setting and that would be in harmony with the scanning mechanic. Currently, the only commodity that players need in order to upgrade their equipment are gold coins. Maybe additional requirements, like special resources or blueprints, could be introduced, which could only be obtained by completing research tasks. Consequently, in order for players to be able to upgrade their their equipment, like for example their distillery, they would first need to gather the blueprint for the item together with all required resources, like for example copper. These research tasks could range from simple ones like "*Scan five different products*" or "*Brew a total of ten potions*" to more complex ones like "*Find 25 different ingredients*". Thus the system would serve as another source of extrinsic motivation for the players by providing them with a number of obtainable and trackable short-term goals which would encourage them to keep coming back to the application. A precursor of this system was added in the final iteration of the prototype in the form of an achievement system, that awards the players achievements for performing specific tasks, but instead of resources or blueprints the players only receive experience points in the prototype.

5.3 Usability Testing

The final iteration of the prototype was evaluated by conducting a usability test with five participants under controlled conditions. Every person has a different viewpoint on the topic of food additives and a different way of interacting with and to use the application, so the ability to observe the participants while doing so offers valuable insights, that could not be obtained through other methods like for example a questionnaire. This section is split up into three parts: setup, data and discussion. Before the results of the tests are going to be be discussed each test is going to be presented in a condensed format, highlighting some interesting parts while also providing an overview of the overall order of events during the tests.

5.3.1 Setup

The usability tests were conducted in private settings with the participants choosing the time and place. Before the individual tests started each participant was handed a consent form which in turn was explained to and discussed with them before they were asked to sign it. By signing the form they agreed to an audio recording of the test, for notes to be taken and for the resulting data to be used in this thesis. Optionally, by checking an additional box, they could also agree to a screen recording of their usability test. If they agreed, the resulting screen recording of the test would allow to analyze on which screens they spent the most time or which ones they ignored or visited less. All of the participants agreed to this optional recording, which proved quite valuable during the evaluation process since it not only captured the screen but also showed when and where the participants tapped on the screen of the phone. The used consent form can be found in Appendix D.

In order to keep the individual tests comparable the participants were given access to an Android smartphone with the *Alchemist* application and the *OpenFoodFacts* applications pre-installed as well a fixed assortment of different products (see figure 5.17), which they could use during their tests.

The individual products were chosen with deliberation in order to provide the participants with a wide array of different additives and different product types. Most of the products were already completely entered into the OpenFoodFacts database and therefore their ingredients were also recognized by *Alchemist* but intentionally some products with incomplete or non-existent records were also included in order to capture the participants reactions. Some of the ingredients could only be found in the products that possessed incomplete database records which therefore were essential in order to brew certain potions.

5.3.2 Data

In addition to the data gathered through the screen and audio recordings and the handwritten notes, further insights were gathered by utilizing the "*Thinking Aloud*" method. Before the beginning of the test, each participant was given a short introduction

Figure 5.17: The assortment of products used as part of the user tests.

into what *Thinking Aloud* was and what it required them to do. After a short setting-in period during which the participants were unsure about their actions most participants got quite comfortable with commentating their actions and with sharing their thoughts.

The usability test was split into two basic parts. While the participants got familiar with the process and the application they were encouraged to explore and use the application and to scan products as they seemed fit. After a few minutes or after they had discovered most of the features they were asked to navigate to the achievement listings and were then further encouraged to try andget as many achievements as they liked. The decision to use the achievements for the user test instead of a fixed set of actions that the participants should perform was made because the achievements tie into almost every feature and mechanic of the application while also explicitly or implicitly requiring the participants to perform certain actions, like scanning various products, brewing potions or improving or repairing equipment but the participants could perform them at their own pace and in the order that seemed appropriate to them, giving them more agency in the process. Since obtaining all achievements would take some time, each participant was asked in regular intervals if they would like to continue the test of if they would like to wrap up and move on to the interview. Therefore, the duration of the individual tests varied and ranged from forty-five to eighty minutes. After the tests concluded the debug mode was activated and some statistical data, which can be seen in table 5.1, was recorded together with the overall duration of the test in order to be able to use the information in the evaluation process.

The usability tests were evaluated using the audio and screen recordings of the tests as well as the handwritten notes that were created during the tests. Cohesive topics and insights are connected and cross-linked between the individual tests. The resulting items

Metric	P1	P2	P3	P4	P5
Test Duration (in minutes)	80 min	45 min	50 min	55 min	50 min
Scanned Products (Total)	39	41	58	40	61
Scanned Products (Distinct)	25	28	40	35	42
Brewed Potions	12	14	22	10	26
Combined Revenue	1575	1851	2597	1409	4576
Discovered Ingredients	23/41	25/41	24/41	24/41	26/41
Discovered Potions	5/10	5/10	5/10	6/10	6/10
Obtained Achievements	15/22	15/22	19/22	15/22	18/22
Earned XP	875	875	1725	875	1475

Table 5.1: Listing of statistical data gathered during the user tests.

are marked from P1 to P5 according to the respective participant and the individual tests will in turn be presented from Usability Test 1 to Usability Test 5.

Usability Test 1

The usability test conducted with the first participant(P1) lasted around 80 minutes. Despite having access to the second iteration of the prototype, P1 did not test the application very extensively due to personal reasons and only opened it a couple of times. Therefore, the participant had little to no knowledge about the application before the start of the user test. When the participant opened the app and the information about the context of the application and the utilization of the OpenFoodFacts projects was displayed, they switched to the provided OpenFoodFacts application and used it to scan their first product. They then inquired if the product information had already been transferred to *Alchemist* or if they needed to scan the product a second time. They then switched over to *Alchemist* and proceeded to scan the product again using the applications built-in scanner. After the scan had concluded and the product page opened, P1 immediately noticed the listing of the nutritional information as well as the icons indicating palm oil usage, and the vegan and vegetarian status of the product. After some guesses about what meaning the individual icons could possess the participant tapped on one of them and was satisfied that their guess, that the monkey face indicated palm oil usage, was correct. Next, the participant tapped on the information icon in the upper right corner which opened the product page in the browser but due to the fact that the page only displayed a white background while loading P1 returned to the previous screen before the page showed any information. When asked about this the participant stated that they just were to impatient and pressed the button again, this time waiting for the page to load. They liked that the web page showed additional information, like the kind of packaging used or the point of origin, that were not included in the application.

From that point forward the participant made use of this feature for every newly scanned product, spending considerable time investigating certain products aspects on the OpenFoodFacts web site. Around ten minutes after the test started the participants

began to navigate other areas of the application instead of exclusively scanning products and then looking at their product pages like they did before. P1 opened the almanac, the brewing screen and the equipment page before returning to the brewing page and selecting different potion recipes. When they found a recipe that only required the discovery of two additional ingredients, among them *wheat*, P1 started to specifically look for products that could contain it. They chose a box of corn flakes which had an incomplete record and therefore did not yield the expected ingredient, although the ingredient was present in the ingredient listing on the product packaging. The participant did not try to complete the database record and instead moved on to scan a different kind of cereal that provided them with the intended ingredient. This was also the approach that was used by the participant for the remainder of the test. Once they found a recipe that only required one or a few specific ingredients to be discovered they tried to specifically scan products that could contain them. The ingredient listings provided on the different products were only consulted once the respective product was already scanned. After the participant had brewed their first potion they proceeded to the equipment screen where they decided to upgrade some equipment items. Once they encountered the first product that was not listed in the database at all they tried to add it in order to get a final missing ingredient. They nearly abandoned the idea after the OpenFoodFacts application crashed shortly before the entry could be completed. The participant repeated the process and was able to successfully add the product to the database but was then, in turn, disappointed when *Alchemist* was not able to identify the product immediately afterwards.

After P1 created a different potion they noticed the pop-up that informed them about an unlocked achievement which in turn caused them to look up the requirements for additional achievements. The test ended after the participant had obtained 15 out of the 22 achievements and decided that the remaining achievements would require too much effort to obtain.

Usability Test 2

The usability test with the second participant(P2) lasted for about 45 minutes. The participant had not participated in the evaluation of the second prototype evaluation and therefore had no knowledge about the application or the project before the start of the test. When the participant opened the application and the introductory text appeared, the participant was quite surprised to learn that *Alchemist* was a game because due to the presented food items they expected a different kind of application. As soon as the participant reached the scan history screen, they scanned their first product. They scanned an item that had an incomplete entry and which was therefore recognized but did not yield any ingredients. Because the participant had read the explanatory text but had not seen any other screens except the scan history screen, they were confused by the outcome and asked how they should proceed. After they were encouraged to explore the rest of the application, the participant navigated to the brewing screen and decided to look for the ingredient *Cranberries*. After scanning two products that the participant suspected to contain cranberries - both of which with incomplete records - they realized that they haven't gathered a single usable ingredient and asked how they could obtain

ingredients and if they did something wrong. After being encouraged to scan more products, they collected their first ingredients and soon afterwards were also able to brew their first potion. Because they saw the different equipment items being listed in the potion brewing screen they tried to gather more information about them and navigated to the equipment screen. They immediately noticed that some pieces of equipment had a progress bar attached to them while others did not and correctly assumed that these items would break after continued use. The *sickle* confused them because they were not sure what it was used for, but due to the information provided on the upgrade screen, they quickly understood that it affected the quantity of collected ingredients. They then asked what would happen if they tapped on the *Upgrade* button, because they had the impression that that action would immediately upgrade the item and they wanted to know first what effect the upgrade had, for example if items would wear down slower. They were then encouraged to click the button which opened the upgrade menu. While they were able to instantly realize that "Uses" referred to the number of times an item could be used before it needed to be repaired, they were unsure about which value the field "Value Multiplier" referred to. Although they correctly assumed that it could only apply to the value of the brewed potions, they stated that the labeling could be worded more clearly. Afterwards, they read through the upgrade information for every equipment item and looked up how much each item would cost to renew or to upgrade before they moved on to scan additional products in order to brew more potions.

The participant did so by searching for recipes that required the least amount of additional ingredients and then went on to specifically look for those. When they then encountered another product with missing ingredient entries they asked if they had to add them to the database. They were then told that they didn't have to but that they were welcome to do so if they liked to use the previously introduced application by OpenFoodFacts, but the participant ultimately chose not to complete the product entry and from this point on also disregarded any products with nonexistent or incomplete database entries.

After brewing some potions, the participant started to explore other sections of the application and found the almanac, the ingredient detail view, the potion history and the achievement listing. Inside the almanac the participant explored the different ingredients and potion recipes that they had discovered and was unsure about how additional potion recipes could be added and therefore asked how this could be done. Then they moved on to look at the entries of various ingredients where they soon criticized the inconsistent inclusion of the button that links to the website, since only products with assigned E numbers had one of those. In their opinion this button should be used for every ingredient or the reason for their absence on some pages should be communicated more clearly in order to avoid confusion. On the product pages they praised the inclusion of the nutritional data table and of the meta icons because they would allow laymen to quickly see important information about a product. Next, they navigated to the brewing history and then quickly switched over to the achievement view. Although they had already collected twelve achievements at that point they acted surprised about achievements being present in the application. When they were asked about this, they stated that they did not notice the achievement pop-up that appeared every time an achievement

was unlocked. They stated that in their opinion the inclusion of achievements was an important aspect in order to motivate the users. After they looked through the achievement list they noticed that they only needed to brew a few more potions in order to unlock two additional ones. After they had obtained those achievements they opted to conclude the test.

Usability Test 3

The usability test with the third participant (P3) lasted for 50 minutes. The participant had no previous involvement in the study. After the participant had skimmed the introductory text they opened the scanner and started to scan their first products. They also immediately noticed the achievement pop-up after the first successful scan and from that moment on believed that the unlocking of the achievements was the overall goal of the test or that the discovery of rare ingredients would also award additional experience points. To test their assumption they tried to find out how much experience points the discovery of each ingredient would bring and navigated to the detail page of a discovered ingredient. There they praised the inclusion of the nutritional information as well as the indicator icons before tapping on the button that opened the OpenFoodFacts website. They looked at the provided information, realized that the information was not there and returned to the application where they continued to scan products. After they had successfully scanned four products they switched over to the brewing screen where they quickly looked through the different recipes to see if they could brew something already. Because they found no recipe for which they had already gathered all the ingredients, they moved on to the equipment screen where they took a look at the different items. They soon realized that they had not enough money for any of the upgrades and therefore returned to the brewing screen where they found the achievement icon. After looking through the list they targeted the "*Scan 25 products*" achievement and proceeded to scan a number of products in quick succession. Because they placed their ambition in the obtaining of achievements and not directly in the potion brewing mechanic, they were not bothered by incomplete records since they still counted towards the achievement requirements. When the participant encountered their first products with an nonexistent database record P3 stated that they would ignore them for now and that they would come back later if they could not obtain some achievements without them. When they switched back to the brewing screen they were able to brew their first potions.

