Food Waste Reduction System

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Submitted by: Thomas Wooliston

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Declaration

This dissertation is submitted to the University of Bath in accordance with the requirements of the degree of Bachelor of Science in the Department of Computer Science. No portion of the work in this dissertation has been submitted in support of an application for any other degree or qualification of this or any other university or institution of learning. Except where specifically acknowledged, it is the work of the author.

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Abstract

This project aims to tackle the amount of food waste produced at the consumer level, for the purpose of this project will be students. By using an application and persuasive technology into such an application. The application will have, as a goal, to advertise and redistribute unwanted food products from consumers to students. This paper will walk through the process of creating a potential solution that will aim to help students receive free food. Hopefully, impacting sustainable behaviour, at the individual's level, for the benefit of the planet.

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Chapter 1

Introduction

This project will take a look at food waste, how it is relevant in the big picture and how it could be tackled and reduced. Therefore, this paper needs to establish the strain food waste has on the planet and how the waste occurs. Finally, to be put into context, pollution and sustainability must be linked, to food waste, in order to show the effects that food waste has in the big picture.

This will include sustainability, pollution and that of food waste as well as how food is wasted and how it could be prevented.

1.1 Definition

1.1.1 Sustainability

Sustainability has become an increasingly important topic of discussion, with the rise of popular global environmental movements such as Extinction Rebellion (*BBC News*, 2020*a*) and personalities of the likes of Greta Thunberg becoming viral (*BBC News*, 2020*b*). Sustainability is defined as the "quality of being able to continue over a period of time" (*Cambridge English Dictionary*, 2019). This dissertation will be focusing on the side of sustainability which involves causing no or only minor damage to the environment and therefore, not negatively affecting its longevity (*Cambridge English Dictionary*, 2019). In our instance, to live on our planet in such a way that it does not hinder its expectancy. As the sun reaches higher temperatures, on its way to becoming a Red Giant, all the planet's oceans will evaporate (Heinberg, 2010) and it's assumed that the Earth cannot exist eternally. However, ignoring the effects of global warming, the planet will not be affected by these changes for an estimate of around 1 billion years (Schröder and Connon Smith, 2008). Therefore, for the purpose of this project, a sustainable future would meet the requirements of the current generation while not impeding on the future generations potential goals (Brundtland Commission, 1987). The sustainable future is maintained by the population having a reduced ecological footprint.

The idea of an "ecological footprint" emerged in the 1990s from Canadian ecologist William Rees and Mathis Wackernagel (Heinberg, 2010). This concept was established to determine the resources needed in comparison to the resources available on our planet as well as to absorb the waste produced (Heinberg, 2010). The concept takes into account 4 factors:

1. the resources extracted from the planet (e.g. fossil fuels)
2. the substances returned to the planet from the effects of taking and using those resources (e.g. antibiotics)
3. physical degradation of our planet (e.g. deforestation)
4. people cannot be restrained by the knock-on effects that the three previous factors have on the planet in order to meet their needs (Heinberg, 2010)

The Global Footprint Network's calculation reflects essentially that humankind is consuming the Earth's resources faster than the planet can regenerate (*Global Footprint Network*, 2019).

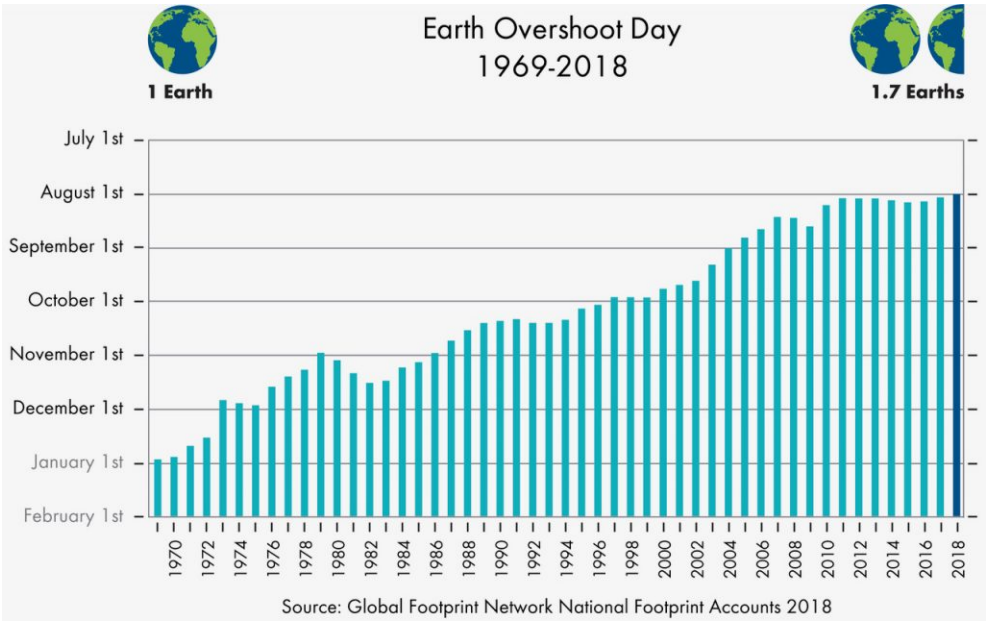

Figure 1.1: Earth Overshoot Day 2018 (*Overshoot Day*, 2019)

The most recent report showing that Overshoot day occurred by the end of July (*Overshoot Day*, 2019) which translates to the resources are estimated at being depleted at 1.7-times the rate, see figure 1.1 above, for the planet to be able to recover in time for the following year (Zwick, 2018). The "ecological footprint" was estimated to be 40% larger than the amount that would

allow the planet to replenish its resources at the same rate (Heinberg, 2010). This shows the prevalence of the issue and the importance of making a difference in as many areas as possible regarding the environment. This, as this project posits could involve ensuring that individuals adopt a more sustainable behaviour to reduce their "ecological footprint" by means of reducing the amount of pollution they produce.

1.1.2 Pollution

The impact of unsustainable behaviours on our planet have affected whole ecosystems as well as ramped up the rate at which entire species are reaching extinction (Jickling, 2000). Humanity's presence has placed profound stress on our ecosystems, a lot due to the pollution we produce, including waste (Raup, 1986). In relevant literature pollution is often categorised in are 10 different types of pollution (Nag, 2018), as seen in table 1.1.

Types Of Pollution	
Air Pollution	Water Pollution
Light Pollution	Visual Pollution
Noise Pollution	Soil Contamination
Plastic Pollution	Radioactive Contamination
Thermal Pollution	Littering

Table 1.1: How Many Types Of Pollution Are There? (Nag, 2018)

The types of pollution that will be focused on in this paper are those that relate to the effects of food production and food waste. Beginning with air and water pollution, which are two forms of pollution that can have the most devastating effects (Nag, 2018). Followed by soil contamination which has consequential effects on natural resources

Air Pollution

Air pollution refers to the collection of all pollutants released into the atmosphere (such as toxic gases and biological molecules) (Nag, 2018). The pollution can be caused by both natural events as well as humans (Nag, 2018). For example, a natural event could be a volcanic eruption which releases volcanic gases and volcanic ash (Sigurdsson, 1982). A result of pollution due to human activity could be, for example, food waste, from the overproduction of food, producing greenhouse gas emissions (Gustavsson et al., 2011).

Natural air pollution, such as from volcanoes (mentioned above) may have an impact on the environment; however, the major cause of air pollution is due to human activity (Kampa and Castanas, 2008). The issue has been recognised by mainstream media such as the Financial Times, announcing

(on 12th November 2019) that the United Kingdom is likely to not meet their already set goals tackling climate change by 2020 (*Finacial Times*, 2019). This pollution is concerning as it has damaging effects on human health and the environment (Kampa and Castanas, 2008). The damaging effects may cause or contribute to an increase in mortality rate, serious illness or other potential threats to human health (Kampa and Castanas, 2008). Hence, there is a risk in living in an environment with air pollution.

Water Pollution

Water pollution refers to the contamination, by means of pollution, of bodies of water. For example, It has been known for industries to have released toxic waste into bodies of water with releases dangerous pathogens and chemicals (Nag, 2018). This can be seen with pesticides in foods infiltrating into ecosystems due to food waste, from the overproduction of food (*World Animal Net*, 2019).

Water has been deemed a crucial commodity since all life needs water and its pollution has become, at present, one of the most important environmental issues (Goel P.K., 2006). This is mainly due to modernisation and the growth in population; this included urbanisation, industrialisation and agriculture (Goel P.K., 2006). Water pollution is a burden on an affected body of water; the pollution interferes with living organisms in the ecosystem, that live in or use the body of water (Goel P.K., 2006). Therefore, there is a direct link to risk of life associated with water pollution.

Soil Contamination

As the name suggests, this type of pollution is when the soil is contaminated which leads to soil pollution (Nag, 2018). For example, the use of fertilisers can lead to soil pollution (*World Animal Net*, 2019).

Soil pollution, in addition, has harmful consequences. A pollutant may harm humans, animals, vegetation or material (Kampa and Castanas, 2008). The damage results directly in the health of any plants using the soil and, consequently produces a lower yield (Nag, 2018); affecting humans and other animals that may use those plants. Therefore, in regards to food waste, soil can be contaminated with no positive benefit; the food is thrown away and the land is rendered unusable until the soil has recovered (*World Animal Net*, 2019).

Conclusion

In conclusion, pollution is mainly caused by human activity, and as a consequence, affects animals and plants, as established in section 1.1.2. Therefore, there is a strain on our natural resources and a risk of depleting resources for future generations (Brundtland Commission, 1987). A particular area of

interest, regarding the impact we have on our planet, is concerning the waste that we produce.

1.2 Proposed Solution

1.2.1 Summary

The population is consuming the Planet's resources faster than it can regenerate those resources, see section 1.1.1. The population's ecological footprint is currently greater than allowed for a sustainable future (Heinberg, 2010). Pollution, caused by human activity, also has a considerable impact on sustainability, posing a stress on animals and plants, see section 1.1.2. Therefore, it is important to make a difference in regards to the environment. As food waste can be linked as a factor of the pollution mentioned in section 1.1.2, this would be a valid aspect to focus on.

1.2.2 Goal

The aim of this project is to help achieve a more sustainable future by reducing the population's ecological footprint, see section 1.1.1. Any positive change from this project will be seen as a positive impact.

1.2.3 Solution

The overall objectives of the project could include the promotion of a more sustainable behaviour to reduce their "ecological footprint" by means of reducing the amount of pollution produced at the consumer level. This project will attempt to reduce the amount of pollution produced by experimenting with a solution that would reduce food waste at the consumer level, which is linked to pollution in section 1.1.2.

The proposed solution will be in the form of a food sharing application which allows individuals at the consumer level of the production chain, seen in section 2.1, to donate and receive food which would otherwise be wasted; therefore, avoiding the pollution tied with that waste explained in section 1.1.2. The solution would initially be targeted towards students as a method to save money and save the planet simultaneously, see section 2.3. However, this would not stop other potential users from using the solution. During the course of the project, existing systems will be analysed to understand the target audience's opinions, on these existing systems, and how that information could be used to aid this project, see section 2.4. Furthermore, as the potential stakeholders displayed a habit of wasting food on a weekly basis (see section 2.3), the solution will attempt to use persuasive technology for the users to gain a more habitual usage of the software. Therefore, tackling the issue of food waste at the consumer level by distributing the food that would have been wasted.

1.3 Aims and Objectives

1.3.1 Aims

Setting goals for this project is important as they will help guide and focus the development and help measure the success of the project. Therefore, the following aims have been established:

1. Increase user awareness on the impact food waste has on the planet.

2. Persuade the user to reduce the amount of food they waste.

3. Develop a system that facilitates the user reducing their food waste.

1.3.2 Objectives

Following the definition of the aims of the project, objectives will now be established to ensure that the aims of the project are met. The completion of the objectives will ensure that the aims are met and provide a clear direction and focus. These objectives will be measurable and can track the progress through the use of the Gantt chart, see section 1.3.3 with figure 1.2.

1. Develop a better understanding of the impact food has waste on the planet.

2. Develop a clear understanding of behaviour change.

3. Develop a clear understanding of persuasive technology and its use in behaviour change.

4. Engage with stakeholders and potential users to define the scope and gather requirements.

5. Conduct deeper research on existing systems, find out what issues they decided to tackle as well as the disregarded. This will provide an adequate starting point in determining the new system's requirements as well as evaluate their positive contributions and shortfalls.

6. Develop a system to support a community style marketplace. Users need to be able to find and exchange products through software.

7. Integrate persuasive features which have been found to be successful.

1.3.3 Project Plan

To ensure all the objective are completed before the final deadline, the following Gantt chart has been drawn up. The Gantt chart will provide a guide to the work that needs to be accomplished in the designated order. If there are any tasks which take longer than expected, the impact will be mitigated by restructuring the plan to allow for the overrun. However, this should not impact the project being completed before the final deadline as more than enough time has been allocated to each objective. The Gantt chart will be updated as the project progresses, see figure 1.2.