Afterwards, they began to to search for specific ingredients, for example *Wheat* as it was the only ingredient preventing them from brewing a high-value potion. As soon as they found it they wanted to stockpile the ingredient by repeatedly scanning the respective product, only to be surprised afterwards by the fact that they still only had two instances of wheat available. When they navigated back to the equipment screen they stated that they misread the satchels description and thought that it allowed them to carry more potions of the same type instead of more ingredients. While on that screen they also stated that they wanted to wait to the last possible moment before they upgraded or repaired their equipment. Because the participant was unsure what the "*Upgrade*" button would do, they wanted to wait until their equipment was inoperable before pressing

the button because, according to them, any upgrade before that point would waste the remaining item uses. So, as soon as their equipment broke they proceeded to upgrade everything except the sickle to level two, before brewing additional potions. While repeatedly brewing the same high-value potion they also encountered the value decrease caused by the market saturation mechanic. Although they overlooked it the first time, the second time they noticed the message and wondered what caused this to happen. At first they thought that it was due to the quick succession in which they brewed their potions but when they looked at the brewing history they correctly guessed that it was due to the type of the recently brewed potions. When they returned to the achievement list, they realized that they had already obtained 15 out of the total 22 and that they were relatively close to unlocking some achievements while others, like for example "Brew ten different potions" were unobtainable. So they opted to conclude the test after obtaining 19 out of the 22 total achievements.

Usability Test 4

The usability test with the fourth participant (P4) lasted for 55 minutes. The participant was previously not involved in the study. After P4 carefully read the introduction text they proceeded to scan their first product, where they immediately noticed the achievement pop-up. They then looked at the detail page of the scanned products where they saw that only three ingredients were listed for that product. Therefore they assumed that these ingredients were the products "main ingredients". They then navigated to the brewing screen where they switched through the different potion recipes. Although the order of the recipes, besides the first one, was randomized the next three recipes that the participant received all had an increasing number of ingredients. This prompted P4 to ask if the switching of recipes would always result in more complex one and therefore in potions which are harder to brew. After the randomness of the switching process and the limited set of total recipes was explained to them, they proceeded to scan additional products. One of the first products that they scanned had an incomplete record and P4 asked if they should add it to the database. After being told that it was up to them they decided not to add that product and subsequently also ignored all following incomplete or nonexistent products.

Instead they opted to explicitly look for three missing ingredients which where needed to brew two recipes. Among them was *palm oil*, which the participant assumed would be very hard to find since its use was frowned upon by the public. They were then quite surprised when two out of the three products that they scanned next contained palm oil. They then spent some time on finding the ingredient *Cranberries*, but because they had no success they switched their strategy and started to quickly scan different products regardless of their contained ingredients. After they scanned around ten new products they switched back to the brewing page where they successfully brewed their first potions. They then looked at their brewing history and they also found the achievement listings, where they got confused by the wording of the not yet obtained "*First steps*" achievement. Because the description of the achievement was "Earn 500 coins" and because P4 had a total of 535 gold coins at that moment they assumed that an error had occurred and

that the achievement should have already been awarded to them. They were unaware of the fact that they had already started out with 50 coins, and that the requirement therefore had not been met by them. P4 realized this after they took a second look at the brewing history where their combined revenue was also listed.

Because they noticed the different equipment items being listed on the brewing pop-up they then switched over to the equipment screen. Upon inspecting the individual items they asked what would happen if they pressed the button and if more information about the individual items could be found somewhere. They then pressed the *Upgrade* button, found the information that they had been looking for in the form of the effect comparison between the current and the next upgrade level and proceeded to upgrade some items, among them the sickle. Afterwards, they returned to their previous strategy of looking for specific ingredients because, as they stated, they were not really comfortable with blindly scanning arbitrary products without having a clear goal or a concrete reason to do so. Since their selected recipe required an ingredient that they were unfamiliar with,they tried to gather information about the ingredient by clicking on it and received the "This ingredient has not been discovered" message. This caused them to put the application and the phone aside and to proceed to search for the ingredient by looking at the ingredient listing of products, which they assumed could contain it. They found the missing ingredient soon afterwards and proceeded to scan the respective product but were then disappointed that the product was not recognized by the application. Because they suspected that the process of adding the product to OpenFoodFacts would be too much work and because they could not find the ingredient in any other product they selected a different recipe. By repeating this process they discovered two additional recipes but because they were hesitant to brew potions that they had already brewed before they opted to end the test soon afterwards with total of six discovered recipes and ten potions brewed overall.

Usability Test 5

The usability test with the fifth and final participant (P5) lasted for 50 minutes. The participant took part in the evaluation of the second prototype iteration but just like P1 they did not spend much time with the application because almost none of the products that they scanned were in the database. Because of this they only managed to discover three ingredients and were not able to brew a single potion. Before the test started P5 estimated that they only spent around twenty minutes in total with *Alchemist*.

At the start of the test P5 carefully read the introductory text since they recollected that they had skipped it the last time. As soon as they reached the empty scanning history screen, they proceeded to scan around fifteen products in quick succession and without looking at the ingredients that each product scan provided. Whenever they encountered a product with an incomplete or non-existent record they placed it on a second pile separate from the other ones. Afterwards they navigated to the brewing screen where they were able to brew their first two potions by switching through the recipe list and brewing the ones they already possessed all ingredients for. Upon seeing the different

equipment items displayed after each brewing process they navigated to the equipment screen where they upgraded the *cauldron*. They also noticed the addition of the *sickle* but due to insufficient funds they were unable to upgrade it. They then repeated the process of scanning around ten products and brewing all eligible recipes, followed by the upgrade of some equipment items.

At one point P5 got confused because the image of the product displayed in the application did not match the design of the scanned product and they theorized that the bar code has been scanned incorrectly and that the wrong product has been recognized. Because they wanted to confirm their suspicion they opened the product detail page, where they realized that the displayed product was correct but that the depicted packaging design has been changed since the picture was uploaded. P5 used this opportunity to inspect the indicator icons and the information button, which were not present in the previous iteration. The participant stated that these were all good additions, since they provided valuable information to the users. They also took a look at the brewing history, which they acted indifferent about, and the achievement listing, which they liked. P5 stated that they were surprised about how many achievements they had unlocked already, given that they did not pursue them consciously.

P5 then returned to the scan history screen where they scanned the remaining products which provided them with enough different ingredients to brew four additional potions. The participant used the resulting revenue to upgrade the *sickle* as well as the *satchel* before returning to the brewing screen. Because they had scanned every available product they could simply look up in which products the required ingredients could be found. Since P5 did not pay attention to which products yielded which ingredients during the scanning phase they needed to heavily rely on the ingredient detail screen in order to find the possible sources for each ingredient. This caused them to state, at various points, that they did not expect so many additives to be present in some products or that they were surprised that some additives could be found in so many different products.

The participant chose to conclude the test after they had completely upgraded their *cauldron*, *mortar* and their *distillery* and because they could not find any undiscovered ingredients in order to brew some new recipes.

5.3.3 Discussion

As expected, the usability tests allowed to gain valuable insights in terms of what the participants expected from the application, how they interacted with it and what kind of usage patterns they used to achieve their set goals, all of which were not possible to capture using the questionnaire that was used to evaluate the second prototype iteration. In order to keep the discussion in line with the representation of the tests in the previous section, the individual participants will again be referred to as P1 - P5. The statistical data that is going to be referenced throughout this section can be found in table 5.1.

The usability test was intended to be conducted in two major parts: A short introduction period during which the participants could interact with the application unguided in

order to let them explore *Alchemist* for themselves which should also uncover possible shortcomings in terms of design or in the communication of features while also getting familiar with the thinking aloud method while in the second part they would be somewhat guided by being encouraged to obtain achievements, which would require them to interact with many of the applications features. This approach only worked for two of the tests as intended because in the remaining tests the participants put big emphasis on the achievements from the moment they were awarded their initial one after successfully scanning their first product. Especially P3 saw the obtaining of the various achievements as the overall goal of the test.

Although only five tests were conducted, a few distinct usage patterns could be observed. P1 for example was very interested in getting as much information about the individual products and their ingredients as possible which manifested itself in careful reading of the respective entries not only inside of the application but also on the OpenFoodFacts website which resulted in P1's test time being nearly thirty minutes longer than the tests with the other participants. As mentioned before, P3 saw the achievements as the major goal of the application which caused them to play in a way that focused on how many achievements they could get. For example they stopped scanning new products once they had obtained the achievement for scanning forty distinct products, since scanning any additional products after that point would not count towards unlocking any of the remaining achievements. P4 initially tried to scan only products that contained ingredients which they would need for their currently selected recipe, or products they suspected to contain those ingredients before switching to the strategy of scanning as much as possible, which was later also used by P5. This caused P4 to be the participant who spent the most time reading and studying the actual physical product packaging, because although P1 also looked at the packaging initially, once they had scanned the product they continued to look for information exclusively through one of the two applications. Finally, P5 used the strategy of scanning all of the provided products, which in turn allowed them to spend less time on the requisition of ingredients since they simply needed to look up where they could obtain the needed substances. Because of that, P5 was the only participant that altogether disregarded the ingredient listing on the product packaging. P5 was also the only participant to fully upgrade their brewing equipment, which resulted in their potions being worth considerably more than those of the other participants.

Another interesting observation could be made in regard to how the participants reacted to products that did not yield all of the expected ingredients or no ingredients at all either because they had incomplete database records or because they had not been added to OpenFoodFacts at all. Although the mobile application of OpenFoodFacts which could be used to add products to the database was installed on the phone used during the test and although the participants were informed about the apps existence in addition to the two applications being placed side-by-side on a separate screen, only two participants opened the application and only one participant ultimately added a product. The other participants did not interact with the second application and instead chose to simply move on and scan other products. This further strengthens the assumption voiced in

section 4.1.2, namely that an application like *Alchemist*, that requires its players to interact with an arbitrarily large set of food products, needs to be supported by a sizable database in order for the concept to work. P1 was the only participant that added a product, which was the only source for a specific ingredient,to the database, but because it takes a few minutes before newly added products are accessible via the OpenFoodFacts API, the participant chose to end the test before they were able to gather their intended ingredient, unlike participants in the following tests which were able to successfully scan the product. Nonetheless the decision of the remaining participants not to add any new products to the database affected their brewing options. As was already mentioned in section 4.3 a total of ten potion recipes were created for the prototype evaluations. Six of the potions described in these recipes immediately where able to be brewed using the products provided for the usability tests. An additional recipe could be completed because of the product that P1 added to the database, while two more potion recipes would have been made possible if more of the provided ingredients would have been added by the participants. Only one recipe was impossible to brew regardless of the actions the participants took, because two out of the three needed ingredients, *Vitamin A* and *Cranberries*, could not be collected using the provided product assortment. The affected potion was the one that was selected per default on the potion brewing screen. This was done in order to observe how the participants would react to this and at what point they would decide to switch potions. Four out of the five participants switched between different potion recipes as soon as they reached the potion brewing screen while experimenting what the different buttons would do. The remaining participant spent a few minutes looking for the needed ingredient before deciding to switch potions.

Some differences in how the participants used the application can also be found in the way they upgraded their equipment. Throughout the usability tests each participant tried out the upgrade mechanic at least once, as soon as they had earned enough coins, but afterwards their upgrade behavior diverged. While P5 explicitly upgraded their items in order to earn more revenue for each potion the other participants mostly upgraded their equipment in order to continue to be able to brew potions. Since the items that they started out with would break after brewing ten potions, they had the option to either upgrade an item or repair it. But because both options cost money and the upgrade also came with the benefits of more valuable potions and more durable items, the ability to repair an item was used not even once throughout all five tests.

The usability also highlighted some aspects of the application that could be improved in terms of usability or clarity in the communication of certain features. One participant for example stated that a guided introduction at the first start of the application would be a great addition since some of the features could be hard to spot for new players. Another participant stated that the mechanic of the market saturation is not communicated enough to the players in terms of why it occurred. Another participant got confused by some of the descriptive texts chosen for some of the potions or the different pieces of equipment. For example, the German translation of the description of the *Potion of Braveness*, which states "*Dieses Tonikum wird den Tapferkeitslevel vorübergehend erhöhen.*", prompted one participant to ask where they could see their current braveness

level. So they thought that this short text with no actual meaning inside of the application referred to an actual game stat or mechanic. As a final example one participant thought that newly discovered ingredients should be highlighted after a successful scan and that potions that can be brewed should be indicated as well.

5.4 Interviews

The people who participated in the usability test were also interviewed after the conclusion of the test. Depending on the length of the test portion of the session a ten minute break was included before the start of the interview. Before the interview started each participant was presented with a prepared consent form which was then explained to them before they were asked to sign it. The consent form used for these interviews can be found in Appendix E. Every participant agreed to sign the form so all of the individual interviews were also audio recorded. The duration of the individual interviews ranged from twenty five to thirty minutes. All interviews were held in German, as all interviewees were native German speakers.

5.4.1 Interview Guide

The interviews were conducted in a semi-structured manner and therefore partly followed a prepared interview guide. The questions can be categorized into three sections. The first section dealt with the nutritional habits and the food related buying behavior of the participant. The second section dealt with food additives in particular and the third and final section contained questions regarding the *Alchemist* application. A translation of the interview guide will be presented below while the original German version can be found in Appendix F.

Pre-Interview

- ☐ Thank the participant for taking part in the interview.
- ☐ Introduce yourself and your personal motivation.
- ☐ Explain the intention behind Alchemist (Creation of Awareness,..).
- ☐ Discussion and signing of the consent form.

I) Questions regarding personal diet

- ☐ How extensively do you concern yourself with your diet?
  - How does this influence you? (Amount, Ingredients, avoidance of certain things„„)
  - Special diet(s)? (eg. Vegetarian, Vegan,...)
- ☐ Which aspects do you pay attention to while shopping for groceries?

- Brand, Packaging, Best-before date, Price, Point of Origin, Ingredients, Nutritional Information, Additional Information,...
- How important is each of these aspects for you and why?
  - Influence on buying behavior

☐ How do you inform yourself about these aspects?

- Only product (packaging) or additional sources?
- If yes: Which?
- Applications (eg. *MyFitnessPal*), Nutritional Databases, online message boards, product reviews,... ?

☐ (How frequently) Do you use convenience products while cooking?

- Why? / Why not?
- In which function? In addition to other dishes or exclusively?

☐ What is your stance on convenience products?

☐ What is your stance on fast food/junk food?

II) Questions regarding food additives / E-numbers

☐ Do you concern yourself with the listed food additives?

☐ How would you assess your knowledge about these substances?

- How/Where did you gain this knowledge?

☐ Do you think that these substances are declared sufficiently?

- In regard to function/origin/possible side effects?

☐ Do you feel that you are informed sufficiently about the uses of these substances?

☐ Do you feel that you are informed sufficiently about possible side effects of these substances?

III) Questions regarding *Alchemist*

☐ What is your impression of the concept of *Alchemist*?

- Useful, Redundant,...

☐ What is your impression of the implemented prototype?

☐ In which areas do you see need for improvement?

- ☐ Did the application increase your knowledge?
  - In which area?
  - How?
- ☐ Was there something that surprised you?
- ☐ Are you more aware about food additives than before the test?
- ☐ Do you think that you will concern yourself more with these substances in the future?
- ☐ Would you use such an application to gain information about products and their ingredients?
  - Why? / Why not?
- ☐ Which features would you like to see added to the application?

Post Interview

- ☐ Thank the person again for participating in the user test and in the interview.
- ☐ Ask if they would like to be informed about project results.

5.4.2 Data

The interviews were evaluated using the created audio recordings as well as the handwritten notes that were taken during the conversations. Cohesive topics and insights are connected between the individual interviews according to the three overlaying question sections. The resulting items and statements are marked from P1 to P5 according to the respective interviewee.

I) Questions regarding personal diet

P1 States that they try to concern themselves with their diet to at least a certain degree.

P2 States to be concerned with their diet and that they regularly try eat the recommended amount of different macro nutrients.

P3 Stated that they try to have a healthy and balanced diet but that they would not forgo product types like sweets altogether. Instead they try to limit the hours during which they eat food, which is also known as intermittent fasting.

P4 Stated that they did not really pay attention to their diet in most aspects but that they would try to eat the recommended amount of different macro nutrients during the day.

P5 Stated that they did not really pay particular attention to their diet in regard to nutrients or caloric intake but that they still tried to incorporate a large variety of different dishes in their diet.

P1 Tries to significantly reduce meat consumption and only consumes meat one or two times a week. States that the reduction of meat happened without any problems because there are many viable alternatives available. The participant changed their dietary behavior in regard to meat in the recent years due to new information regarding meat production and meat consumption.

P1 Is not really interested in the nutritional data (eg: carbohydrates) provided on the packaging and in the ingredients contained in a specific product. An exception is palm oil which the participant tries to avoid as much as possible. Other aspects of a product like brand, packing and pricing are not very important to them.

P2 Aspects like nutritional information, especially details about the amount of fat, sugar, carbohydrates or the caloric value of a product in general, are very important to P2. The product brand is also important for some product categories, like for example meat products, while for other categories aspects like the price and the best before date are more important. P2 also mentioned the controversies surrounding palm oil but stated that they do not pay much attention to them.

P3 P3 stated that to them the used ingredients and the provided nutritional information are very important product aspects. The interviewee further stated that they didn't care about the price or the brand of a product as long as the brand does not belong to a particular food company.

P4 Stated that for them the price and the point of origin of a product are major factors. According to them they sometimes look at the list of nutritional information but that they do not make buying decisions based on that information. Other factors like the used ingredients or the brand are not important to P4.

P5 Stated that the price and whether or not they have purchased a product before were the major deciding factors for them. Aside the best-before date, P5 is not really interested in other product aspects.

P1 Information about products is gathered by looking at the ingredient list and nutritional information provided on the packaging. No other tools or sources are used. The participant states that this is due to the effort required to search for trustworthy information about certain products. The participant further states that the applications used in the test (*Alchemist* and *OpenFoodFacts Scanner*) would massively simplify that process. They mention that these applications would also offer great value for vegans or vegetarians because they could easily verify the status of a product without the need to look at the ingredient listing.

P2 Information about the products is mostly gathered by looking at the product packaging. Other sources of information are almost never used.

P3 Information about products is gathered exclusively through the product packaging.

P4 Both aspects important to P4, the price of a product and its point of origin, are typically found on the price tag or on the product packaging itself.

P5 Information about the best-before date is obtained by looking at the product packaging while the price can be found on the price tag.

P1 P1 does not know or use any applications that provide information about food products.

P2 Stated that they knew some applications in that area but that they did not use any due to a lack of a personal need.

P3 Knew some applications that provide nutritional or other food related information but did not use any due to the fact that for the most part they regularly bought the same set of products.

P4 Had heard of some applications intended to keep track of nutritional information but had not used any of them.

P5 Did not use any kind of nutrition tracking application. When they were given *MyFitnessPal* as an example they were surprised because although they have heard of that application before they thought that it was solely a fitness or workout application.

P1 P1 states that they use ready meals maybe once or twice a year and that they prefer home cooking.

P2 Does not use ready meals unless no other option exists.

P3 Does not use ready meals at all and prefers home cooking.

P4 Makes use of ready meals sometimes, depending on how much time they have on a particular day but prefers to cook their meals themselves.

P5 Does only use ready meals during camping trips and otherwise prefers home cooking.

P1 P1 is critical of ready meals because in their opinion they do not offer a time benefit compared to regular cooking but rely heavily on additives. They also state that these products often do not taste very good neither.

P2 Is very critical of ready meals and thinks that people should cook more at home.

P3 Saw the appeal that ready meals could possess for some people but never came into much contact with them and therefore had no experiences with them.

P4 Stated that such products are not a problem as long as their use is not the norm.

P5 Thinks that ready meals have their uses in certain situations but that they do not really have any issues with them because of how rarely they incorporate them in their diet.

P1 When asked about their stance on fast food and junk food the participant mentions that they see them in the same manner as meat in general. They are OK with infrequent consumption but are critical of regular use due to the high caloric density of such products.

P2 Does not like fast food and thinks that fast food that targets children in their advertisements is a problem.

P3 Differentiated between junk food and fast food, with the term "fast food" being used by them to indicate food that could quickly be purchased and consumed but that provides a certain amount of nutrients. They stated that they would occasionally eat fast food but that they would avoid junk food as much as possible due to its lack of nutrients.

P4 Stated that fast food and junk food are a viable option if not much time for cooking and for eating is available. They do however not recommend to eat such meals on a daily basis because of their high calorie count.

P5 Stated that they only consume junk food maybe three or four times a year and that they did not have a strong opinion of it.

II) Questions regarding food additives / E-numbers

P1 The participant stated that they can't identify substances based on their E number and that they have no insight into or an understanding of how the system works.

P2 They stated that they had no idea how the E number system worked or why it was used.

P3 According to P3 they look at the nutritional information and the ingredient list of products that they intend to buy for the first time but that they do not do so for products that they purchase regularly. P3 also stated that they have some understanding about the functions of some specific additives (eg: some coloring agents) but that they do not have any knowledge about how the E number system works or how the number for a specific additive is decided upon.

P4 They stated that they would be able to recognize some of the more widely used additives by their name but as soon as a substance was only listed under its E number, they typically had no idea what substance it was or what it was used for.

P5 Stated that they did not really pay attention to food ingredients or additives and that they would only look at the nutritional information and the ingredient list sometimes during down time while cooking or when they were particularly interested why a certain product tasted the way it did. P5 also stated that they were only familiar with one of the additives that they encountered during the test.

P1 The participant stated that food additives should be indicated more clearly on product packaging as some substances are listed solely with their E number while others are listed with their name.

P2 The participant stated that food additives should be displayed more prominently among other ingredients.

P3 Stated that in their opinion additives were not displayed clearly enough on product packaging. They also noted that the system should also provide information for people with certain allergies

P4 In their opinion food additives should be able to be differentiated visually from other ingredients in some shape or form, for example by listing them separately from other ingredients.

P5 They stated that they have previously read an article that described how certain additives would be listed with their name while other additives would be listed solely under their number as a way to obfuscate to the public which additives were present, since it would require the people to actively inquire about any given substance. P5 stated that they found this to be problematic.

P1 The interviewee stated that they had a certain degree of understanding what functions individual additives serve, based on whether or not they have encountered or have heard about the substance before. They further stated that they would have little to no information about these substances based on the information provided on product packaging alone.

P2 The participant did not know what functions different additives serve but that some of these functions could be identified based on short descriptions on the packaging. As an example they mentioned the listing "Farbstoff: E150d" (coloring: E150d) which was used in one of the products.

P3 Stated that they knew why specific additives were added (eg: coloring or flavoring agents) but that they did not feel informed about the system as a whole.

P4 Stated that that they did not feel informed about the reasons why a particular food additive is added to a product.

P5 Stated that they could piece together why most of the ingredients and additives in a given product where added based on the ingredient listing.

P1 They did not feel informed at all about possible side effects of food additives and thought that this aspect should be communicated more clearly.

P2 Stated that they did not feel informed about possible side effects.

P3 Stated that they were not aware that certain substances could possess unwanted side effects.

P4 They stated that they were not aware of the possibility of side effects and that, in their opinion, information about these effects or the risk of over provisioning should be provided on the packaging of products that use many additives.

P5 Stated that they were previously unaware about possible unwanted side effects and thought that they should be added to the product packaging, for example in form of a logo or explicitly through text.

III) Questions regarding *Alchemist*

P1 The participant liked the concept of the application because, according to them, it required the players to go out of their way and to look for specific substances. According to P1 the game aspect provided additional motivation to continue to use the application.

P2 P2 stated that they found the concept to be sensible. They further explained that in their opinion such a concept would be well suited as part of a school project that teaches children about nutrition.

P3 The participant liked the concept, which they summarized as "*Just like Pokemon GO, but with food*" and stated that the game aspect could be well suited to create awareness as a byproduct of the app usage. This could especially be the case if the player has no prior knowledge about nutrients or food additives.

P4 The participant liked the concept and the incorporation of the various game elements and further stated that the approach to make the gaining of knowledge about these substances a byproduct of the app usage instead of the sole purpose of the application would make sense in that context.

P5 Stated that they liked the playful approach of the concept but did not believe that such an application would be used by people that were not interested in the topic at all.

P1 The participant liked the current implementation of the application. Nevertheless some areas in which it could be improved and some features that could be added were mentioned. These included the ability to initiate a product scan from every screen instead of only being able to do so from the scan history page and the ability to get hints about where undiscovered ingredients might be found. P1 also came

up with a feature that would allow allergens to be recognized and that would alert users as soon as they scanned a product that contained a substance that they were allergic to. Another feature that the participant would like to see added involved warnings for products that used plastic as part of their packaging where the use of plastic could not be identified by simply looking at the product. As an example they mentioned cornflakes or different kinds of cereal that are typically sold in cardboard boxes but often also contain inner packaging made out of plastic. Finally, the participant mentioned a feature that would show them which recipes they could prepare with their currently stored ingredients or which recipes would require the least amount of additional ingredients to be discovered.

P2 The participant stated that they were quickly able to navigate and to use the application and that they liked the overall presentation. Nevertheless, they stated that the functions of some elements, for example the information button on the product page, could be indicated more clearly. In addition, P2 stated that in their opinion the option to show healthier alternatives to scanned products would provide additional value. Another feature that they mentioned involved the ability to flag certain ingredients and to subsequently receive a warning once the ingredient had been found in a scanned product, helping the person to avoid it.