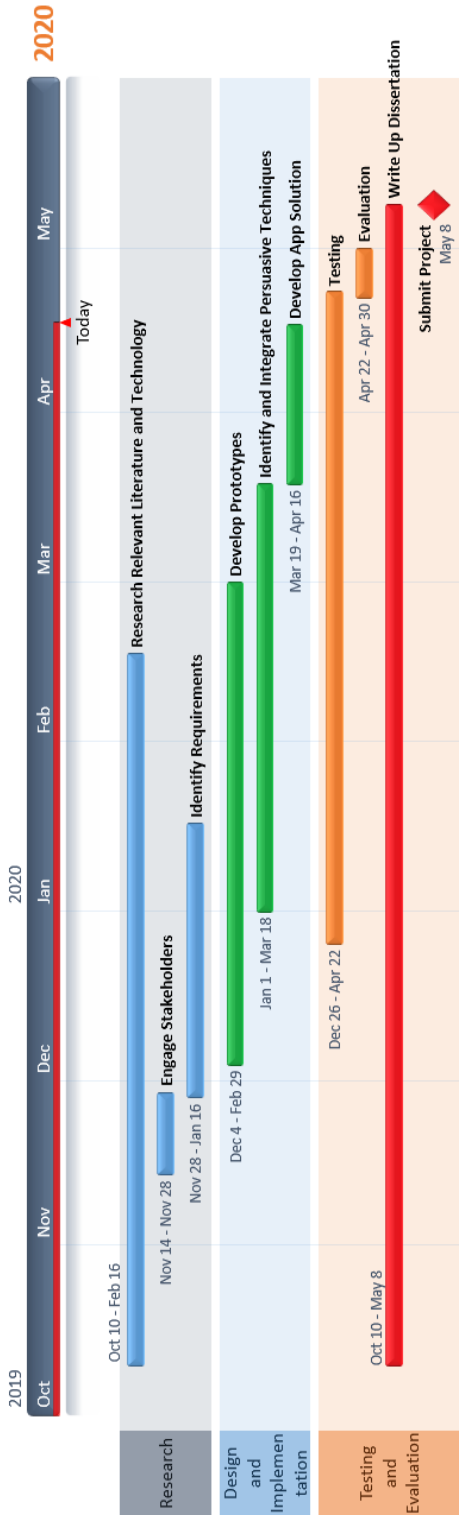

Figure 1.2: Gantt Chart

1.4 Motivations

The motivations behind this project can be broken down into two parts. Climate change and saving money on buying food.

Climate Change

Over the last few years I have become increasingly aware of climate change. With the rise of organisations such as Extinction Rebellion (*BBC News*, 2020*a*), the topic is discussed frequently which lead to thinking about the amount of pollution produced on an individual level. Therefore, I became more conscientious about how much waste I was producing and how much food I was wasting. Hence, beginning to select products which produce the least amount of waste, such as buying loose fruit and vegetables.

Saving Money on food

Naturally as a Student, there is a strain on personal finances. Therefore, I started looking up ways to get cheaper food. Some friends of mine mentioned an app called TooGoodToGo, which is a food waste saving app which allows users to buy take away food at a fraction of the price as the food would otherwise be thrown out at the end of the day, for more details see section 2.4.2. Hence, being a student with limited funds, the application was attractive and I began using the app occasionally. However, being a takeaway app it is not a viable option to eat every day and did not have a focus on the environment.

Food Waste Reduction System

Therefore, while thinking about an option similar to TooGoodToGo and being a viable daily option, I thought about blending these two parts together. Aiming to impact pollution as well as help feed those who have a strain on funds. Therefore, after researching food waste and its impact on the environment, I found that it was a pressing issue which I was not familiar with. Hence, my motivation for this project.

1.5 Document Structure

1.5.1 Literature and Technology Survey

Food Waste on Pollution

A literature review will be conducted on the topic of the effect of food waste on the environment. This will look at the different types of pollution that food waste contributes to as well as the scale of the pollution.

Consumers on Food Waste

The paper will discuss the issue of food waste in industrialised countries and engage stakeholders to gain different perspectives on the matter and understand why the food is wasted.

Using Persuasive Technology

After defining the context of the solution, persuasive technologies will be investigated to understand how the technology can be used to improve the solution and reach a target behaviour.

Stakeholders and Existing Solutions

In addition, potential stakeholders will be engaged to gain a broader understanding of students and their current behaviour regarding food waste and justifying the need for the solution. Furthermore, existing solutions will be analysed as a basis to understand what users expect from such systems and how the project can utilise the knowledge gained for the benefit of the solution.

1.5.2 Requirements Analysis and Requirements Specification

Requirements

Following the collection of information for the literature review, the initial requirements will be established as well as the project's risks.

1.5.3 Design and Prototyping

Creating a Persuasive Technology

A small literature review will be conducted to understand the practice of creating a persuasive technology and apply this process to the project.

App Structure

Following the research, the structure of the app will be established to ensure that the implementation process is as efficient and direct as possible.

Designing the Interface

Once the app structure has been decided, the interface will be designed and the first prototype will be created. From here, the iterative design process will begin and any changes through the process will be recorded, until the final version is reached.

1.5.4 Implementation and Testing

Development

Following the definition of the user interface, the final version will be implemented and developed into an application. The choice of language will be discussed as well as the building process of the app.

Testing

The project will establish how to test the developed system and how it has been recorded.

1.5.5 Evaluation

Finally, the solution will evaluated. A small literature review will be conducted as to how to decide the most appropriate methods to conduct an evaluation of a persuasive system. Then the results will then be discussed.

1.5.6 Conclusion

The project will finish with a summary of what has been learnt during this project and where it could be improved upon in the future.

1.6 Research Methods

For this project both qualitative and quantitative research methods were conducted.

1.6.1 Literature Review

During the literature review, a questionnaire and a focus group was used. The questionnaire will permit a statistical analysis of the participants while the focus group will create the required detail for a thematical analysis. These methods were chosen as to establish the users' needs and define the requirements of the solution. The questionnaire reaches a larger audience than possible with interviews and therefore, better reflects the average student. However, it is harder to draw specific requirements as the questions do not allow for precise and detailed answer, especially with the lack of follow up questions. However, a focus group will also be used to gain more detailed answers once the initial questionnaire has been completed, allowing for more informed questioning. The focus group will be semi-structured to allow for the participants to steer the conversation. Hopefully, this provides a more informal atmosphere and may help participants share genuine thoughts and feelings.

1.6.2 Testing

When testing the prototypes on potential users, the participants engaged in a informal brief interview which was recorded to thematically analyse before moving on to the next prototype. This method was used as it allowed for rapid design iterations working closely with the end user to produce a system which better meets the user needs.

1.6.3 Evaluation

For the evaluation process, a questionnaire has been planned for each participant which will then be used to statistically analyse the feedback from the evaluation. This method was put in place to avoid taking too much of the user's time, allowing them to quickly reflect on their experience with the system. However this method does not allow for descriptive answers. Therefore, the study will also be accompanied by observations which will be thematically analysed. This will produce results that the user may not be able to express themselves but can be directly noticed during an observation. There will also be follow up questions to confirm certain impressions leading to more informed results.

Chapter 2

Literature and Technology Survey

Some food does not meet its purpose of being consumed and is eventually wasted. It is suggested that roughly one-third of food produced for human consumption is lost or wasted globally, which amounts to about 1.3 billion tons per year (Gustavsson et al., 2011). Therefore, the resources used in the production of this food is also wasted and leads to pollution in itself. For example, in the agriculture stage, fertilisers are used when growing crops. The use of these fertilisers contaminate the soil and as a result the land is rendered unusable until the soil has recovered, see section 1.1.2. Therefore, if these foods are wasted then the resources have contributed to pollution with no benefit. Food waste is arguably one significant contributor to unnecessary pollution such as greenhouse gas emissions (Gustavsson et al., 2011). Thus, there is a rationale for globalised efforts to improve upon the amount of food waste we produce.

2.1 Understanding the Food Production Chain

2.1.1 Food Waste

The food production chain is the network which links the suppliers to the customers and finally to the consumer. The chain undergoes the necessary steps to produce a final product from raw materials (Claassen, 2020). For example, the process of going from an apple seed to the final product of a packet of six apples which reaches a consumer to be eaten.

Throughout the food production chain, there is a significant amount of unnecessary food waste produced. This project will now look into the waste in each stage of the food production chain, see figure 2.1.

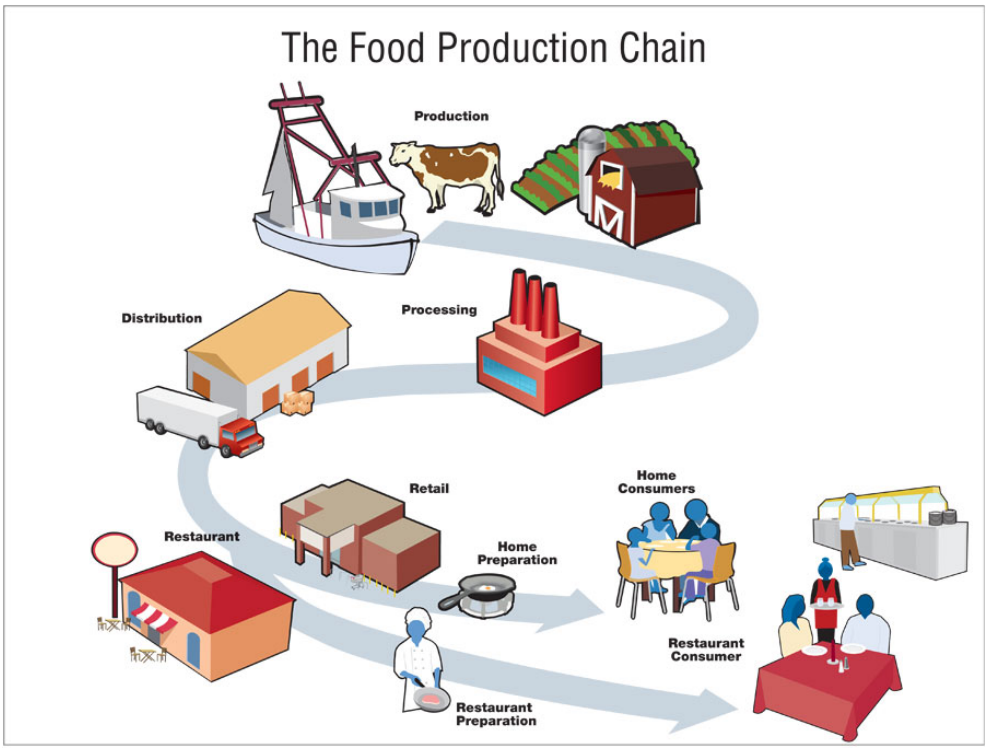

Figure 2.1: Food Production Chain (*Food Production Chain*, 2013)

Agriculture

From the start of the chain, at the agriculture stage, the crops can be wasted by a variety of reasons (Gunders, 2012). One of the possible reasons is that the produce could fall victim to weather or disease which risks harming the crop and an end result of not being able to utilise the produce (Gunders, 2012). For example, in the case of a drought, farmers may not be able to water their plants to the required degree to produce healthy crops. This can lead to the plants dying or producing a lower yield.

Processing

In the Processing stage, often food goes through a cutting, trimming and peeling process. This is where parts of the food, often undesirable or inedible, are removed and thrown away (European Food Information Council, 2017). If the produce undergoes this trimming process, then there will be a portion of the produce that is wasted (Gunders, 2012). For example, in the case of orange juice, peel and sediment is removed, therefore producing food waste.

Distribution

During distribution, there can be technological malfunctions (Gunders, 2012). For example, failing refrigeration or transportation can cause the produce to spoil if they remain in poor conditions for an extended period of time.

Restaurants and Takeaway Services

In regards to food services, such as restaurants and takeaway services, there is an important amount of waste. Due to the structure of meal preparation, more produce must be kept on hand to prepare the meals (Gunders, 2012). The choice of meal options and the number of orders in a day are unpredictable to an extent, which leads to produce behind the scenes being wasted. Restaurants' first priority is to provide service to as many consumers as possible, this translates to not running out of produce which contributes to food waste.

Retail Stores

In retail stores, food can be wasted by different management strategies aimed to boost sales (Gunders, 2012). for example, physical stores often keep shelves visually "fully stocked" and offer ready-made food which has a shorter shelf life and leads to more food waste (Gunders, 2012).

Consumer

The consumer, at home, mainly wastes produce based on planning, products expiring and lack of awareness (Gunders, 2012).

Planning is what constitutes the consumer deciding what products to purchase, to consume immediately or over a certain time frame. This usually involves predicting what food to consume in the near future. Thus, consumers may intend to use a product in a meal but end up changing the plan and not using it. Hence, the product may no longer needed and will either be thrown out or stay in the fridge until the product eventually expires and contributes to food waste, see section 2.3.