P3 The participant liked the overall structure of the application. When asked about areas in which the prototype could be improved the participant mentioned the indicator icons on the product pages. According to them they could be confusing when they are first encountered and should be introduced to the player in some way. P3 estimates that this could be done in a similar fashion to the overlay that appears on the first application start. Another feature that the participant would like to see added was a hint system which the player could use in order to get information about in which products undiscovered ingredients could be found. In order for the mechanic to not be overused by the players, P3 also suggested that each use of that system should cost 100 gold coins. P3 also mentioned that the inclusion of various allergens could be important for some people.

P4 The participant liked the current state of the prototype implementation but offered some advice about certain elements that could be improved. For example they noticed that the buttons on the brewing screen would change position if a recipe needed a large number of ingredients. They also would like newly discovered ingredients to be highlighted after a scan was completed.

P5 Stated that they liked the application but that a tutorial which explains the different mechanics and elements should be added and that the wear down of the equipment items should be communicated more visibly and clearly to the players. For example, P5 mentioned that the brewing popup would be the perfect place to inform the players that certain pieces of their equipment would soon be inoperable. In addition, they would not disallow the brewing of new potions if some items were not operational but they would decrease the value of the resulting potion instead.

P1 According to the participant the application has led to a knowledge increase about these substances and their usage in regard to how many different substances with E numbers exist and what additives can be found in different kinds of products.

P2 P2 stated that the application increased their knowledge about where certain ingredients could be present for what purposes they could be used.

P3 The participant reported that the test made them more aware about how many different additives are used across different product categories, especially in sweets and snacks.

P4 Stated that they had learned a lot of new information about these additives, like what they were used for or where they could be found, during the test.

P5 The participant stated that they learned a lot of new information regarding additives during the test, largely due to the fact that they had not previously concerned themselves with the topic and therefore had little to no knowledge to begin with.

P1 The participant was particularly surprised about how many additives were present in a scanned bottle of soda and that many people, according to the OpenFoodFacts website, are likely to be oversupplied with these substances. They also stated that they expected a number of additives to be present in the provided products but that the applications made them aware about how widespread their usage actually is.

P2 P2 stated that they were surprised about how widespread the use of palm oil was among the presented products.

P3 The participant was especially surprised about how many different additives were used in a specific product. They stated that they knew that some would be present in the product but expected less of them to be there.

P4 Was surprised that some food additives were present in products in which they would not have expected them to be. The participant was also surprised about the high number of products that contained palm oil. P4 further stated, despite expecting to encounter lots of new additives, that they were still surprised about how many additives were present in some products. P4 also would also like to see usages for different potions to be added to the application.

P5 Stated that they were surprised about how widespread the use of food additives was and that some ingredients that they knew by name also had an assigned E number.

P1 They stated that it was very likely that they will concern themselves more with these substances and where they are used in the future.

P2 The participant stated that they were unsure whether they would pay more attention to these substances in the future or not but that they would try.

P3 Stated that they already pay much attention to the ingredients and additives of products that they consume regularly.

P4 Stated that they would pay more attention in the future to whether different products used palm oil or not.

P5 Stated it was very likely that they would read the ingredient listings more carefully or more regularly in the future.

P1 Stated that they are very interested in using applications that would simplify the process of gathering information about food ingredients and additives because the have been made more aware about these topics.

P2 P2 stated that they could see themselves using such an application to get information about products but only if they needed fast access to specific information that could not be easily obtained otherwise.

P3 Stated that they would be likely to pay more attention to different products if they got to play a full version of the application. P3 further stated that these types of applications would also simplify the process of gathering product related information in general.

P4 Stated that they would use such an application to keep track about the palm oil status of different products.

P5 Stated that they could imagine themselves using *Alchemist* or a similar application, especially if more actual gameplay elements like uses for the potions were added.

5.4.3 Discussion

In this section the items identified in the precious section will be interpreted and discussed. Overall observations and key points will also be discussed, if they can be used to answer the research questions. This was especially the case for items that dealt with the prototype itself or with the underlying concept.

Although three out of the five interviewees stated that they did not pay much attention to their diet overall, all of them nonetheless either tried to reduce certain substances (eg. palm oil), product categories (eg. meat), and to limit the time periods during which they ate or they tried to consume the recommended amount of macro nutrients each day. So, with the exception of the interviewee who practiced intermittent fasting, the interviewees still had to gather information about the food product that they bought or consumed in order to achieve their set goals.

Interestingly all of them got this information solely by looking at either the packaging of a product or at additional information provided by the store, like the price tag or the products point of origin. Even the participants that paid much attention to contained ingredients or nutritional data did not use any other sources of information, like for

example a nutrition tracking application, because of a lack of personal need or knowledge of such solutions. This point will later be continued during the discussion of some features that could be added to the prototype.

The interviewees ranked the importance of different product aspects similarly to the participants of the first questionnaire, with some of them attributing great importance to the brand, used ingredients and the contained nutriments while others pay more attention to a products price, its best-before date or its point of origin.

The answers in regard to the participant's stances concerning ready meals and fast food also mostly lined up with the answers provided by the questionnaire participants, with some of the interviewees acknowledging the usefulness of such products in certain situations but being critical of them otherwise, while other participants dismissed them outright.

In regard to the interviewees self-assessed knowledge about food additives an interesting observation could be made. Although all five interviewees stated that they were not particularly familiar with the E number system or had little to no knowledge about different food additives, they all thought that the declaration of additives on product packaging was insufficient in its current form. When asked about what changes they would like to see, some interviewees stated that they did not like the inconsistent use of ingredient names and E numbers across different products and that this should be fixed or that additives should be displayed separately from other ingredients. But some of the proposed additions to the system regarded functions, that are already present in the current system. One participant for example stated that they would imagine that people suffering from allergies would appreciate a way to quickly make out allergens in the ingredient list, and was in turn delighted when being told that allergens were already highlighted via the use of **bold text** since 2014. This could be an indication that certain features of the declaration system currently in place should be more clearly communicated.

Two of the five interviewees also stated that they could still piece together why certain additives were added to a product or what purpose they served based on information provided on the packaging, even though they had not encountered the substance before, while the other three participants stated that they did not feel informed about the uses of additives or about the possibilities of over provisioning or unwanted side effects at all. Another interesting observation was that due to a lack of familiarity with the substances some participants automatically equated an E number or food additives in general with artificially produced chemicals that would not occur naturally.

The underlying concept used to create *Alchemist* was received well by all of the interviewees, with some of them seeing the gaming elements as a way to provide additional motivation to the users while others saw the scanning mechanic and the inclusion of real world food products as a means to realize the game concept and the creation of awareness as a byproduct of that. Nevertheless, two of the interviewees expressed concerns about the ability of the application to reach its target audience. While one interviewee stated that in their opinion people who were not interested in the topic at all would probably

hardly install and use such an application, another participant voiced similar concerns but also provided a possible solution. In their opinion *Alchemist* would be a well suited tool to teach children about nutrition in a school setting where they would be instructed to use the application by their teachers. The fact that the individual interviewees perceived different aspects of the application as its main intent can be seen as an indication that in the prototype the two main parts of *Alchemist*, the game elements as well as the elements that aim to transfer information or create awareness, were neither over- or underdeveloped and were balanced in a way that enhanced the overall perception of the application.

The prototype itself was similarly well received by the interviewees with all of them also providing valuable feedback in terms of improvement and pointers for the future development of the application. Some constructive criticism was voiced in terms of how and where certain features, like for example the scanning mechanic, could be accessed or how the way in which certain mechanics and app features, like the ingredient meta information icons or the option to visit products or additives on the OpenFoodFacts website, could be improved. A tutorial that guides the user through the application and that introduces all relevant elements on the first start of the application would surely be a sensible improvement. Other mentioned practical improvements involved granting the players the ability to quickly see which potions they could brew with their ingredients without them having to look at different recipes or the addition of an informative text that would appear after a brewing process if some of the equipment would soon be inoperable or the addition of highlighting for newly discovered ingredients.

One participant also mentioned a hint system that would allow the players to gather information about undiscovered ingredients in exchange for gold coins. And two of the interviewees also would like to see actual uses for the potions added into the game instead of them just being a means to acquire coins like they are in the current version.

All of these suggestions would certainly be able to improve the usability and the overall appeal of the application but some of the features that the participants described or would like to see added to the game already exist in popular other food or nutrition centered applications.

These features for example include the ability to track allergens across products or to flag certain ingredients so that the user receives a warning as soon as they scan a product which contains those unwanted substances. Another mechanic would involve the ability to directly compare two products in terms of their ingredients or nutritional data or the ability to receive information about healthier alternatives to scanned products or the ability to receive information about the ingredient packaging like for example if plastic is being used for the packaging.

While the existence of these features in other applications would by itself not be enough reason to not include them into *Alchemist* they would also transform the application from its intended format of a pervasive game into something more resembling a nutrition tracking application. Therefore, these features would not be very sensible additions to

the game in its currently intended form, with its main purpose being the creation of awareness.

But an interesting observation can be derived from these suggestions nonetheless. Like the interviewees alluded to during the conversations, they suggested these features primarily because they resembled something that they themselves would like to use and that would aid them in their day-to-day lives. These claims can also be supported by the fact that some interviewees explicitly mentioned, in later sections of the interviews, that they would be interested in using such an application if these features were included, which made their existence in other applications more relevant. The abilities to gather additional information about product packaging, to directly compare two products in a side-by-side view or to receive warnings about allergens can, for example, all be found in the OpenFoodFacts mobile application, which was also provided as part of the usability test.

So, a number of applications that would fulfill the needs or the demands of the participants exist which they were either unaware of, or which they have heard about but did not think that these applications would also provide a feature that they wanted to see implemented in *Alchemist*.

In terms of answering the research questions, all interviewees reported that the usage of the application as part of the usability tests has either increased their knowledge about food additives, or has made them more aware about additives, nutriments or a similar issue, like the widespread use of palm oil, or both. A caveat to this result is however, that all participants started the test with relatively low self-reported knowledge levels about most of the researched topics. Therefore most of the additives and information that they encountered about them during the test was new to them. Consequently, it remains unsure if a comparable effect can also be observed if the application is tested by participants with moderate to high knowledge levels in these areas, but then again, these user groups would probably already possess some awareness about these topics and therefore would not be part of the core target group of such a pervasive game.

CHAPTER 6

Discussion

This chapter reflects on the work described in this thesis. Important points and aspects are picked from the development process to highlight relevant factors and outcomes. While the presented positive aspects may be helpful for other researchers, the highlighted weak spots of the process may draw attention to potential improvements and may also suggest future work. Furthermore, the thesis is reflected upon as a whole, possibly raising additional remarks, which were not brought up before.

The work on this thesis began when the game concept described in section 4.1 was presented to the researcher as a possible thesis project. Since no other documents or information, aside from the resulting concept, could be provided it was decided that for the thesis project methods should be used which are typically associated with user centered design approaches, like design games, usability testing or interviews. But because the concept that acted as the starting point for the project resembled an idea that was typically found at the end of the ideation phase of an UCD process, the incorporated approach was adapted and shortened. So, as a first design step the insights gained from the literature review of related work in the fields of serious and pervasive gaming were used to create a design game based upon the initial concept. This design game was used to test various assumptions about what kinds of game mechanics or features could be present in the resulting application. These assumptions for example included whether a possible multiplayer component should be designed cooperatively or competitively, the way that the brewing system should function, or whether already collected ingredients should be perishable or not.

These assumptions were tested in a number of game sessions with a total of nine participants. During these sessions different rule sets were used in order to be able to test different assumptions independently of each other or in different combinations. Some of the assumptions could be verified while other assumptions turned out to be false. As a result of the game testing certain elements, like perishable ingredients or ingredients that would need to be further processed before they could be used for brewing purposes,

were omitted from the prototype. Other mechanics, like for example the removal of fixed potion recipes in favor of potions whose effects are based on the used ingredients, were received favorably by the game testers but due to certain limitations it was not possible to implement them in the game.

Alongside the literature review and the creation and the testing of the design game, different providers of nutritional databases were contacted about a possible cooperation for the duration of the project. As was already described in section 4.1.2, in the end *OpenFoodFacts* was chosen as the information provider, but this decision also required additional work in the form of an additional server component, to be feasible. Initially this server component was only intended to convert the ingredient information received from *OpenFoodFacts* upon a successful product scan into a format that could be used by the application. But it later also proved to be useful because it allowed to transmit other data, like for example additional potion recipes or achievement information and requirements, to the prototype without the need to update the application itself.

Since a big portion of the development time that was allocated to the server component would need to be used for the creation of the matching table for the different ingredients, an alternative in the form of an algorithm that could perform an automatic matching of the ingredients based on a set of target ingredients was also considered. In the end it was decided that the manual creation of the required matching table was the more sensible approach, since the effort and time needed to create and test this algorithm would far outweigh its usefulness for this limited use case and, under certain circumstances, could even require more time than the manual approach.

After the intended ingredients were added to the server the next task was to use them to create the different potion recipes. Even though with this limited set of forty ingredients effect-based potions could have still been implemented, the system would need far more ingredients in order for the intended effect of having the player discover the various ingredient effects for themselves by combining them in different ways to work. Instead, the decision to include fixed recipes was used to evaluate how the players would react to the different kinds of potions. The decision which ingredients should be included in which recipes also turned out to be rather complex since it could be assumed that some participants would connect the effect of the resulting potion with the effects of the individual ingredients. A possible example for this was provided with the *Rat Poison* in section 4.3.2. Interestingly, in the usability tests of the second and third prototype iterations the topics of the potion names, their effects, or the required ingredients were never brought up by the participants. Although one participant thought that the description text of the *Potion of Braveness* referred to an actual game mechanic, they did not question the effect of the potion itself which consists of a blend of *Aspartam*, *Palm Oil*, *Sunflower Oil* and *Wheat*. Another issue that resulted from the decision to omit effect-based potions was that that the different recipes needed to be balanced in terms of how hard it should be to brew them and how much coins each potion should be worth. The balancing of the different recipes turned out to be a time-intensive task since the ingredients and the worth of each recipe were tweaked multiple times before they

were added to the server component. But, as was discovered during the evaluation of the second prototype iteration, one vital aspect was not considered during the balancing phase, namely that simply because an ingredient appears in a multitude of different products throughout the database does not mean that those ingredients are also easy to find for the players. Based on the experiences of some participants of the first usability test, they were unable to brew most of the potions because they could not find some of the required ingredients. In retrospect, these problems could have been avoided if the effect-based approach would have been used, since there would have been no reliance on specific ingredients.

After the server component was deployed and after the data that was gathered through the design game was evaluated, the development of the actual prototype of the application began. As was described in section 4.4.1, a technical proof of concept was created as a first development step instead of less time-intensive artifacts like wireframes or a mockup. Although these methods would have allowed for quicker turnaround times in regard to how fast different design approaches (e.g. placement of menu items or included information) could be created and evaluated, the goal of the first iteration was to verify that the intended technical infrastructure was suited for the task at hand, which was not doable with wireframes and mockups alone. For example, several inconsistencies and incorrect queries in the underlying relational database that was used to store data about the products, the potions and the identified ingredients were found as a direct result of experimentation within the first iteration. These errors would have been much more expensive to fix, in regard to how much work would have been required to do so, had they been discovered in the second iteration instead of the first. Although the first iteration was never feature complete as some elements like the different equipment items were not included, by choosing this approach in combination with the decision to evaluate the first version internally other elements like the database schema or the scanning mechanic had already been thoroughly tested and were improved by the time the development of the second iteration began.

Because the first iteration was developed as an Android-only application and the final prototype should be able to support both Android and iOS devices, the second iteration of the prototype needed to be developed from scratch. As was already described at the beginning of section 4.4.2, the Flutter framework was used to achieve the multi platform functionality. The decision to use Flutter instead of a more established solution like Xamarin or Unity was made because in doing so this relatively new framework could be explored as part of this thesis project. The decision turned out to be right, as the framework allowed for quick and easy development phases while also supporting quick interface experiments akin to mockups due to the declarative nature of the framework. Although the framework is still incomplete and currently lacks some functionalities like the ability to run services while the application is closed or a lack of support for home screen widgets, that could make it unsuited for different software projects, it proved to be a great fit for *Alchemist*.

The second iteration not only delivered a redesign of the different UI elements, which

were not a focus of the first one, but also improved upon various uncovered shortcomings of the first prototype like the ability to switch recipes without losing the already collected ingredients or the inclusion of the different equipment items. The resulting application was then published as a closed beta to both Apple *Testflight* and the Google *Play Store* in order to be able to perform the intended form of the usability test described in section 5.2. On Android devices the application could also be downloaded as a standalone apk-file which did not require the participants to sign up for the beta using the mail address associated with their Google account. In turn, every participant who participated in the usability test using an Android device made use of this option.

The two questionnaires that were also distributed in this phase of the study, one as a means to capture overall data while the other one was designed to be used to evaluate *Alchemist*, collected sufficient data, although the high dropout rate of participants could be seen as a shortcoming. While a total of ten people signed up for the usability test, only five submitted the evaluation questionnaire. While two out of the five people who dropped out later agreed to also participate in the second usability test, the other three people did not respond to any contact attempts and therefore their reasons for abandoning the study could not be uncovered. While it could be possible that they shared some reasons with the other two participants (e.g. insufficient detection rate of products and ingredients) it could also be possible that they did not start the test to begin with. This problem would not have been as severe if more people had decided to take part in the usability test. But although the study and the accompanying questionnaire was advertised in multiple different channels, only thirty-eight people submitted the first questionnaire which was the requirement to be eligible to take part in the study.

The insights gained from the evaluation of the submitted questionnaires was then used to develop a final prototype iteration. This version added new features like the achievement system or the ability to view additional information about products and ingredients. The second usability test which involved five participants also made use of the *Thinking Aloud* method as a means to gather data. Together with the created screen recordings and the following interviews the usability tests were able to provide many new insights and also uncovered possible design inconsistencies or elements which could be confusing to the users. And although the results from the two usability tests mostly matched one another some interesting differences still exist. The current state of ingredient declaration for example was seen as sufficient by 31 participants(81,6%) (see figure 5.5) in the questionnaire, while all five of the participants of the second usability test found it to be insufficient. While all five participants stated to have little to no knowledge about the current declaration system twelve participants(31,6%) of the first questionnaire (see 5.6) stated the same. Therefore, the self-assessed knowledge of the declaration system can not be the only deciding factor for this decision, if it is a factor at all. A study that intends to uncover these factors could be an interesting topic for further work.

The two usability tests also resulted in a number of feature requests that could be used to increase the overall usefulness of the application. But while some of the suggestions fit in well with the theme or goal of the application (e.g. indicators for brewable potions)

other suggestions, like the ability to see information about the used packaging, would possibly require further user tests since those features would steer the potential use cases for the application in a different direction. Overall, the decision to conduct two usability tests utilizing different methods of data gathering resulted in a large amount of quantitative and qualitative data that largely matched one another in terms of the effect of the application usage.

The main aspect of the thesis was whether a pervasive game could create awareness about the topic of food additives and whether this newly created awareness could influence the customers buying behavior while shopping for groceries. The two research questions have already been discussed to some extent in the discussion sections of the respective methods, namely in section 5.2.3, section 5.3.3 or 5.4.3. The evaluation of the data suggests that the resulting prototype of the *Alchemist* game was in fact capable of creating awareness about food additives, as intended. The main indicators for this being that four out of five participants of the usability test conducted with the second prototype iteration reported that the usage of the application has led to an increase of their knowledge about additives and after the conclusion of the second usability test all five participants stated that the application had increased their knowledge and made them more aware about additives in general.

In terms of whether this awareness also leads to a change in the users buying behaviors the question can not be answered conclusively. During the interviews conducted after the second usability test, one interviewee stated that they already paid much attention to the ingredients and additives of the products that they consume. And although the remaining four interviewees stated that they would try to be aware of the ingredients of the products that they intend to buy, these statements were made shortly after they had participated in the usability test. To confirm whether an actual change could be observed observations and further interviews would need to be conducted over longer time periods which would exceed the scope of this work. So, although the gathered data seems to suggest that the second question can also be answered positively, the actual confirmation needs to be subject of future work.

The alchemist setting proved to be an effective metaphor for this type of game because the need to actively look out for specific ingredients gave the players a logical reason to interact with various food items in a way that they might not have done otherwise, like for example by reading the ingredient listings. Although the development of the prototype focused largely on the underlying technical infrastructure (e.g. the core brewing mechanic) and the provided information, instead of elements more commonly associated with mobile games like game graphics or sound, the prototype was still suited to achieve the intended goal. It therefore stands to reason that future versions of the application that expand the scope of the game or similar applications that make use of the same concept, would be equally effective, if not more effective, in achieving their intended effect. This work may inspire other researchers to conduct further research in this area or specific portions of it.

CHAPTER 7

Conclusion

7.1 Summary

This thesis addressed the question if a pervasive game can be used to create awareness about the topic of food ingredients and food additives in particular. It showed in detail how the described methods were used and how their results directly influenced the development of a prototypical game over the course of three design iterations. In terms of methodology, the applied adapted version of a user-centered design approach was found to be appropriate for the iterative development of the prototype of such a pervasive game. Although the provided game concept could have easily been implemented without user involvement and then be evaluated once with outside users at the end of the project, the applied methods helped to understand the users expectations of such an application and in turn shaped the application itself. The resulting prototype was evaluated iteratively with a number of users, which enabled various adjustments to be made in the next iteration based on the gathered user feedback. The literature review that spanned multiple disciplines ranging from pervasive and serious game projects, to the different kinds of food additives currently used in the European Union, all the way to the microbiome of the human digestive tract not only acted as the starting point for the exploration of the topic, it also served as a way to identify design requirements for the resulting prototype.

Some ideas of the initial concept and of the adapted concept that was created in the initial brainstorming sessions proved to be infeasible or out of scope for the project and had to be removed from the prototype. Especially the creation of the design game proved to by quite valuable because during the game sessions multiple aspects and mechanics of the intended game could be explored and evaluated in quick succession.

Although there exists great potential for improvements in various areas of the application, the users were mostly pleased with the state of the application as it was presented during the usability tests. Furthermore, the application might stimulate the interest of the user

to gather more information about a product and in turn act as a potential entry point into the field of eHealth and nutrition tracking applications.

7.2 Limitations and Future Work

A major limitation of the project in its current state was already discussed in section 4.1.2. The lack of universal ingredient tags across the database resulted in each ingredient that should be present in the application having to be added manually to a matching table. For some ingredients more than eighty individual entries needed to be created in order for the recognition of the ingredient to work as intended. This restriction also made the effect-based brewing system infeasible as it would have required a much larger number of ingredients to work. Therefore, it needed to be replaced with fixed potion recipes in the prototypes which resulted in some users being unable to brew most of the potions since the recipes needed specific ingredients, instead of generic ingredient effects. After the prototype had been implemented *OpenFoodFacts* announced that the project had implemented global ingredient tags, which means that, for example, hundreds of different salt variations across multiple languages are now tagged internally as "*en:salt*". Future work could therefore implement a brewing system as intended without the need to rely on a costly matching table. Other aspects of the concept that were omitted from the prototype like the adept system or the barter system that would involve alchemist haggling with potential buyers about the prices of different potions, could also be subject of future work in this area.

A possible shortcoming of the study could also be that all of the participants of the second usability test started the test with little to no knowledge about food additives which means that the results of the test could be biased towards that group. Finally, it was not possible to conclusively answer the second research question, as the required study design would have exceeded the scope of the project. Although the second iteration of the prototype was tested over a longer time period by some study participants, far more data is needed for this question to be answered conclusively. Here, future work in this area is needed in order to investigate whether usage of the application over longer time periods leads to changes in the players' buying behavior.

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Appendix A

Figure A1: API Call that returns a list of all ingredients that can be used in potion recipes.

get **/ma_ingredients/getbyOFFIngredient/tags/**

Get a list of ingredients based on the tags of OpenFoodFacts ingredients.

Body application/json

```
[
    {
        "tag": "en:Nonfat milk",
    },
    {
        "tag": "de:pasteurisierte _Milch_",
    },
    {
        "tag": "en:aspartam",
    },
]
```

Response application/json

200 ok

```
[
    {
        "id": 2,
        "name" : "Milk",
        "translations" : [...]
    },
    {
        "id": 6,
        "name" : "E951 - Aspartam",
        "translations" : [...]
    },

]
```

Figure A2: API Call that returns a list of ingredients that can be interpreted by the application.

get **/ma_ingredients/getbyOFFIngredient/id/{id}**

Get a specific ingredient via the id of a matching ingredient.

Parameter

id id of the ingredient

Response application/json

200 ok

```
{
        "id": 2,
        "name" : "Milk",
        "translations" : [...]
    }
```

Figure A3: API Call that returns a specific ingredient based on its internal id.

get **/ma_ingredients/getbyOFFIngredient/tag/{tag}**

Get a specific ingredient via the tag of a matching ingredient.

Parameter

tag tag of the ingredient

Response application/json

200 ok

```
{
        "id": 2,
        "name" : "Milk",
        "translations" : [...]
    }
```

Figure A4: API Call that returns a specific ingredient based on the tag provided by OpenFoodFacts.

get **/potion/all/**

Get a list of all potions.

Response application/json

200 ok

```
[
    {
        "id": 1,
        "name" : "Health Potion",
        "description: "A potion that restores health",
        "baseValue": 100
        "level": 2,
        "ingredients" : [...]
        "translations" : [...]
    },
    {
        "id": 2,
        "name" : "Garlic Juice",
        "description: "Some garlic dissolved in water",
        "baseValue': 50
        "level": 1,
        "ingredients" : [...]
        "translations" : [...]
    },
    ...
]
```

Figure A5: API Call that returns a list of all potions

get **/potion/{id}**

Get a specific potion via the id.