Furthermore, poor planning may also lead to food expiring. As mentioned above, the consumers need to predict the food they plan to eat in the near future. Therefore, it is feasible that consumers may poorly predict their needs and either buy too little or too much. Excessive food product purchases may result in the items expiring before consumption and lead to food waste.

Finally, consumers have a lack of awareness for the consequences of the food that becomes waste. Supermarkets use marketing strategies to influence potential consumers to purchase products at a lower price. For example, the use of offers such as two products for the price of one. As a result, the consumer may purchase goods which seem like a good idea at the time but will most likely not be used, see section 2.3. In addition, when discarding these products,

the most common thought is not about the effect the food waste is having on the environment, but rather the financial cost (see section 2.3). Consumers are more concerned about if the purchase was a waste of money or the price was so low that the produce is not worth worrying about (Gunders, 2012).

Food Waste

Finally, as in all steps of the food production chain, the food may spoil and hence, wasted. However, how is food waste justified as a cause for concern?

2.1.2 Pollution Caused by Food Waste

In addition to the other means of pollution, mentioned in section 1.1.2, the planet is being polluted at higher rates because of wasted food (*World Animal Net*, 2019).

Air Pollution

Food waste contributes to Air pollution. At the agricultural level of the food supply chain, greenhouse gas emissions are released (*World Animal Net*, 2019). In addition, as a result of farming, there are emissions of ammonia which further contributes to air pollution (*Finacial Times*, 2019).

Pollution due to transportation, of food that ends up being wasted, would also fit in the same category as the motor vehicles used that contribute to the general air pollution (McCubbin and Delucchi, 1999).

A part of the food produced in the agricultural stage ends up going to waste, and thus this pollution could be attributed to food waste (Food and Agriculture Organization of the United Nations, 2013*a*). In the event that the distributed food is not eventually consumed, one of the methods of dealing with the waste is to use a landfill. The food decomposing in landfills also releases greenhouse gas emissions, including carbon dioxide and methane, see section 1.1.2. Notably, the greenhouse gas emissions from landfills are substantial; if they were grouped up as a country, food waste would rank 3rd world wide after USA and China, in terms of emissions (Food and Agriculture Organization of the United Nations, 2013*a*).

Taking all this into consideration, it is clear that food waste is an important contribution to air pollution. Emissions have been increasing and are predicted to increase to 400%, of the current rates, in the next hundred years if the planet continues to waste food at the same rate (Food and Agriculture Organization of the United Nations, 2013*b*).

Water Pollution

As for Water pollution, with the presence of landfills, the pollution from the sites contaminates underground water in the vicinity as well as any body of wa-

ter that the pollution could come into contact with (*World Animal Net*, 2019). The fertilisers, still present in the food waste, release nitrogen and phosphorus into the water. This pollution poses a stress on surrounding ecosystems and is not sustainable (Nag, 2018).

Soil Contamination

Soil contamination, in the case of food waste, is caused by an overuse of synthetic fertilisers (*World Animal Net*, 2019). This harms fertile lands by reducing the soils ability to retain water as well as the soils fertility as it continues to be degraded by pollution (Food and Agriculture Organization of the United Nations, 2013*b*). Once the soil has been put under stress by fertilisers, the land needs time to recover and must be left alone otherwise, it will reduce its fertility (Food and Agriculture Organization of the United Nations, 2013*b*). So when food is wasted then this soil is put under stress unnecessarily, restricting the space for agriculture (*World Animal Net*, 2019). Furthermore, using landfills can also lead to soil contamination and with the United Kingdom soon depleting its available landfill sites, it is increasingly concerning (Food and Agriculture Organization of the United Nations, 2013*b*).

Food Waste

Food waste contributes a considerable amount to global pollution, as shown in section 2.1.2. Therefore, reducing pollution by tackling food waste will be the purpose of this project.

2.1.3 Comparing Industrial and Developing Countries

There is a noticeable difference between food waste in Industrial and developing countries. Developing countries produce tremendously low waste in comparison to Industrial countries (Gustavsson et al., 2011). Therefore, This section will look at the possible reasons for this difference to occur.

Per capita, food waste in Europe and North-America is 95-115 kg/year, whereas in sub-Saharan Africa and South/Southeast Asia the food waste is 6-11 kg/year (Gustavsson et al., 2011). Developing countries have a lower standard of technology. However, the lack of technology does not translate to the level of food waste produced, with industrial countries producing significantly more waste on a yearly basis. Thus, developing and industrial countries have different reasons for producing the food waste (Gustavsson et al., 2011).

Following the food production chain, shown in figure 2.1, this section will compare the amounts of food wasted in each stage between industrial and developing countries.

Agriculture

Due to developing countries not having access to the same quality of agricultural technology, producing a consistent quantity and quality of crops is a challenge. Crops are often failed or rushed which render the food inedible (Gustavsson et al., 2011). The failure is mostly caused by the weather conditions and disease (Gustavsson et al., 2011). These countries do not have equivalent technology, compared to industrial countries, to counter harsh conditions, such as droughts which could cause the crops to fail due to lacking the needed quantity of water to maintain a healthy plant. In contrast, industrialised countries do not produce as much waste at the agriculture stage, due to the Superiour access to technology (Gustavsson et al., 2011).

Processing and Distribution

Moreover, Developing countries have a weaker technology meaning that they do not have reliable technology for food storage or transportation (Gustavsson et al., 2011). For example, during any of these two stages, if refrigerators used to store fresh food fail, then it is likely that the goods will perish in the warmer conditions. In addition, with the added stress from the sun, food expires much faster and is understandable why it an important an issue if food needs to be processed or transported. Similarly, industrialised countries produce a similar amount of waste but for different reason, as explained in section 2.1.1. Significant losses occur due to "ugly" food and lack of coordination between farmers and food suppliers while at the consumption stage, discarded while still edible or kept past the "expiry" date (Gustavsson et al., 2011). These foods which are deemed "ugly" are goods which do not meet the standards set but the suppliers' customers. This includes, items of food which are under or over sized, the wrong colour or are the wrong shape.

Retail Stores

Waste in this stage, in developing countries, is due to similar reasons to the processing and distribution stages. Due to unreliable technology, storage appliances may fail or stores may not have access to enough appliances to store their products in their entirety (Gustavsson et al., 2011). Otherwise, both types of countries produce food waste when food is not sold or manage to distribute it to charities that handle excess food, as seen in section 2.4.

Consumer

However, as shown in figure 2.2, industrialised countries waste significantly more at the consumer level. The reason for this is that developing countries cannot afford to waste food, as explained in section 2.1.4. On the other hand,

industrialised countries have a surplus of food and waste it in the reasons mentioned in section 2.1.1.

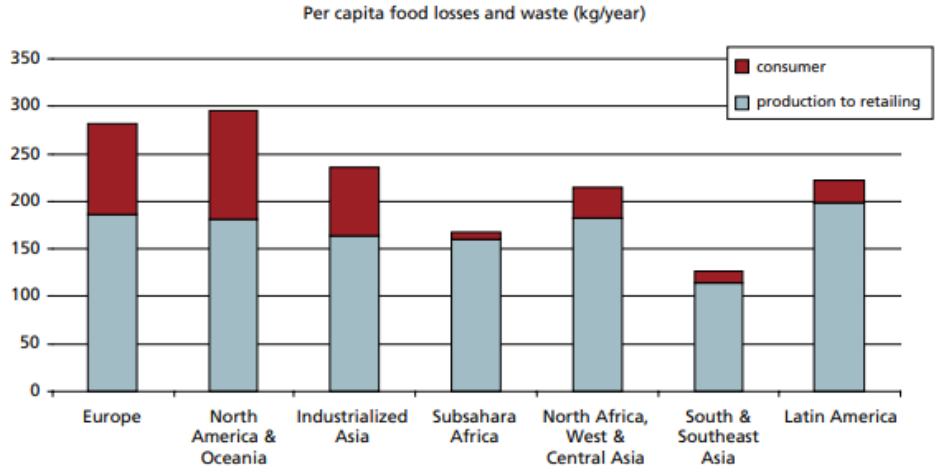

Figure 2.2: Per capita food losses and waste, at consumption and pre-consumption stages, in different regions (Gustavsson et al., 2011)

In conclusion, in developing countries, most of the wasted food is during the early and middle stages of the food supply chain; much less food is wasted at the consumer level, as shown in figure 2.2. On the other hand, industrialised countries waste food at all stages, also shown in figure 2.2.

This project will be focusing on food waste at the consumer level as it is more prevalent in western societies and therefore, its resolution is more pressing in those counties (Gustavsson et al., 2011).

2.1.4 Comparing Attitudes at the Consumer Level in Industrial and Developing Countries

In developing countries, at the consumer level, food is mainly wasted because of environmental and sanitary problems (Thi, Kumar and Lin, 2015). These countries have higher rates of poverty and hunger than industrialised countries (Reutlinger and Pellekaan, 1986). Taking that into consideration, food is more valuable and there must be as little waste as possible. Wasting more food may pose higher health risks to a country which already has issues with malnutrition (Müller and Krawinkel, 2005).

On the other hand, looking into the behaviour of consumers in industrialised countries, it can be observed that simple issues like poor planning and being able to afford wasting products are creating food waste in the household (Gunders, 2012). This could arguably be interpreted as, in the industrialised world, consumers may have a more careless attitude.

2.1.5 Concluding the Comparison of

The comparison of industrialised and developing countries is interesting to include as a considerable amount of food is wasted by industrial countries, at the consumer level, more than developing countries, see section 2.1.3. Therefore, since it is possible for a developing country to produce lower rates of waste, at the consumer level, industrialised countries are able to match the food waste rates per capita, see figure 2.2. We can conclude this as industrialised countries do not posses the same technological obstacles as developing countries. Thus, should not have reason to produce food waste at higher levels.

In conclusion, this justifies the rationale of developing a solution for the consumer level in industrialised countries, using those consumers as the target audience.

2.1.6 Conclusion of the Food Production Chain

In conclusion, The food wasted throughout the food production chain contributes to a significant carbon footprint, see section 2.1.2. A big part of this problem could be focused on unsustainable behaviours and attitudes of consumers regarding food waste that escalate rather than alleviate the problem.

Indeed, food waste is influenced by crop production choices and patterns, internal infrastructure and capacity, marketing chains and channels for distribution, and consumer purchasing and food use practices (Gustavsson et al., 2011). Economically avoidable food losses have a direct and negative impact on the income of consumers which could act as an incentive for potential users to use the solution. Considering the amount of food wasted, in comparison to developing countries (see section 2.1.3), there is room for consumers to take advantage of the food that would have otherwise been wasted.

Furthermore, as established in section 2.1.1, there is a lack of awareness. Therefore, it is important to raise awareness of the effects that food waste has on the planet which could be implemented into the solution, to aid the efforts to reduce food waste at the consumer level. Current behaviour is not environmentally sustainable, as seen in section 2.1.2. To make an impactful change, the solution must be able to persuade the user to behave differently.

2.2 Research into Technology for the Proposed Solution

2.2.1 Why use Persuasive Technology

Persuasive technology, specifically, is used in order to achieve a change in attitude or behaviour with the use of an interactive system (Orji, 2014), without coercion or deception (Fogg, 2002*a*). Therefore, persuasive technology is not a side-effect of technology but the main focus.

As Orji (2014) suggests, the use of persuasive technology in environmental sustainability is significant. As discussed on the topic of pollution due to food waste, in sub-section 2.1.2, any positive change could have a positive impact on the environment. A behaviour change could help with reducing food waste and help recycle that food to be used by other consumers. In order to provoke a behaviour change, as mention in section 2.2.3, the use of persuasive technology would be a viable method. With the use of persuasive technology, the solution could resolve even small parts of the issues concerning the environment, which could lead to long-term sustainable behaviour (Orji, 2014).

2.2.2 Behaviour

Behaviour consists of psychological and social processes people undergo in a particular situation or under particular conditions (Bagozzi, 2002), when discussed in psychology. However, how can behaviour be understood and persuaded?

2.2.3 How to Change Behavior

Grob (1995) suggests , we can assume that a person's behaviour, in regards to the environment and proposes that the behaviour is determined by 4 factors, seen in figure 2.3.