Parameter

id id of the potion

Response application/json

200 ok

```
{
"id": 1,
    "name" : "Health Potion",
    "description: "A potion that restores health",
    "baseValue": 100
    "level": 2,
    "ingredients" : [...]
    "translations" : [...]
}
```

Figure A6: API Call that returns a specific potion via its id.

Appendix B

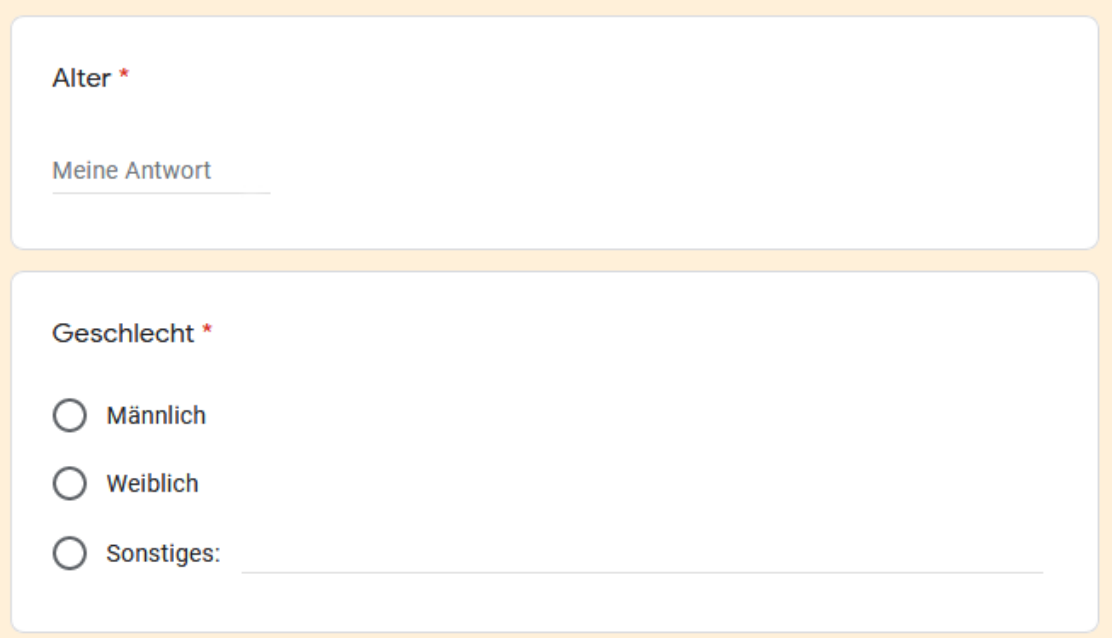

Figure B1: Through the first two questions participants are asked to share some personal information.

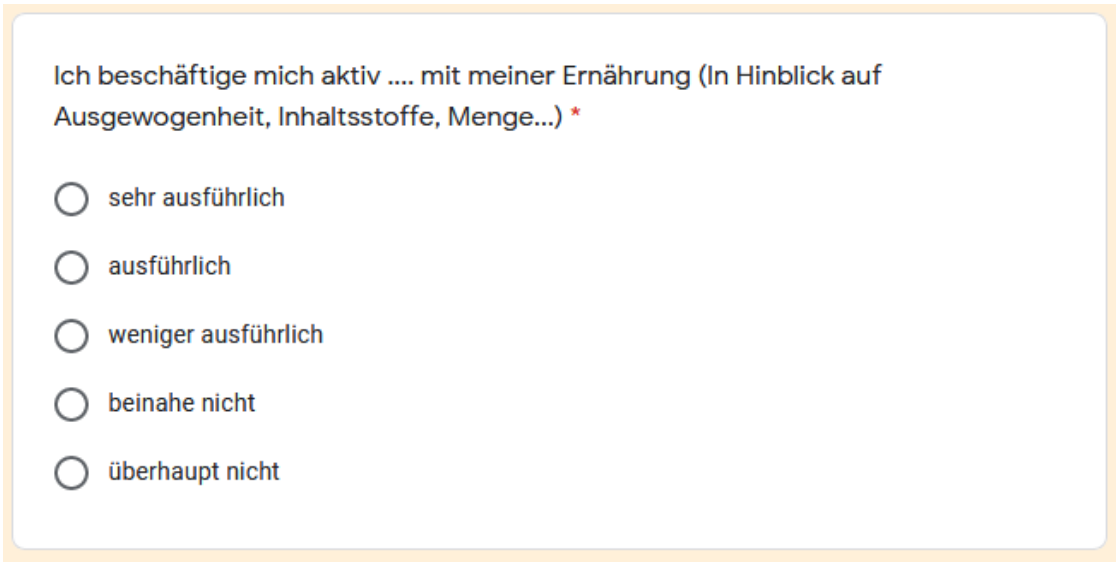

Figure B2: This question tasks the participants to self-evaluate their nutritional habits.

Figure B3: This question allows the participants to rate the importance that different aspects of food products have to them.

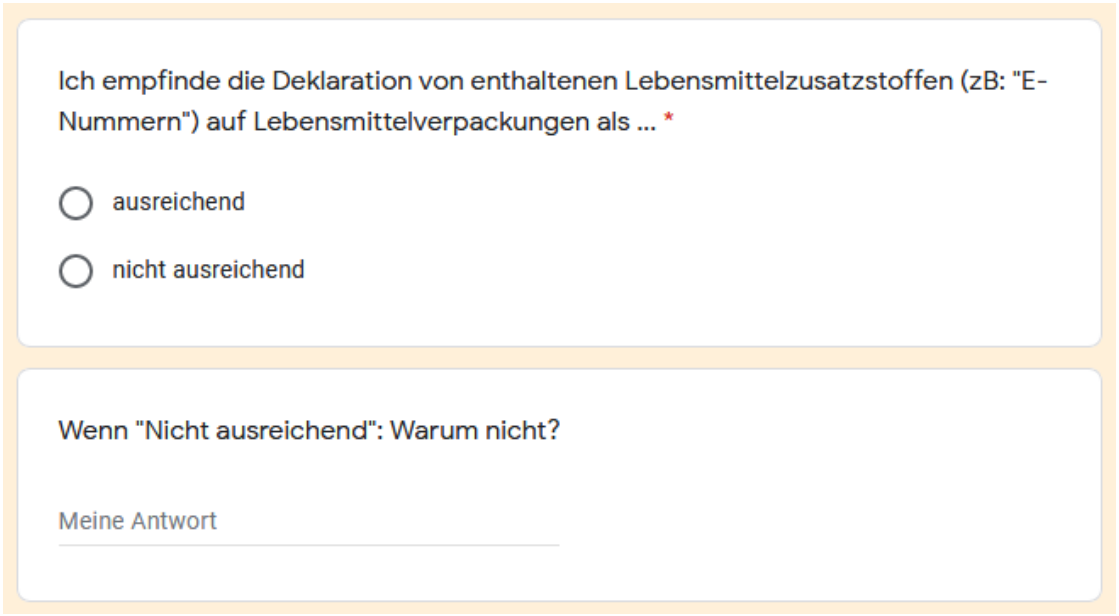

Figure B4: This question aims to gather information about how the participants would describe the effectiveness of the current declaration system.

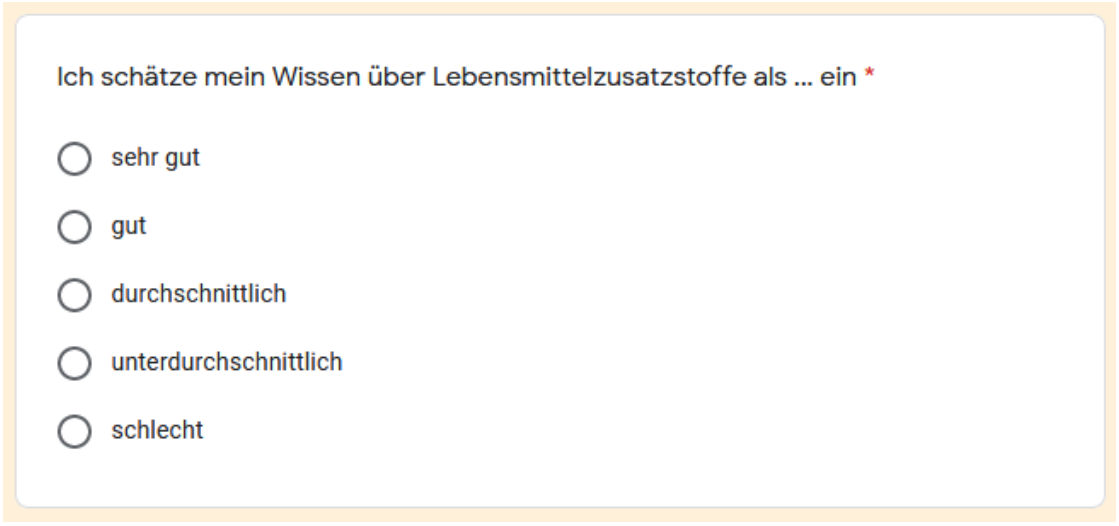

Figure B5: This question requires the participants to self-assess their knowledge about food additives in particular.

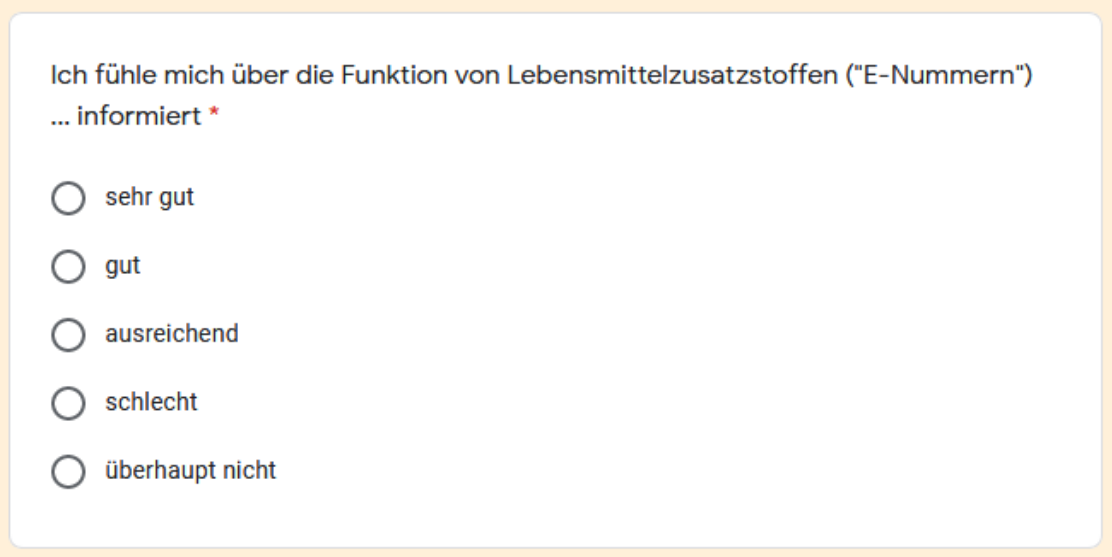

Figure B6: Another aspect of the declaration system is how well the participants feel informed by it.

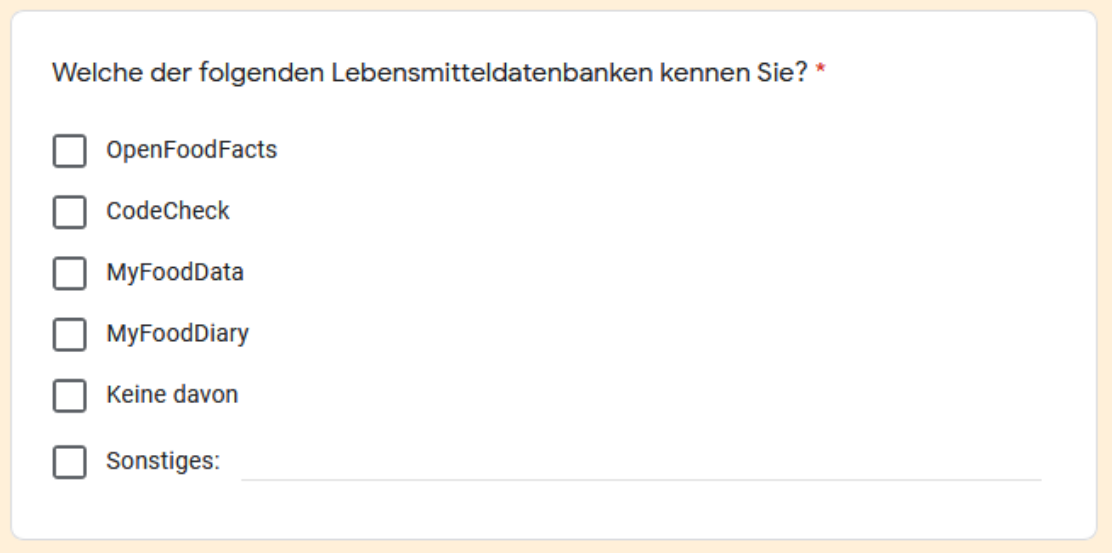

Figure B7: Question 9 aims to determine how widespread the use or the knowledge about nutritional databases is.

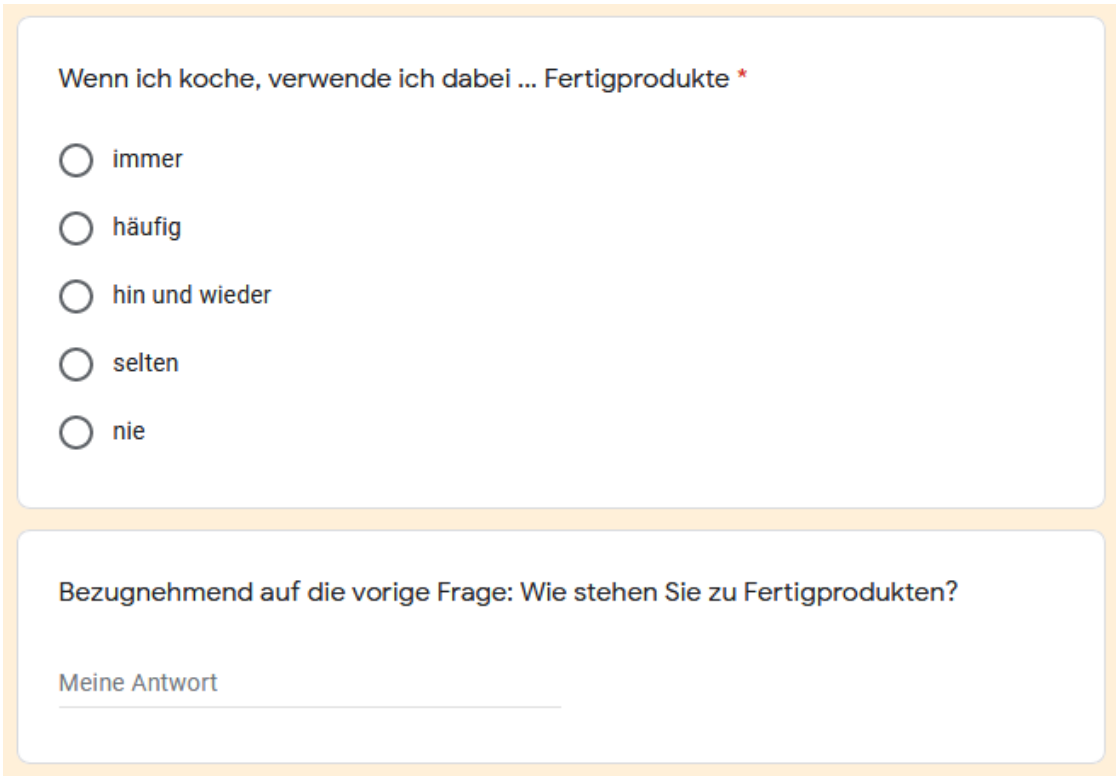

Figure B8: The final questions deal with how often and extensive the participants use convenience foods in their diet.

Appendix C

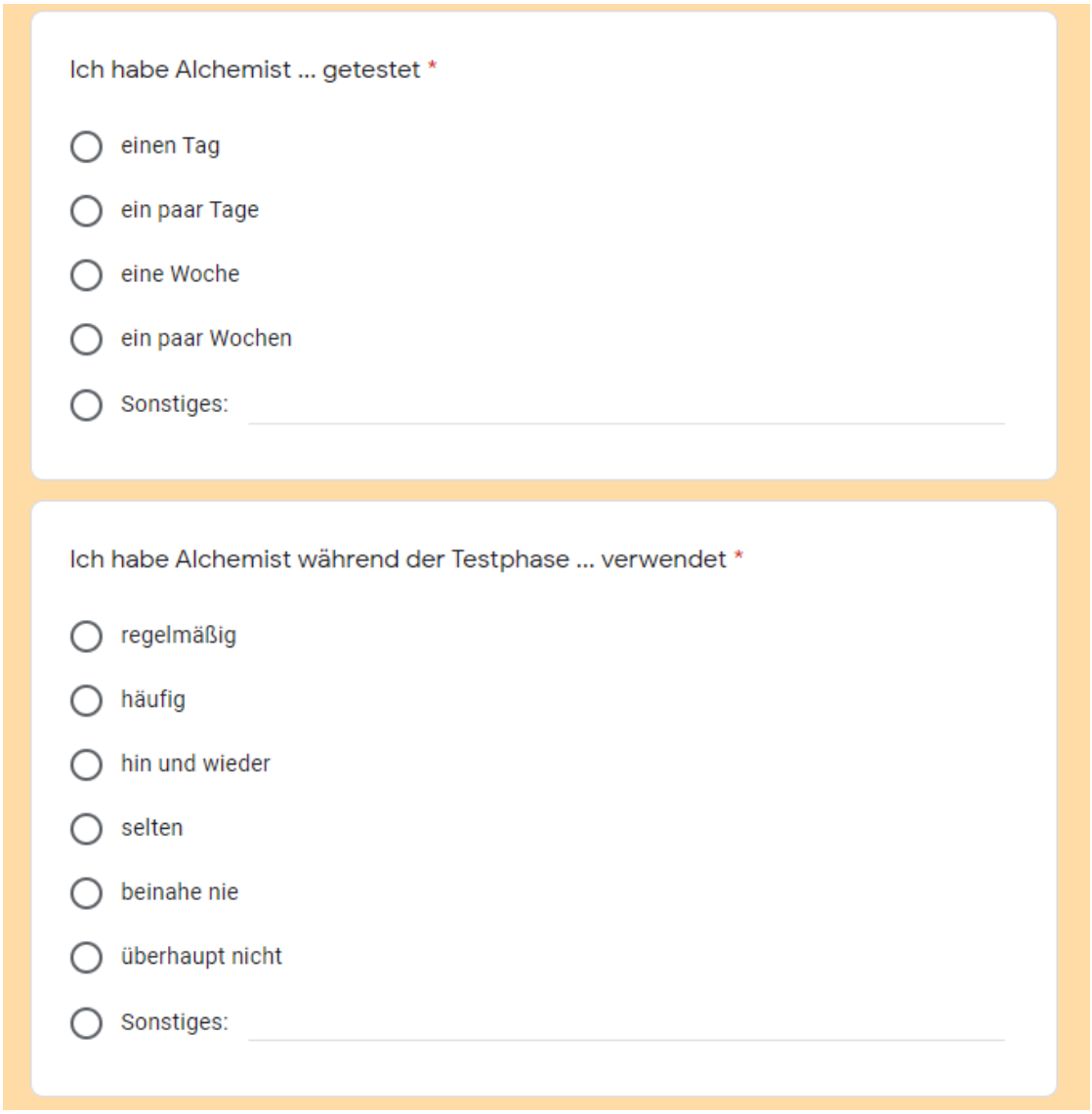

Figure C1: Questions 1 and 2 apply to the duration and the frequency of the app usage.

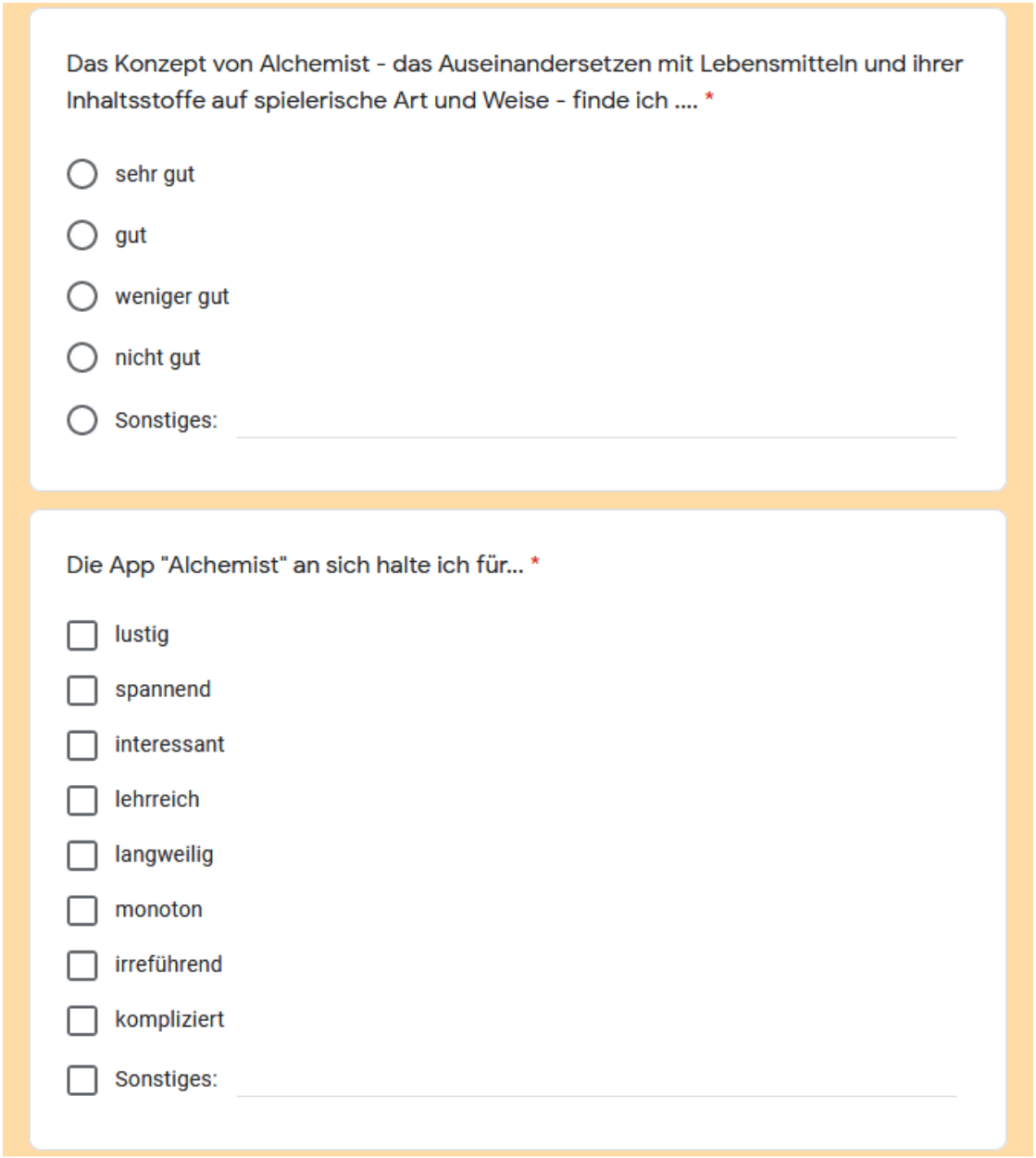

Figure C2: Questions 3 and 4 deal with how the underlying concept of the application is perceived and the participant's opinions about the app itself.