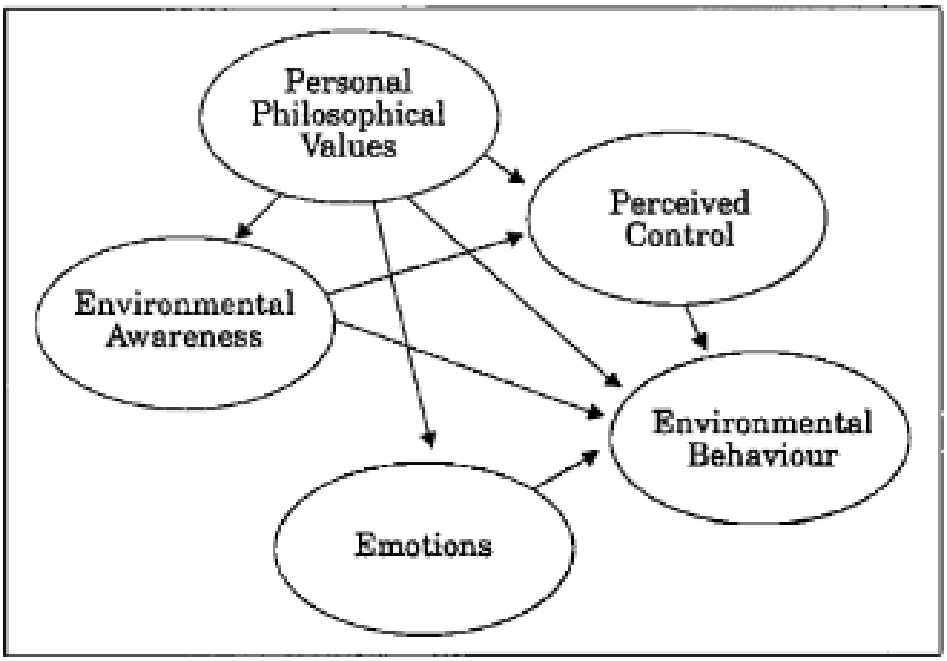

Figure 2.3: The proposed model of environmental behaviour (Grob, 1995).

Personal-philosophical values

The personal-philosophical values component. Just like in all areas of life, a person makes decisions based on thoughts, beliefs, concepts, and attitudes. This component is split into material values and creative/open thinking (Grob, 1995).

To encourage open thinking, the solution will use language, a form of persuasive technology, to influence the user (Fogg, 2002*a*). The users will relate to a greater personal level to the solution if the system displays messages in spoken word (Fogg, 2002*a*). It conveys social presence which calls for social cues from the user, making the system able to persuade the user through the use of language (Fogg, 2002*a*). Therefore, better able to influence thoughts, beliefs, concepts and attitudes towards a more environmentally sustainable behaviour. For example, in the introductory messages, the system could convey, in spoken word, the effects of food waste and well as the benefits of reducing the food waste of a personal level.

Furthermore, the use of praise, another form of persuasive technology, would reinforce the behaviour (Fogg, 2002*a*). One of the most impactful uses of language is to praise the user when completing a task (Fogg, 2002*a*). It offers positive reinforcement which has shown to increase the likelihood of the persuasion of the user. Therefore, praising the user with words, images, symbols, and/ore sounds, the user would be more likely persuaded. This would ensure that the user believes that their thoughts, beliefs, concepts and attitudes, towards a more environmentally sustainable behaviour, are correct. For example, when completing an action to reduce food waste, the user would be shown a message of praise.

However, there is a limit of who can be persuaded at the personal-philosophical level as some people have stronger material values and therefore, are less likely to act in favour of the environments (Grob, 1995).

Environmental awareness

As the name suggests, this is the based on the person's knowledge of the environment as well as know environmental problems and their threat (Grob, 1995). The further the person is knowledgeable, the further the person will act in favour of the environment (Grob, 1995). Therefore, this component is heavily influenced by the personal-philosophical values component as it requires knowledge, as seen in figure 2.3.

As mentioned in the personal-philosophical section, the use of language will convey environmental awareness.

Emotional

This comprises of the reaction a person has (Grob, 1995). For example, the reaction to the knowledge that the environment is deteriorating. The stronger

the emotional reaction to this information, the more potential the person has to behave appropriately in regards to the environment (Grob, 1995). Therefore, this component is influenced by the personal-philosophical component as there needs to be knowledge in order to have a reaction, as seen in figure 2.3.

To communicate the deterioration of the environment, the solution will display spoken word, a form of persuasive technology (Fogg, 2002*a*) as a way to influence the users perception of the effect food waste has on the environment.

Furthermore, the solution will appear to have a psychology, another form of persuasive technology (Fogg, 2002*a*). By demonstrating that the solution has emotion, preferences, motivations and a personality; the solution is more likely to persuade the user (Fogg, 2002*a*). This can also dissuade if it is perceived negatively. For example, with the use of language, the system will convey the message that it wants to save the planet and will further this idea by using praise and attempt to encourage the user to continue using the system.

Perceived control

This is the belief that the person in question's actions have an impact on the goal the person wishes to accomplish (Grob, 1995). For example, the solution will display the cumulative effect the user has had on the environment, by displaying the number of food items saved as well as the amount of pollution prevented. However, those who deem the cause to be due to external factors (natural law, chance, society, or peers) are unlikely to change their behaviour (Grob, 1995). In addition, there is a sub-component concerning the possibility of a technological or scientific solution. Having faith in this possibility may result in the person not acting appropriately (Grob, 1995). Therefore, there is a limit to how much the perceived control will affect the user's behaviour, in regards to the environment.

Taking this into consideration, this component must be determined the personal-philosophical component and the environmental awareness component as there needs to be knowledge of the environment and/or technologies and science as well as awareness of then environment and its challenges, as seen in figure 2.3.

Environmental Behaviour

All this influences the environmental behaviour component, see figure 2.3 below. From testing this model, Grob (1995) comes to the realisation that the most important influence was open mind thinking. Within the research, individuals we're able to consider environmental issues in new ways. Taking this into consideration, raising awareness for environmental problems would likely persuade users to try the solution.

Other Methods of Persuasion

It is important for the system to be attractive. Fogg (2002*a*) presents his research, where an unattractive and attractive model were used, and shows that the users are almost three times more likely to be persuaded by an attractive model. Therefore, it is important that the interface is attractive and that the HCI principles are respected (Hinze-Hoare, 2007).

Furthermore, it is also important to have the best user experience possible. For example, if the system has bugs or is not as responsive as it should be, this can be conveyed as uncooperative or vengeful (Fogg, 2002*a*). It has been shown that systems which are similar, in some way, to users may persuade them to behave differently (Fogg, 2002*a*). Therefore, the system testing, seen in section 5 has a great importance for this project in order to iron out as many bugs as possible.

Finally, the use of social dynamics will provide a competitive element which has the potential to prolong the users engagement with the solution (Fogg, 2002*a*). Following the example of Microsoft's Clippy, the system was able to persuade the user to interact with Clippy's presence. However, this example is not perfect as it was seen as intrusive and left the users feeling frustrated (Sampson, 2006). Using this imitation of social dynamics leaves the user more open to persuasion (Fogg, 2002*a*). In the case of the solution, for example, the system will implement a leader-board for users to compete with their friends for the best score.

Conclusion

In short, the user can be persuaded by technology in similar ways to those of being persuaded by people (Fogg, 2002*a*). Therefore, persuasive technology is a valid method, to implement in the solution, to reduce food waste and eventually lead a more environmentally sustainable behaviour.

2.3 Research into Potential Stakeholders

2.3.1 Students Questionnaire

Aims

This questionnaire is aimed at students, the target audience for the solution, to gain a better understanding on food waste as well as check if there is room in the market for a system that helps users reduce food waste. The questions will focus on how students behave around buying and throwing away food as well as their use of similar systems.

Participants

The sample had 29 participants. Any responses which were not from students were discarded in order to correctly reflect the target audience. However, due to the size of the sample, being smaller than expected, there could be a negative bias. Therefore, reflecting on the results of the questionnaire, the size of the sample should be taken into consideration. The sample had a good range of student ages (between 20 and 23) and therefore should reflect the results form students across all year groups, with 1st to 5th year students being represented in the sample. Furthermore, there was 9:11 ratio of girls to boys, respectively. Which should also provide a good representation of students at university.

Materials

For this questionnaire, google survey was used to assure that it was as accessible as possible to anyone with an internet connection. Furthermore, to ensure unbiased answers, the director of studies of Computer Science at the University of Bath was asked to broadcast the questionnaire to other students.

Procedure

There was no strict procedure to follow as it was a questionnaire to complete in their own time. However, an approximation of 5 to 10 minutes was added in the description of the questionnaire. Some of the questions were only available to participants who gave specific answers to previous questions. For example, for the question about loyalty applications (see figure C.18) the following question was only available if the participant gave an answer other than "never" (see figure C.19).

Results

Initially, the questionnaire asked about the participant's food buying habits. They were asked to list their three most important criteria when shopping for food, see figure C.11. The participants were also offered an option to leave an answer that was not listed. The questionnaire found that 75.9% of the sample thought the price was one of the three most important factors. Taking this into consideration, the solution will be providing food for free and therefore, should be attractive to users such as those from the sample. Furthermore, the questionnaire used a Likert scale to determine the effect of special offers or reduced prices on deciding which products to buy. Which found a skew towards having a significant influence, see figure C.13. The participants show the ability to adapt to different ingredients which allows for similar behaviour, such as in the solution, with picking up a new item, from the solution's marketplace, to incorporate into the user's meal.

Secondly, the questionnaire questioned the participants about their food wasting habits. When wasting food 69% thought about the money spent on that product and it going to waste, see figure C.17. Taking that into consideration, since the money aspect is important to the majority, the solution will keep track of the money saved from receiving free food. Moreover, 27.6% of the sample thought about giving the food that would be otherwise wasted, away to someone else, see figure C.17. Therefore, the solution would make this option more accessible as the app would allow for a wider audience of people that may be interested in the product. In addition, 49% of the participants throw away food at least once every two weeks, see figure C.12. The solution will aim to reduce that figure and the finding supports that there is a market for the solution.

Finally, the finding from participants using similar systems will be discussed. The questionnaire found that the participants' use for loyalty/reward apps was for money reasons, to reduce price or receive free food, see figure C.19. The solution will provide free food so that aspect should be attractive to similar potential users. Furthermore, the lack of the participants' use of food waste reduction apps was due to lack of awareness, see figure C.26. However, marketing strategy is not covered in this project and therefore, will not be discussed further.

2.4 Looking at Existing Solutions

The following existing solutions have been analysed with the help of interviews (see appendix D) and online research. Using these methods, this section will discuss what the solutions are, how the process works, the advantages and limitations, and how this information could be applied to this project's solution.

2.4.1 Non-Technological Solutions

Food Banks

Food banks are a solution to supply food, free of charge, to people in need. Food banks stocks mainly non-perishable goods as well as other food products in order to produce meals. This solution operates at the consumer stage of the food production chain, see figure 2.1. Food banks depend on the donations from the customers of selected supermarkets. These donations are collected by the supermarkets and then picked up on a weekly basis by a member of the food bank. If there is a surplus then the food is left with the supermarket. Personally grown produce may also be accepted by the food banks.

The advantages of this process is that the food banks are able to satisfy the people requesting their services and there is little to no waste produced in house. The limitations are that occasionally not enough fresh produce is

donated, as it is not recommend by the supermarkets, and therefore, the food bank's work force must purchase the good they desire themselves. However, personally grown produce can be a great benefit in regards to this area. Moreover, as there is usually a surplus of donated food from the supermarket, there could be food which is unnecessarily wasted.

In conclusion, in future work for this project, the use of waste from the surplus of donations could be utilised to distribute to other consumers.

Minimal Waste Supermarkets

Minimal waste supermarkets, otherwise known as "zero waste" stores, aim to produce "zero" or minimal waste by purchasing products with little to no packaging. Deliveries to the store are in bulk and the large containers, used for transportation, are reused. The store also uses dispensers so that the customers bring their own reusable containers and select the products as well as the exact quantities that they desire as opposed to buy predetermined supermarket portions. This solution operates at the customer level (retail), see figure 2.1.

The benefits to this are that the consumers are directly responsible of the quantities that they choose. This decreases the waste from buying large quantities of food which could potentially not be consumed, such as from deals or offers used as marketing strategies by other supermarkets (Gunders, 2012). Examining the reviews and considering its customer base, using the example of "Hetu", because of the underlying motivation to reduce waste and pollution, the stores are highly rated by customers (*Hetu*, 2019). The limitations are that it would be difficult to make deliveries using this business model. Alongside this, some negative reviews were suggesting that the store was a "bit short on inventory" which could be due to the supermarkets operating on a smaller scale than major companies.

In conclusion, the current solution will utilise similar aspects of minimal waste supermarkets by allowing users to request the exact amount of food that they desire, as well as providing a larger range of products as the products can come from any supplier.

Food Waste Reduction Schemes

Using the example of "Leftovers" a scheme to sell food not ordered, during the lunch period, for a cheaper price. This system, implemented at the "Fountain Canteen" restaurant at the University of Bath, has been put into place to tackle the food waste problem. Students who want to participate in this scheme need to queue at 2:15 (when the lunch service finishes), to choose from the selection of leftover food. This solution operates at the customer level (restaurant), see figure 2.1.

From preliminary discussions with the users, students which will also be the target audience for the development of this project, of the "leftover" system and personal experience, the impression is that the system is "poorly" advertised but has a high rate of returning customers. This could be due to the fact that consumers are offered meals at a fraction of the normal price. There is also the choice to bring your own reusable container to reduce the price even further, as an environmental incentive.

In conclusion, it is important to properly advertise the services provided by the current solution but will not be included in the scope of this product. However, the existing solution demonstrates the acceptance of a service of providing food at a cheaper (in the case of the current solution, free) price.

2.4.2 Technological Solutions

OLIO

OLIO is a market place on an application for mobile devices which caters to consumers who would otherwise throw away products that they no longer desire, similar to the solution currently being developed in this project. This solution differs from the project by allowing users to sell or give away any products they not longer need, including consumable and non-consumable items which are advertised in a feed structure (Harvey, Smith, Goulding and Illodo, 2019). The users list an item on the marketplace and wait for another user to request or purchase the item. This solution operates in the consumer stage of the food production chain, see figure 2.1.

The benefits of this solution are that products are recycled and not discarded. Furthermore, the underlying goal of recycling instead of throwing away goods is applauded by the users. Users are able to list "items you no longer need [that] a charity won't take" and other users go as far as to call it a "lifesaver" (*Google Play Store*, 2019*a*). However, there are some limitations preventing the application's growth. A vast number of negative reviews with similar messages mentioned that the "Interface felt slow" (*Google Play Store*, 2019*a*). A number of users even "gave up" when navigation buttons were not working as intended other users gave the review "Totally unusable" (*Google Play Store*, 2019*a*). However, users rating the app poorly with 1 star still mentioned that it was a "wonderful idea that really helps bring the community together" and that they "love[d] it" (*Google Play Store*, 2019*a*). Hence, the behaviour would be hard to encourage when the ability, to use the application, to reach the target behavior is low (Fogg, 2009*a*).

In conclusion, the solution is well received in concept, however, the progress of the application is hindered by the user experience. Therefore, following the feedback form this similar system, the solution should be well received and it is important to place focus on the user experience to ensure the best possible outcome.

TooGoodToGo

TooGoodToGo is essentially a takeaway application which offers reduced prices on food prepared by restaurants as a method of tackling food waste. Restaurants usually have a surplus of food which will end up being thrown away at the end of the day. This system helps use that food by offering the meals at a lower price than that offered by the restaurant. The user simply reserves the number of meals that they desire and goes to pick up the food at the designated time. This solution operates in the customer stage (restaurant) of the food production chain, see figure 2.1.

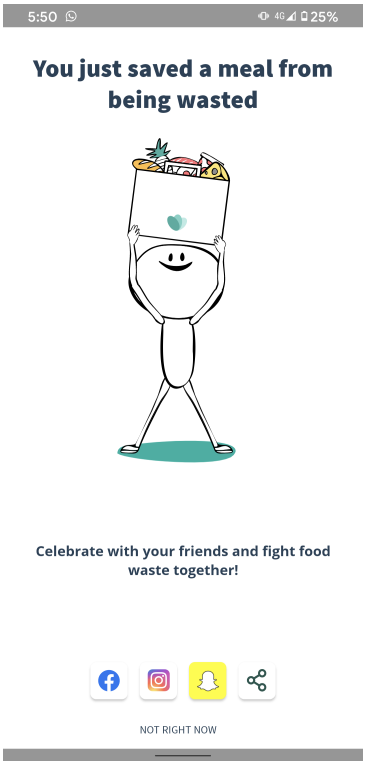

Figure 2.4: Example screenshot of the confirmation of purchase screen

TooGoodToGo already has a much higher rating overall compared to OLIO (see section 2.4.2) with 4.8 out of 5 (*Google Play Store*, 2019*b*) compared to OLIO's 3.3 stars (*Google Play Store*, 2019*a*). Therefore, users are much more impressed here. The advantages of this solution is that it helps reduce food waste while providing an already prepped meal, meaning it is hassle free. However, the disadvantages are that because of the nature of the food being wasted at the end of the day, going to pick up your food reservation as late as 12am is not feasible for some consumers.

The food will not be restricted to being available for pick up in the evening so should be attractive to a wider range of potential users. Furthermore, the solution will be structured in a similar way as the reservation and pick up aspect will be used in the system, including small details such as congratulating the user for saving food from being wasted, see figure 2.4, as this praises the user which could persuade the user to continue using the application (Fogg, 2002*a*).

2.4.3 Conclusion

Analysing existing solutions has been helpful as a good basis for what potential users are expecting as well as feature that could be implemented in the solution, such as praise, seen in section 2.4.2. Furthermore, general aspects have also been insightful. For example, the importance of a good user experience and that the area of work, recycling food, is already well received and should continue to be popular with more causes spreading awareness, see section 1.1.1.

Chapter 3

Requirements Analysis and Requirements Specification

3.1 Introduction

To develop the requirements for this system, an iterative approach was used. Gathering initial requirements with the use of qualitative and quantitative research, such as interviews and questionnaires. In addition the requirements were then prioritised to ensure the success of the project. To validate the need of the proposed solution, a questionnaire was conducted, see section 2.3. This allowed for a scope definition as well as identifying some initial key requirements. Following up on this, a focus group was organised to further define functionalities to include in the solution.

From this point, the project became clear that the system scope would be a community style marketplace. Therefore, this led to key requirements coming into place that would be needed for an application based shop. For example, requirement 'FR 1.3', ' Must allow users to list products on the marketplace'.

Moreover, background research was completed about current literature and technology in the context of the project, see section 2. This information provided a better starting point before entering the design process. This research also covered existing systems that had parallels, see section 2.4, and were analysed to imitate features that were successful, see section 4.1.5. The information gathered Literature and Technology Survey, in section 2, will be used to determine the requirements.

The requirements were each given an Identification code, a description, a source and a priority rating of 'Low', 'Medium' or 'High', signifying how critical the requirement is to the solution. For example, requirement FR 1.1, 'Must store relevant user data' is of 'High' priority as it is critical to the system that it tracks who reserves food products and who is listing them on the marketplace. This has been give a source of 'basic project idea' because it is the main functionality of a application based shop.

3.2 Non-Functional Requirements

1. Ethics and Legality			
ID	Requirement	Source	Priority
NFR 1.1	All data held in the system must adhere to the Data Protection Act 1998.	Law	High
NFR 1.2	The system must account for ethical issues in the specification, design, development and testing of the system.	Law	High
NFR 1.3	Must complete the 12 point ethics checklist for this project.	see appendix A	High
NFR 1.3.1	Must distribute consent forms to students that participate in the studies.	see appendix A	High

Table 3.1: Non-Functional Requirements: Ethics and Legality

2. Usability			
ID	Requirement	Source	Priority
NFR 2.1	The system must have a large focus on user experience.	see section 2.2.3	Medium
NFR 2.2	The system should have a consistent style and layout.	see section 2.2.3	High
NFR 2.3	The solution must be application based and compatible with iOS and Android	see section 4.1.4	Medium
NFR 2.4	Must be streamlined to be as efficient as possible, to keep users from getting bored by the process.	see appendix E	Medium
NFR 2.5	Must test the usability of the system after any interface changes to ensure the user experience is keep to the best standard possible.	see appendix E	Medium

Table 3.2: Non-Functional Requirements: Usability

3. General Non-Functional Requirements			
ID	Requirement	Source	Priority
NFR 3.1	Must regularly review the functional requirements.	System Development	Medium
NFR 3.2	Must incorporate risk management into the project development.	see section 3.6	High
NFR 3.2.1	Must evaluate the effect of COVID-19 on the project.	see section 3.6	High
NFR 3.3	Must account for ethical issues in the specification, design, development and testing of the system.	see table 3.1	High
NFR 3.4	Must account for time spent learning a new language.	see section 4	Medium

Table 3.3: Non-Functional Requirements: General Non-Functional Requirements

3.3 Functional Requirements

1. User Data			
ID	Requirement	Source	Priority
FR 1.1	Must store relevant user data.	Basic project idea	High
FR 1.2	Must allow users to access their data.	Basic project idea	High
FR 1.3	Must allow users to list products on the marketplace	Basic project idea	High
FR 1.3.1	Must allow users to enter a description of the product they are listing	Basic project idea	High
FR 1.3.2	Must allow users to view the description of a product that has been listing	Basic project idea	High
FR 1.4	Must allow users to reserve products on the marketplace	Basic project idea	High
FR 1.5	Should have a section for user leader-boards	see sections 2.2.3 and 4	Medium
FR 1.6	Should have a section for user gained rewards and those yet to unlock	see sections 2.2.3 and 4	Medium
FR 1.7	Should have a section for the products the user has listed, in the user section of the app	see section 4	Medium
FR 1.8	Must allow the user to create an account	Security	Medium
FR 1.9	User must be allowed to log-in to thew system using unique credentials	Security	Medium
FR 1.10	User must be allowed to log out of the system	Security	Low

Table 3.4: Functional requirements: User Data

2. Persuasive Technology			
ID	Requirement	Source	Priority
FR 2.1	Should raise environmental awareness and explain the impact of food waste in the introductory pages to the application, for new users	see section 4 idea	Medium
FR 2.2	Should display the users food reduction stats (overall score, items saved, money saved and pollution prevented) so that users can perceive their control	see sections 2.2.3	Medium
FR 2.3	Must have an attractive interface to keep users from leaving the system	see sections 2.2.3 and 4	Medium
FR 2.4	Should notifications as a form of trigger to gain more user engagement with the app while avoiding being irritating	see section 4 and appendix E	Medium
FR 2.5	Should praise the user when a product has been reserved	see sections 2.2.3 and 4	Medium
FR 2.6	Should track users in the system and generate a leader-board to increase competitivity	see sections 2.2.3 and 4	Medium
FR 2.7	Should use natural language (as if spoken word) where possible	see sections 2.2.3 and 4	Medium
FR 2.8	User should be able to unlock rewards for completing certain tasks (for example, listing their first item)	see sections 2.2.3 and 4	Medium

Table 3.5: Functional requirements: Persuasive Technology

3.4 What is not included in the scope

Due to parts of the work need for a complete app are not covered in the dissertation part of the project, there will be some limitations for what is included in the scope. Due to the rewards section of the solution requiring artwork for each reward, each reward will be represented by a star. This would be updated in future works.

Furthermore, functionality which is not needed for this project and would only be an accessory feature that would aide usability will be excluded from the project. For example, allowing users to view other users account would fall into that category and has not direct impact on the functionality of the system.

Finally, the project will not need high levels of security as the data used in the application will be anonymous to prevent data being compromised.

3.5 Conflicts Between Requirements

To avoid conflicts between requirements, the larger requirements were split into smaller sub-requirements. As a result, no conflicts were found. However, if any conflicts had arisen while designing and/or implementing the solution, depending on the requirements' priorities, the most critical requirement would have been dealt with first. However, in the case that the requirements that are conflicted both have the same level of priority, potential users will be used to gain more information on how to handle the issue.

3.6 Project Risks

The risks for this project were continuously reviewed for the duration of the project and therefore the risk table has been updated frequently. Initially, basic risks were established which were applicable to a non specific app development project and those which could effect this project based on personal skills and experience. Each risk has been categorised with both a probability and its effect on the outcome of the project. In addition, each of these risks have also been provided with how the problem will be mitigated if the risk becomes true and occurs. The probability of a given risk could be ranked 'Low', with little to no chance of it occurring, 'Moderate', with a reasonably likely chance of occurrence, and 'High', with a high chance of it happening. The effects have been categorised into 4 levels of impact: 'Negligible', 'Marginal', 'Critical' and 'Catastrophic', increasing in severity respectively. 'Negligible' and 'Marginal' can easily be recovered from while 'Critical' could put the project under a lot of stress and 'Catastrophic' could ultimately lead to the failure of the project.

However, with the rapid spread of COVID-19 (*BBC News*, 2020*c*), the COVID-19 section of the risks table, see figure 3.1, have a very high chance of becoming a reality. Therefore, the work which would be affected by the virus should be prioritised before the situation become severe, see section B in the appendix.

ID	Risk	Probability	Effects	Mitigation
R1	Fall ill and may not have enough time to complete the project to the desired level.	Low	Negligible	Establish new schedule to complete the project
R2	Changes to requirements which could have a major impact on progress.	Moderate	Critical	Establish parts that are reusable and new schedule to complete the project
R3	Do not have the relevant experience to complete certain tasks			
R3.1	Do not have any experience with the chosen programming language	High	Marginal	Take online courses available to the University of Bath
R3.2	Do not have the necessary experience to produce design diagrams	High	Marginal	Take online courses available to the University of Bath
R4	COVID-19			
R4.1	Social distancing is implemented and restricts the use of qualitative research (such as interviews and focus groups).	High	Critical	Conduct research to the best degree possible using online tools
R4.2	Social distancing is implemented and restricts the ability to test the system (such as observations)	High	Critical	Conduct research to the best degree possible using people quarantined in the same location
R4.3	Companies begin to shut down temporarily and effect the ability to conduct research (such as existing solutions)	High	Critical	This research is moved to a higher priority. If the apps shut down, then refer to online resources.