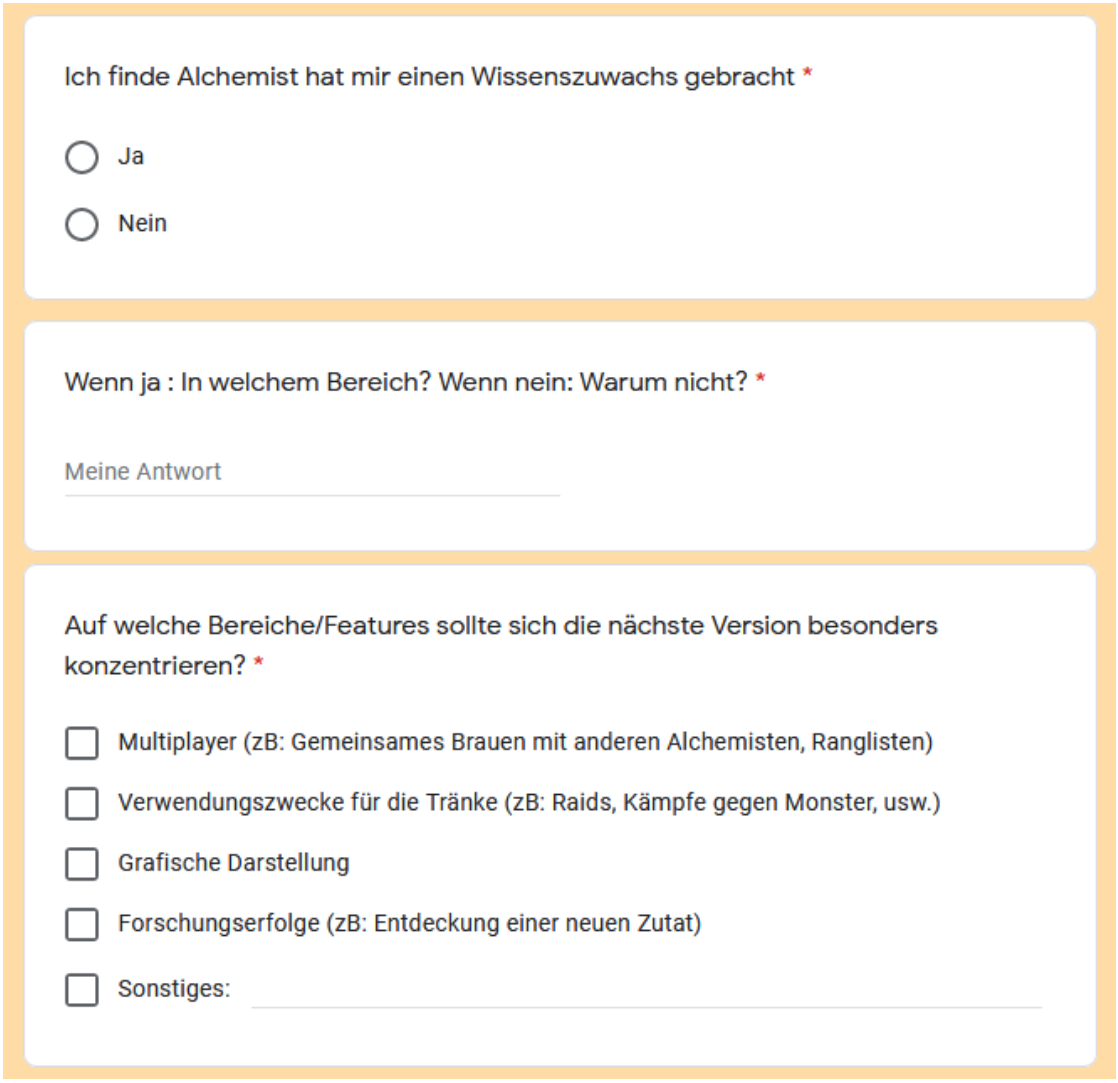

Figure C3: The final questions regard the effects of the application and participant's wishes concerning the further development.

Figure C4: Most of the questions also had room for optional remarks. In addition, the participants were able to mention anything that has not come up before.

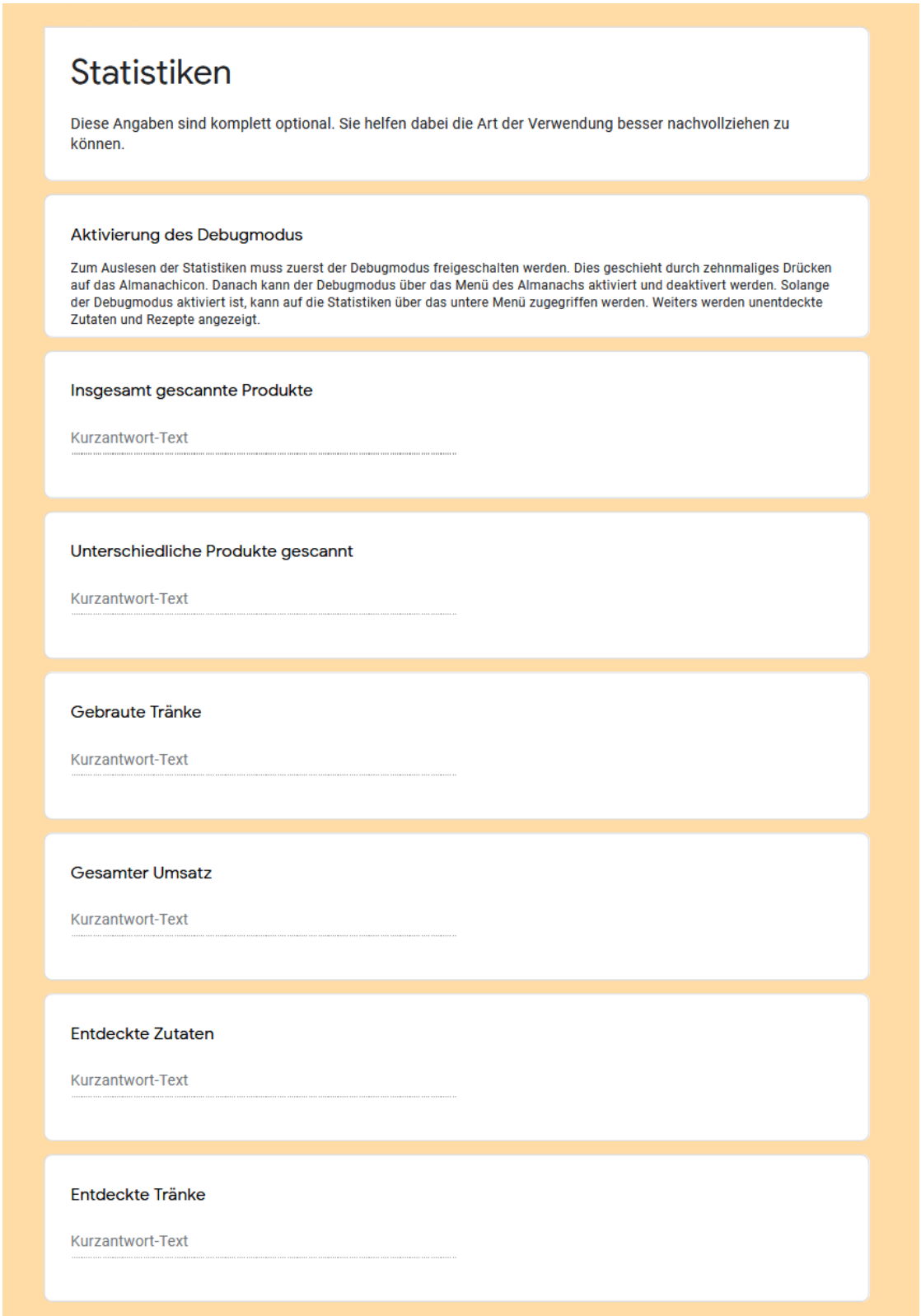

Figure C5: The participants could also choose to share some of their usage statistics.

Appendix D

Einwilligungserklärung zur Erhebung und Verarbeitung personenbezogener Daten im Zuge eines User Tests

Interviewer: Maximilian Ulreich, maximilian.ulreich@tuwien.ac.at

Dieser User Test wird im Rahmen des Masterstudiums Media and Human-Centered Computing an der Technischen Universität Wien durchgeführt.

Der User Test dient der Evaluation der aktuellen Version des Prototypen der Applikation „Alchemist“. Qualitatives Feedback soll eingeholt werden, um die Evaluierung der Applikation zu ermöglichen und um die Erkenntnisse schließlich schriftlich in der Diplomarbeit festzuhalten.
Die Teilnahme an diesem Test der Applikation ist freiwillig und kann auf Wunsch jederzeit abgebrochen werden. Die Daten werden nach Fertigstellung der Arbeit gelöscht.
Die Daten werden anonymisiert verarbeitet und lassen keinen Rückschluss auf die teilnehmende Person zu.

Die Daten werden nur für die Verarbeitung im Zuge der Diplomarbeit in folgender Form verwendet:

1. Das Festhalten handschriftlicher Notizen.
2. Die Aufzeichnung des User Tests auf Tonträger.
3. Etwaige Transkription und Zitation der Tonaufnahme.
4. Optional: Das temporäre Speichern eines Videos der Interaktion mit der Applikation durch einen ScreenRecorder.

Optional:

☐ Ich bin damit einverstanden, dass meine unmittelbare Interaktion mit der Applikation durch einen ScreenRecorder festgehalten wird. Dabei wird lediglich der Bildschirm des Gerätes aufgenommen.

Ich,_____, habe obigen Text verstanden und erkläre mich damit einverstanden.

Datum:

Unterschrift (Teilnehmer/in):

Unterschrift (Interviewer):

Appendix E

Einwilligungserklärung zur Erhebung und Verarbeitung personenbezogener Interviewdaten

Interviewer: Maximilian Ulreich, maximilian.ulreich@tuwien.ac.at

Dieses Interview wird im Rahmen einer Diplomarbeit im Zuge des Masterstudiums Media and Human-Centered Computing an der Technischen Universität Wien durchgeführt.

Die aus dem Interview gewonnenen Informationen sollen die Evaluierung eines Prototyps einer Applikation, deren Ziel es ist, Bewusstsein über diverse Lebensmittelzusatzstoffe zu bilden, unterstützen.

Die Teilnahme an diesem Interview ist freiwillig und kann auf Wunsch jederzeit abgebrochen werden. Die Daten werden nach Fertigstellung der Arbeit gelöscht.

Die Daten werden anonymisiert verarbeitet und lassen keinen Rückschluss auf die Person zu.

Die Daten werden nur für die Verarbeitung im Zuge der Diplomarbeit in folgender Form verwendet:

1. Das Festhalten handschriftlicher Notizen.
2. Die Aufzeichnung des Interviews auf Tonträger.
3. Etwaige (partielle) Transkription und Zitation der Tonaufnahme.

Ich,_____, habe obigen Text verstanden und erkläre mich damit einverstanden.

Datum:

Unterschrift (Befragte/r):

_____

Unterschrift (Interviewer):

_____

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Appendix F

Interviewleitfaden – Alchemist

Präinterview:

- ☐ Sich für die Teilnahme am Interview bedanken
- ☐ Mich vorstellen und persönliche Motivation erklären
- ☐ Intention hinter Alchemist erklären (Bewusstseinsbildung, …)
- ☐ Einverständniserklärung besprechen und unterzeichnen lassen

I) Fragen bezogen auf die persönliche Ernährung

- ☐ Wie ausführlich beschäftigen Sie sich mit Ihrer Ernährung?
  - ○ Wie äußert sich das? (Menge, Inhaltsstoffe, Verzicht auf bestimmte Dinge…)
  - ○ Bestimmte Ernährungsformen? (zB Vegetarier, Frutarier,..)
  - ○ Hat sich dies im Laufe der Zeit verändert?
- ☐ Auf welche Aspekte achten Sie beim Lebensmittelkauf?
  - ○ Marke, Verpackung, Mindesthaltbarkeit, Preis, Herkunftsort, Inhaltsstoffe, Nährwertangaben, Zusatzinformationen
  - ○ Wie wichtig sind Ihnen diese Aspekte jeweils und warum?
    - ▪ Einfluss auf das Kaufverhalten
  - ○ Wie informieren Sie sich über diese Aspekte?
    - ▪ Nur Produkt(-verpackung) oder weitere Quellen?
    - ▪ Wenn ja: Welche?
    - ▪ Applikationen zB:MyFitnessPal), Lebensmitteldatenbanken, Onlineforen, Produkttests,…
- ☐ (Wie regelmäßig) verwenden Sie Fertigprodukte beim Kochen?
  - ○ Warum? Bzw. Warum nicht?
  - ○ In welcher Funktion? Ergänzend oder als einziges Gericht?
- ☐ Was ist ihre Meinung zu Fertigprodukten?
- ☐ Was ist ihre Meinung zu Fast Food / Junk Food?

II) Fragen bezogen auf Lebensmittelzusatzstoffe / E-Nummern

- ☐ Setzen Sie sich auch mit den aufgelisteten Zusatzstoffen auseinander?
- ☐ Wie schätzen Sie Ihr Wissen über diese Stoffe ein?
  - ○ Wie/Wo haben Sie sich dieses Wissen angeeignet?
- ☐ Sind diese Stoffe für Ihrer Meinung nach ausreichend deklariert?
  - ○ Im Bezug auf Nutzen/Herkunft/Mögliche Nebenwirkungen?
- ☐ Fühlen Sie sich über die Funktionen von solchen Stoffen ausreichend informiert?
- ☐ Fühlen Sie sich über mögliche Nebeneffekte ausreichend informiert?

III) Fragen bezogen auf Alchemist

- ☐ Welchen Eindruck macht das Konzept von Alchemist auf Sie?
  - ○ Sinnvoll, Überflüssig, …
- ☐ Wie ist Ihr Eindruck vom umgesetzten Prototypen?
- ☐ In welchen Bereichen gibt es Verbesserungsbedarf?
- ☐ Hat das Programm Ihnen einen Wissenszuwachs gebracht?
  - ○ In welchem Bereich?
  - ○ Wodurch?
- ☐ Gibt es etwas, dass für Sie überraschend war?
- ☐ Sind sie sich dieser Stoffe jetzt mehr bewusst als vor dem Test?
- ☐ Glauben Sie, dass Sie sich in Zukunft mehr mit diesem Bereich auseinandersetzen werden?
- ☐ Würden Sie eine solche App verwenden, um Informationen über Produkte und ihre Inhaltsstoffe zu erlangen?
  - ○ Warum? Bzw. Warum nicht?
- ☐ Welche Funktionen würden Sie gerne noch hinzugefügt sehen?

Postinterview:

- ☐ Sich nochmals für die Teilnahme am Test und am Interview bedanken
- ☐ Fragen, ob Person an Projektergebnissen interessiert ist.