Figure 3.1: Identifying Potential Risks

Chapter 4

Design and Prototyping

What Does the User Need?

As seen in the focus group in appendix E, participants mentioned that they often "offer [their near expiration] food to flatmates" before throwing the food away. However, some participants brought to attention that when they "cannot find anyone to give [the food] to" they "throw [the food] away". Therefore, users are making efforts to reduce their food waste but do not see any options past giving the food to the people they live with. Therefore, the users need a solution allows them to give their food away to more than just the people they live with.

On the other side, using the results from the stakeholder questionnaire, see section 2.3, 75.9% of participants consider price to be an important factor when making food purchases as well as substituting products when a better price is found. Therefore, potential users have a need to save money. Therefore, users need a solution allows them to save money while receiving/purchasing food.

Proposed Solution

The app will be a marketplace, structured similarly to most application based shops and will use persuasive technology to gain a more consistent user-base and help users reach the target behaviour of reducing the amount of food waste that is produced.

Why is This Solution Appropriate?

The proposed solution meets the two user needs, mentioned in section 4.

1. Users need a solution which allows them to list the food they would otherwise waste on a marketplace to therefore, reach an audience outside of the people they live with. Hence, being able to distribute the food to someone who could use it.

2. Users need a solution which allows them to acquire food while saving money and obtaining food for free from a such a market place meets that need.

People do not currently avoid wasting food as much as they could, see section 2.3 and therefore, the target behaviour could be met with a system that facilitates this process.

4.1 Creating a Persuasive Technology

For this project, the eight-step design process, see in figure 4.1, has been used in the early stage persuasive technology design. Choosing to follow the eight-step design process is important for someone who has never build persuasive technology beforehand (Fogg, 2009*b*). Using the process will ensure that a manageable target behaviour is selected and therefore, not too ambitious and will allow the target behaviour to be expanded on and become more ambitious. Hence, increase the odds of the project being successful.

A focus group session was conducted to gain a better understanding of the needs of the target demographic. The results found in appendix E will be mentioned throughout this section.

4.1.1 Target Behaviour

It is important that the target behaviour be small, along side a higher success rate, so that it has the success was measurable (Fogg, 2009*b*). To follow this, the target behaviour should be the simplest behaviour, to focus on, related to the project. The overall goal of the project is to reduce the amount of food waste produced by students. Therefore a suitable target behaviour would be the one agreed upon in the focus group, see appendix E, with the help of the Behaviour Wizard (Fogg, 2010). The behaviour wizard helps determine the target behaviour that is desired by using a grid, see figure 4.2. In the case of this project, the aim is to increase behaviour over a period of time, a "purple span" behaviour.

Using the behaviour wizard has been useful as it has helped focus the needs of the solution to achieve the target behaviour. The solution must increase the number of triggers, ability and/or motivation to reach the target behaviour. The target behaviour chosen is as follows: Use produce which has been left over by other students (by me for the purpose of the test), 3 times in a week.

As there will be no users listing items on the system, the items available will be bought and given to the users that requested it. This will emulate the availability of items on the marketplace. The users in the study will be informed that the listed food is unwanted and that if not requested will be

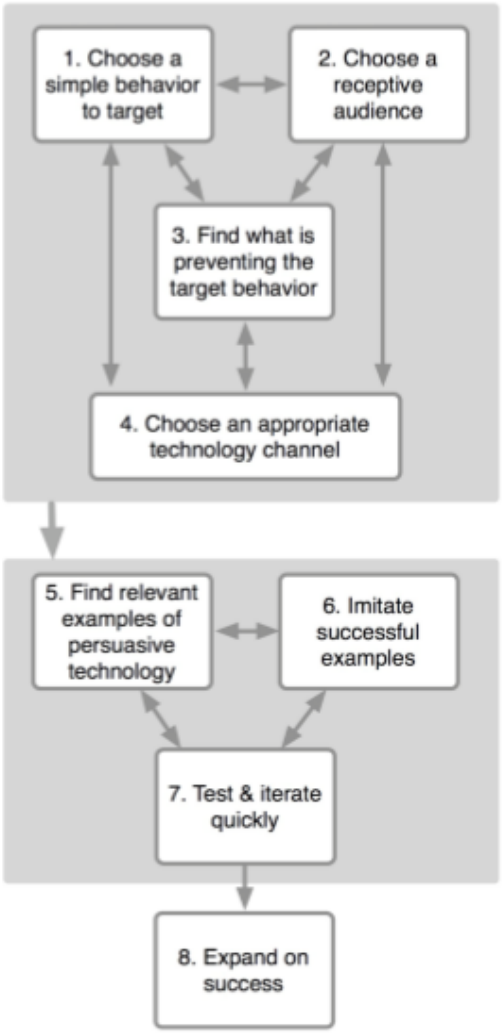

Figure 4.1: Eight-step Design Process (Fogg, 2009*b*)

thrown away and contribute to food waste. Furthermore, the time frame, of one weeks, was chosen because the behaviour needs to span over a period of time, as determined by the behaviour wizard.

Following the potential success of this trial, the project will be able to progress on to larger target behaviours (Fogg, 2009*b*), such as using the app on a daily basis over a longer period of time or increasing the usage per week.

	GREEN Do new behavior	BLUE Do familiar behavior	PURPLE Increase behavior intensity	GRAY Decrease behavior intensity	BLACK Stop existing behavior
DOT One time	GREEN DOT *Do a new behavior one time*	BLUE DOT *Do familiar behavior one time*	PURPLE DOT *Increase behavior one time*	GRAY DOT *Decrease behavior one time*	BLACK DOT *Stop behavior one time*
SPAN Period of time	GREEN SPAN *Do behavior for a period of time*	BLUE SPAN *Maintain behavior for a period of time*	PURPLE SPAN *Increase behavior for a period of time*	GRAY SPAN *Decrease behavior for a period of time*	BLACK SPAN *Stop behavior for a period of time*
PATH From now on	GREEN PATH *Do new behavior from now on*	BLUE PATH *Maintain behavior from now on*	PURPLE PATH *Increase behavior from now on*	GRAY PATH *Decrease behavior from now on*	BLACK PATH *Stop behavior from now on*

Figure 4.2: Behaviour Wizard Grid

4.1.2 Receptive Audience

For the receptive audience, students were chosen. Students would be a good target audience as students are more likely to be conscience of their finances, as seen in section 2.3. 69% of participants of the questionnaire answered that when throwing away food, the first thought is the cost of the item and therefore, how much money is being wasted. It has been shown that the number of loans taken out by national students as well as the amount loaned has been increasing exponentially (Bolton, 2019). Students continue to require more and more money to cover their tuition and maintenance. Students have mention that in some cases the loans do not even cover their rent and are required to look for a part-time job, or money form their family to support their education, see figure C.7. Therefore, students are more likely to adopt the target behaviour as it consists of incorporating free food into their usual meal planning.

Furthermore, students are very familiar with the technology channel, see section 4.1.4. The majority of students that participated in the questionnaire

and focus group have mentioned the use of similar apps, from ordering take-aways to loyalty schemes, see figures C.18, C.21 and C.24. Therefore, using students would increase the odds of reaching the target behavior being successful, see section 4.1.1.

Moreover, with a growing awareness to climate change due to media coverage, see section 1.1.1, there could be a stronger desire to address the issue and make conscious decisions towards more environmentally sustainable behaviour. Following the results from the focus group, the students mentioned that they would like to aim to produce little to no waste, in general, and were already likely to offer food, that they were not going to eat, to their flatmates/housemates, see focus group in appendix E. Therefore, already have some level of ability to prevent food waste.

Hence, students will be the receptive audience.

4.1.3 Barriers to Target Behaviour

The barrier could be at any of the levels established in the proposed model of environmental behaviour (Grob, 1995). For example, if there is no perceived level of control then they may not think their actions will have an impact.

Behaviour can be broken down into three factors following Fogg's Behaviour Model, motivation, ability and a trigger. Therefore, the failure to achieve target behaviour is due to either a lack of motivation, a lack of ability, a lack of a well-timed trigger, or a combination of. Looking at the graph, in figure 4.3, the target behaviour is represented by the green star. In order to reach the star, there needs to a high enough motivation, represented by the vertical (y) axis, and a high enough ability, represented by the horizontal (x) axis, to reach the target behaviour. The amount of motivation and ability depends on the person, therefore, the curve (in the shape of $y = x^{-}1$) separating the prevention of reaching the target behaviour and reaching it, is dependant on the person. Hence, the arrow on the graph reflects this by representing the increase in motivation as well as ability which leads to a higher likelihood of the user performing the target behaviour.

Furthermore, it is important to note the extremes of this graph, see figure 4.3. At the highest level of motivation, not a lot of ability is required. This is because the person with the extremely high motivation with go to any lengths, of greater difficulty, to reach the target behaviour. On the other hand, when a person has the highest level of ability they need minimal motivation to reach the target behaviour. For example, there may not be motivation to give away food when there is no intention to eat it but may check with flatmates if they are interested in eating it because of the high level of ability, as the flatmate is living with them and is only one conversation away (in this case the trigger is seeing that there is food about to expire in the fridge).

However, it is important to note that the likelihood of a person reaching the target behaviour does not guarantee that the target behaviour is completed.

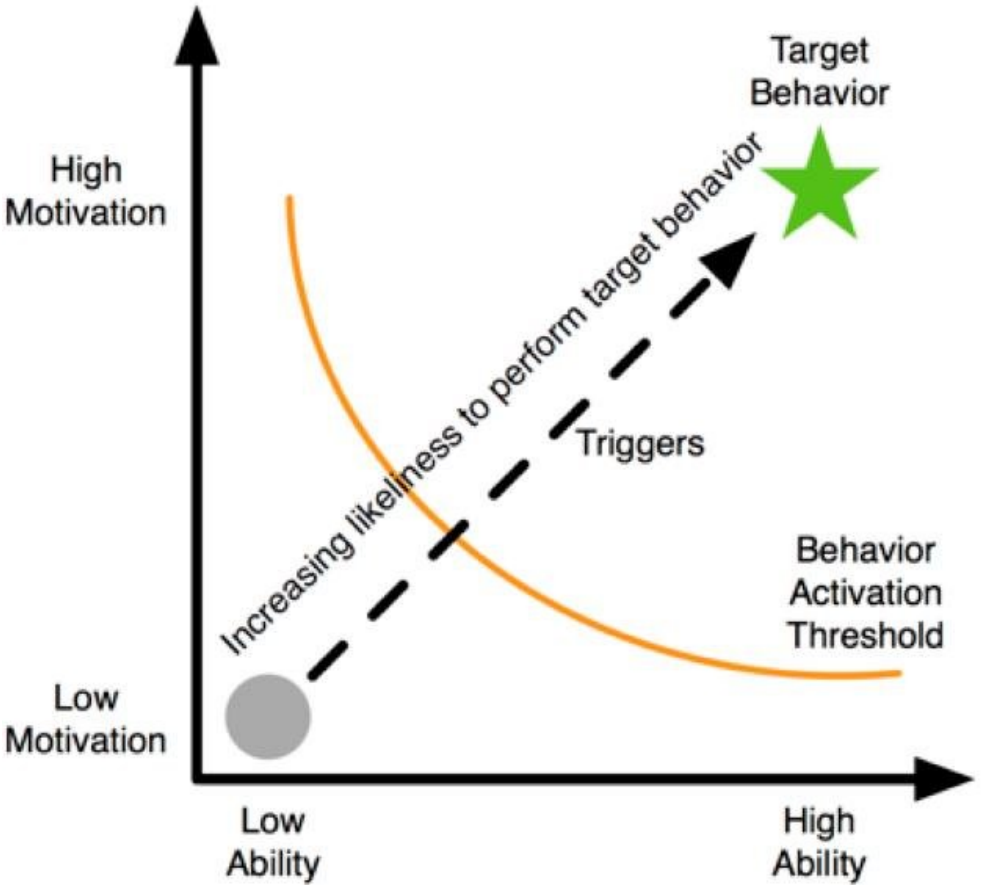

Figure 4.3: Fogg's Behavior Model and their Sub-components (Fogg, 2009*a*)

Therefore, an important factor is the trigger. When past the threshold of the of motivation and ability, all the person needs is a trigger to complete the behaviour (Fogg, 2009*a*). For example, if a person is motivated to recycle, for the benefit of the planet, and has to ability to recycle from their own home, as it is collected weekly; the person could still forget to put the recycling out on the correct day. Therefore, the trigger to remind the person that the recycling bins need to be put out is also an important factor. Otherwise, the bins will not be put out and the behaviour is not reached.

On the other hand, while the trigger is the most important factor, if the threshold of motivation and ability is not crossed then the trigger will become a distraction/irritation (Fogg, 2009*a*). This state needs to be avoided in order to reach the target behavior. Therefore, all three factors need to be taken into consideration.

What Would Prevent the Chosen Target Behaviour?

For the results from the questionnaire and focus group, see appendix C and E, participants mentioned that they would "like to reduce their waste" and some even saying they would like to "eventually reach a zero waste lifestyle". Therefore, students seem to have the required amount of *motivation*, as mentioned in section 4.1.2, if they are aware of the effects of food waste, discussed in section 2.1.2. Therefore, in the solution it is a requirement that the effects of food waste are discussed as well as the benefits of reducing that pollution.

Furthermore, as for the *ability*, participants of the focus group mentioned that the activity on the app would preferably need to take little to no time and fit into everyday life. Therefore, the solution will need to simplify the task and create focus on the tasks that are most important to simplify this process.

Finally, there needs to be a presence of a *well-timed trigger*. There is no dedicated time of day to decide on what to eat for a meal. Therefore, the trigger could be in the form of a notification and could be pushed to the user at a random time in the day. However, in future works, the notification could potentially be triggered when the user visits a supermarket to encourage them to plan buying food around saving a food product from another user on the solution. In addition, following the information gathered from the focus group, see appendix E, the trigger could use a *spark*, a trigger with a motivational element (Fogg, 2009*a*), to further motivate the user into pursuing the target behaviour. For example, use some motivational prompts in the notification, such as topics like saving the planet and reducing pollution.

4.1.4 Technology Channel

The choice of technology channel is based on the previous 3 steps (Fogg, 2009*b*). This is because the target audience cannot learn a new behaviour and a new technology channel at the same time. Therefore, as the focus is reaching the target behaviour, the choice of technology channel should be one that is familiar to the audience.

Using an app on users' smart phones will be the chosen technology channel because the solution needs to allow notification, be accessible when ever it is needed by the user and able to track the users progress, as these requirements were established by the previous step. Thus, a web application would not be suitable to meet the requirements. Furthermore, the audience is familiar with the technology, as discussed in section 4.1.2, and using a mobile device allows the service to go beyond the desktop and moves into people's day to day lives (Fogg, 2009*a*).

Moreover, for this project, Flutter will be used as it compiles to both Android and iOS. This allows for the app to be available to the 99.2%, as of September 2019, of the population (O'Dea, 2020).

4.1.5 Relevant Persuasive Technology

Due to COVID-19 analysing relevant persuasive technology has become more challenging with many food apps temporarily shutting down service until further notice, see section 3.6. However, some research prior to the outbreak was completed and will be discussed.

While looking at existing solutions, see section 2.4, there were some examples where the systems used persuasive technology.

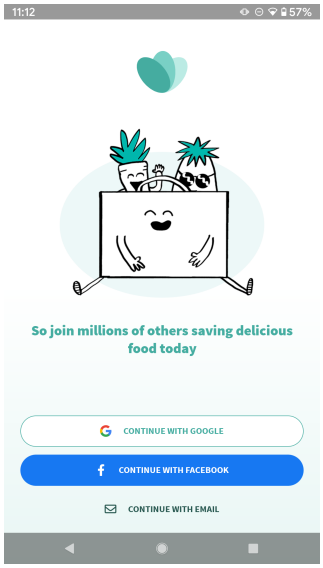

Figure 4.4: Saving Food Example

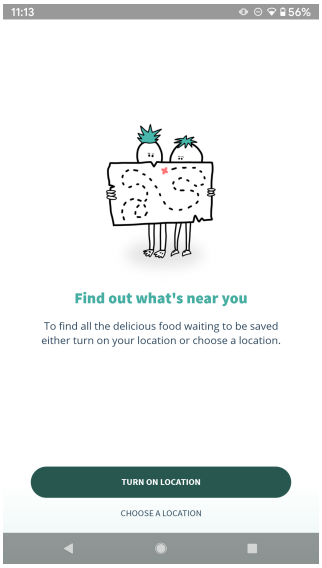

Figure 4.5: Another Saving Food Example

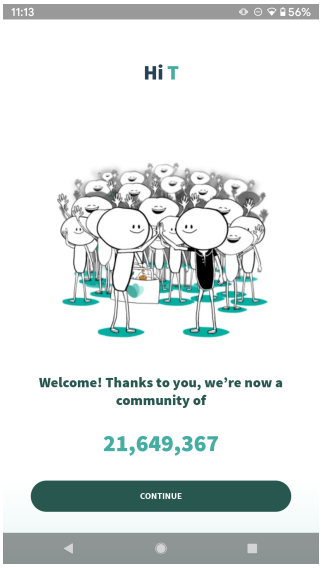

Figure 4.6: Social Acceptance Example

Aside from the use of praise, as seen section 2.4 when talking about figure 2.4, there are other forms of persuasive technology used by the TooGoodToGo system.

The system uses an element of motivation, one of the core motivators in Fogg's Behaviour Model, social acceptance. Research has shown that people are motivated to avoid social rejection and has impacts throughout their daily lives, from how people style their hair to what hobbies they enjoy (Fogg, 2009*a*). Therefore, TooGoodToGo has utilised this technique, in the registration process, by disclaiming that the new user has joined "millions" of other users, see figures 4.4 and 4.7, enforcing the idea that the app is successful and increasingly popular. Hence, motivating users to reach the target behaviour.

Furthermore, the system uses language to influence the user, see section 2.2.3. Using the word "saving" when talking about food conveys the idea that food needs saving and advertises it in a positive light inferring that saving it is a positive action, see figures 4.4 and 4.5. This is motivating as it reinforces

that the idea of saving food is a positive behaviour.

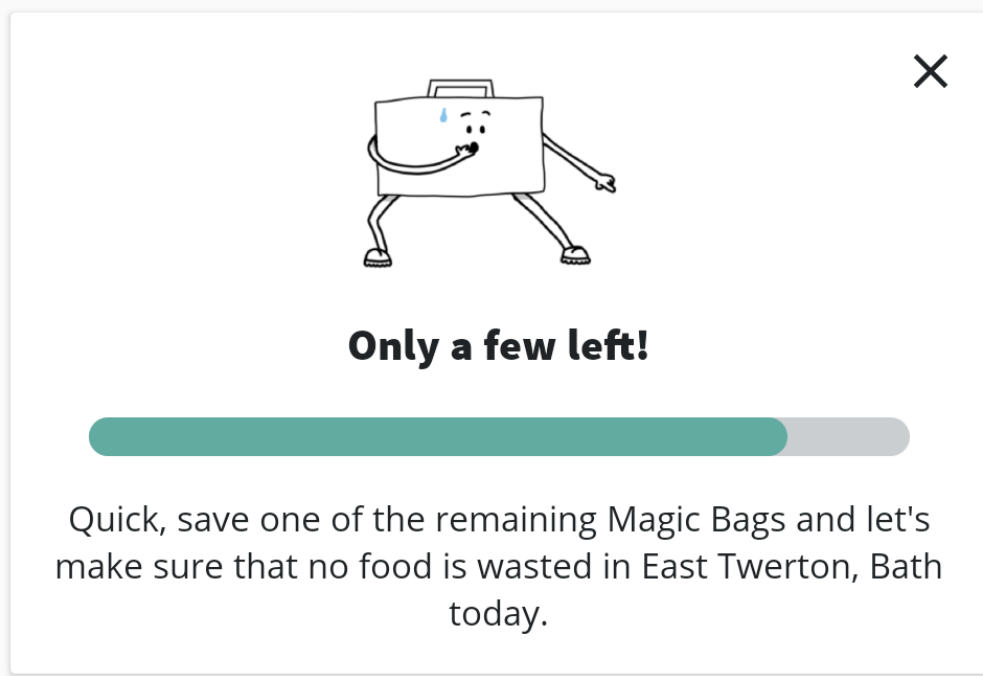

Figure 4.7: Use of Scarcity

TooGoodToGo also uses a spark (Fogg, 2009*a*), a scarcity prompt to motivate the user into making a purchase as soon as possible, as seen in figure 4.7. Furthermore, within the scarcity popup, the system also displays a sentence to persuade the user further. This text attempt to influence through the use of natural language, a technique discussed in section 2.2.3. Therefore, attempts to trigger the user into adopting the behaviour of purchasing a meal and saving food.

General Applications

As is true amongst all apps, being physically attractive is just as important as other persuasive techniques, as discussed in section 2.2.3. This can be seen in many related apps such as TooGoodToGo, as seen in the screenshots, as well as apps like Deliveroo and the Nike store app. Furthermore, it is also important to ensure there is a good user experience as it can have a negative effect if the user experience is unsatisfactory, as discussed in section 2.2.3 and seen in the example of OLIO in section 2.4. These factors cater towards the ability factor of the Behavioural Model because a well built interface design is easy to navigate and therefore, to complete tasks while the greater user experience reduces the problems the user has with the system, potentially slowing the

user down or stopping them form using the system in the future.

Furthermore, the use of gamification can have positive effects on persuading the user to continue using the system (Hamari, Koivisto and Sarsa, 2014). Therefore, providing a competitive element to the solution could also see these positive results, as discussed in section 2.2.3. For example, the use of a competitive leader-boards can lead to users trying to increase their score (Landers, Bauer and Callan, 2017). Hence, spending more time on the app and continuing to pursue the target behaviour. Thus can be seen as a motivating factor.

4.1.6 Imitate Relevant Successful Persuasive Technology

Following the persuasive technologies discussed, in section 2.2.3 and shown to be successful in section 4.1.5, the following techniques will be applied to the solution:

1. language to influence across the system
2. praise when the user reserves an item
3. an attractive interface
4. competitive feature, a scoreboard

The persuasive technology first needs to be imitated as the solution needs to have the foundation before becoming unique (Fogg, 2009*b*). These persuasive technologies will be discussed further when implementing the system.

4.1.7 Test and Iteration

Research has shown that small rapid testing is more beneficial compared with one larger test (Fogg, 2009*b*). Therefore, an iterative design process will be conducted later on in the project, where multiple prototypes are built and evaluated with user engagement, see the process from section 4.3 to 4.6; before moving on to developing the app in Flutter, see section 4.1.4.

4.1.8 Expand

Once the target behaviour has been reached and deemed a success by the evaluation, covered later in the project in section 6, the project can scale up the target behaviour (Fogg, 2009*b*). This is where we move through iterations to eventually reach the desired solution: save food that would otherwise be wasted from other users on a daily basis. On expansion, it is important that the target behaviour only varies by one or two attributes (Fogg, 2009*b*). Hence why it is important to have multiple iterations and slowly scale up the target behaviour. It is important to keep the same audience through this process as well as the same channel. In addition to have gain usable results, the iterations

must also have the same underlying psychology and keep the same methods of measurement.

4.2 App Structure

To build the app structure and functionality, the requirements were used and translated into features. To gain a better understanding of how the requirements should be implemented, user stories and scenarios were used to establish the required system structure and behaviour.

4.2.1 User Story and Scenarios

The user story helps determine the needs of the user and the scenario helps think about how the system should behave to meet that user need. These user stories and scenarios were created using the standard templates defined by Solis (Solis, 2011). Below are examples of the two most important features:

Giving Away Food

The first part of the app is the ability to list food on the marketplace.

User Story 1: The user has food that 'needs to be eaten' and decides to give the food away

As a user with food that 'needs to be eaten'

I want a method that facilitates the process of finding someone who wants the food

So that I can get rid of the food without the need to throw it away, hence, being more environmentally friendly

Scenario 1: The user lists an item on the marketplace

Given that the user has a photo of the desired item they wish to list, along with the name and description of said item

And the user wishes to list that item on the food waste reduction system's marketplace

When the user clicks on the 'list your own item' button, on the homepage

Then the user is sent to the required page to add a new item

And can enter the the data mentioned (in **Given**)

Then once the data has been correctly entered, the user clicks on the 'save' button

And is sent to the marketplace where the user can see their newly listed item

Receiving Food

The second part of the app is the ability to reserve food that has been listed on the market place.

User Story 2: The user has no food at home and needs to plan their next meal

As a user with no food at home

I want a method tho find free food to incorporate into my next meal

So that I can get food, save money (by not spending money on the found food) and be environmentally friendly by helping to reduce food waste

Scenario 2: The user looks for food on the marketplace

Given that the user wants food

And the user wishes to search for free food on the marketplace

Then the user can browse the different food options listed on the marketplace, on the homepage

When when the user sees an item that takes their fancy, the user can click on said item

And looks at the item's description

Then if the food's description suits the users needs, the user can click the reserve button

And the user is presented with a message of praise before going to collect the food that has been reserved

Conclusion

The user stories and scenarios have facilitated the visualisation of the structure and expected behaviour of the desired solution. Other Scenarios were created for different tasks as well as different behaviours concerning the same task. For example, for scenario 1, there are equivalents for where the scenario has incorrect or incomplete data, causing the system behaviour to let the user know that the data is incorrect or incomplete.

Using the gathered information from user stories and scenarios the system will be able to be concretely defined with a system hierarchy diagram, see figure 4.8.

4.2.2 System Hierarchy

Homepage

To ensure the implementation of requirement NFR 2.4 'Must be streamlined to be as efficient as possible, to keep users from getting bored by the process', see section 3, the most important features will be accessed from the homepage.

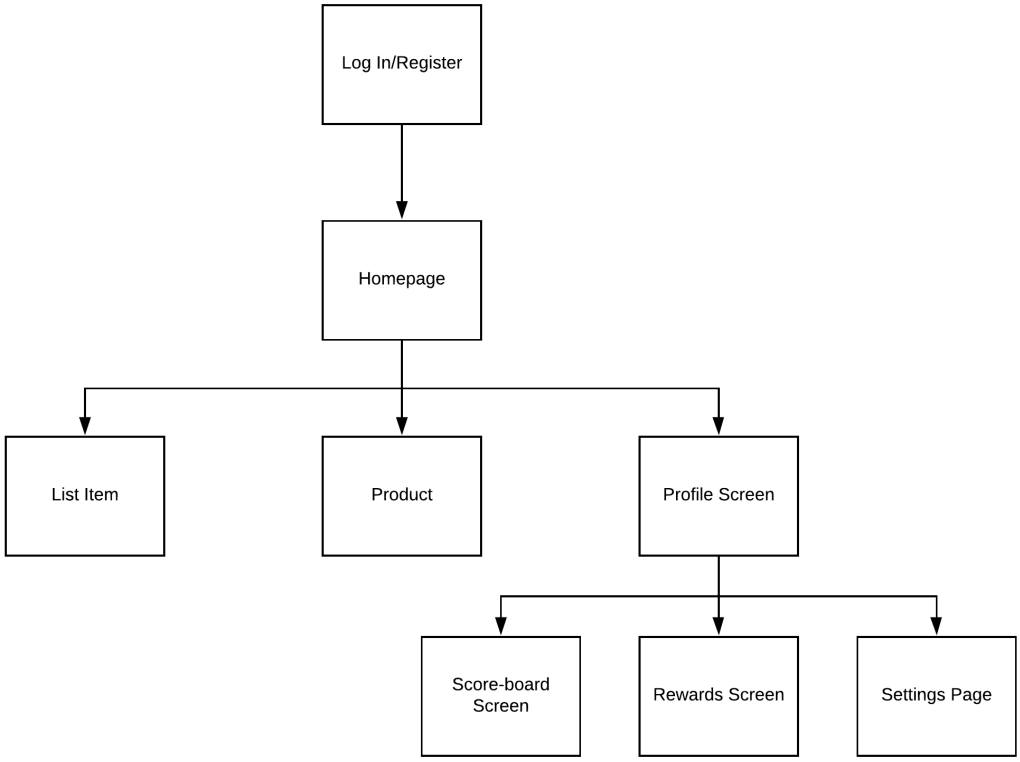

Figure 4.8: App Structure

The two most important features in the app will be listing and reserving items (requirements FR 1.3 and 1.4) as these features will allow for the pursuit of the target behaviour. Therefore, from the homepage the users will have access to each item on the marketplace, which each having a product details page, and a button to allow the user to enter details, to list a new item, in another page. Furthermore, the homepage will need to provide access to the rest of the app, which will be the profile section, see figure 4.8.

Profile Screen

The main feature of this screen will be requirement FR 2.2 'Should display the users food reduction stats (overall score, items saved,money saved and pollution prevented) so that users can perceive their control'.

On the profile screen users will have access to 3 more pages. Users will have access to the competitive leader-boards (requirement FR 1.5 'Should have a section for user leader-boards') and the rewards that the user can achieve (requirement FR 1.6 'Should have a section for user gained rewards and those yet to unlock'). The profile section will also provide access to user data, following requirement FR 1.2 'Must allow users to access their data', through

settings page, see figure 4.8.

Furthermore, the user will be able to log out from the settings page, following requirement FR 1.10 'User must be allowed to log out of the system'.

Account Creation and Log in

Similarly to other account based systems, users will need to be able to create an account and be able to log in (requirements FR 1.8 and FR 1.9). These screens will be positioned prior to the homepage. The default screen will be a log in screen, however, the user can click the register button to change the screen into the register a new account page, see figure 4.8.

1st Use Introduction Screens

To implement requirement FR 2.1 'Should raise environmental awareness and explain the impact of food waste in the introductory pages to the application, for new users', 3 introduction screens will be created to brief the user about the impact of food waste and the context and use of the app. However, these pages are not included in the app structure figure as they will only be part of the system on the first use of the app.

Conclusion

Now that the basis of the app has been structure, a use-case diagram will be constructed to gain another perspective and determine if any other events are required in the system.

4.2.3 Use-Case Diagram UML

The use-case diagram has been created to demonstrate further what the user has access to and how they can interact with the site, reflecting the structure discussed above, see figure 4.9.

Events

The event "View Marketplace", seen in the figure, is the content displayed on the homepage alongside the options to "Add New Listing" and access the product details page where the user can "Reserve a Product", as discussed in section 4.2.2. Furthermore, the access to the "View Account", "View Leaderboard" and "View Rewards" events also reflect the structure determined in the system hierarchy, see the Profile Screen section of the app in figure 4.8.

As mentioned in the conclusion of section 4.2.1, there are different scenarios for the same tasks. The use case diagram demonstrates this with the specified events on the right hand side of the diagram. Using the example seen in section 4.2.1 with the listing of an item, the system verifies the input details. Hence,

Figure 4.9: Use-Case Diagram UML

there are different scenarios depending on the input data. For example, if the user does not input a valid photo, the user will return an error message saying that the image is in the incorrect format.

A similar case can also be seen with the register and log in screen. With

the input details also being verified. Hence, returning different error messages.

Conclusion

The user case diagram has helped bring to light the placement of the marketplace as well as secondary events such as verifying data and displaying error messages when needed. Furthermore, the diagram has established another point of view to provide more clarity and a better guide to how to design and implement the system.

4.2.4 High Level Architecture Diagram

The following section is to demonstrate how the system would be structured and what systems are contained within the system at a high level.

Authentication System

The authentication system is the entry point of the system. The user must enter their unique credentials, their username and password, to authenticate the user and grant access to the rest of the system. Using their personal details allows the system to provide the user with data specific to their account and protect it from other users, for privacy reasons. Once the user has been logged in, the user may then communicate with the input system to reserve or list a new product.

Input System

The input system is where the users adds data into the system. The user may list a new item in their store, as shown as product input sub-system in figure 4.10, to be displayed on the marketplace, or reserve an item, in its named subsystem. This data is then sent to the data processing system.

Data Processing System

This system is made up of three subsystems as well as the database.

The ordering sub-system is where reserved items are processed to check the availability of the product, then if the product can be reserved, the database is updated. The order is then also sent to the Data analysing sub-system where the system checks if the user' score and otter stats are updated and check if the user is entitled to any rewards. This data is then passed on to the data output sub-system.

The data analysing sub-system can also receive data from new listings which is processed to determine if the user' score and otter stats are updated and check if the user is entitled to any rewards, similarly to when an item is reserved. Following this, if stats and rewards need updating, then the data is

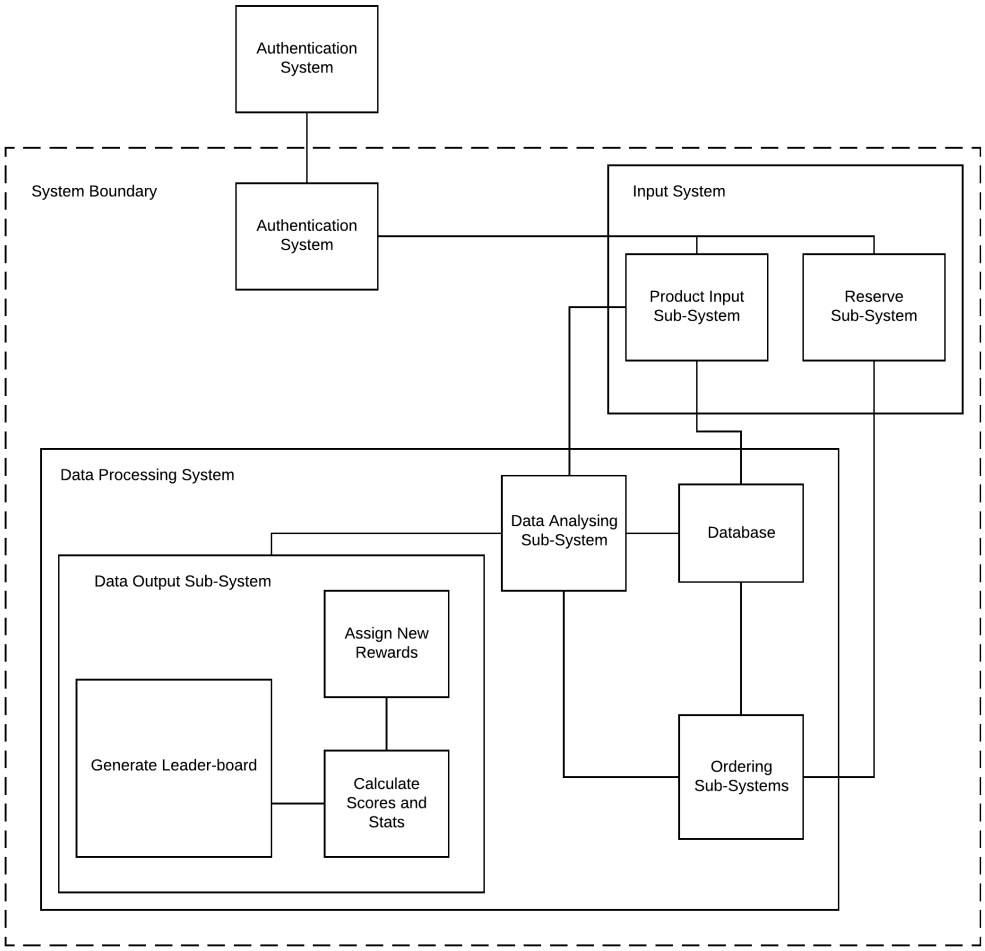

Figure 4.10: High Level Architecture Diagram of the System

sent to the data output sub-system, and the new listing details are stored in the database.

Data Output Sub-System

This sub-systems is dedicated to producing the scoreboard, rewards, score and stats of a user based on the data received from the data analysing sub-system.

Conclusion

The use of user stories and scenarios has been important as it has envisioned realistic use of the application and how the user would think about using the system and therefore, permit the creation of the behaviour and structure of

the app that would most reflect the user needs. The next step in the design process will be designing the Interface.

4.3 Interface

Following the definition of the solutions structure and functionality, the interface and its design will be discussed. As mention in section 2.2.3, the system needs to be attractive and have a good user experience if it is to hold a strong user-base. Therefore, focus on the system's interface is of great importance. Hence, a great user experience (UX).

Before reaching the final design, two different prototypes were created, see the complete prototypes in the appendix under sections F and G. These different versions of the system were created using behaviour-driven development (Solis, 2011). Behaviour-driven development allowed the development to focus on the behaviours of the system, defined in the requirements, section 3 as well as in test cases in the testing section, see section 5. However, no automated acceptance testing tools were used as the system is small enough to conduct manually.

4.4 1st Prototype

To have a good starting point, The discussed structure needs to be supported with HCI principles to avoid having to restructure the whole prototype. Hence, the design choices made for the first prototype will be justified.

4.4.1 Uncluttered Interface

For a great user experience, the interface needs to avoid making the user think (Krug, 2006). Therefore, the first implementation of the interface it to limit the amount of interactive elements on the page to a maximum of 7. This will help users not get confused or overwhelmed. Furthermore, all interactive elements are placed in familiar locations as seen in other applications, see section 2.2.3, which will reduce the learning curve. Therefore, new users should be able to have just as great of a user experience as those who have been using the system for a longer period of time.

4.4.2 Aims

The aims of this prototype is to best represent each screen shown in the system hierarchy diagram, see section 4.2.2, while following HCI principles.

4.4.3 Prototyping Software

The 1st prototype was build using JustInMind Prototyping software (*JustInMind Prototyping tool*, 2020). This application was the first which seemed to fit my requirements most appropriately, being free and allowing access to the tools to provide a basic user experience when testing. However, during the implementation of this prototype, it became apparent that the software was more limited that first anticipated. The software restricted the vision for the final product, providing out of date design implementations. In addition the mobile download of the app, to access the prototype on a smart phone had clearly not been updated recently as it was full of bugs and the prototype did not fit within the screen correctly. Therefore, for this prototype, the testing was conducted on a computer and from the next prototype iteration, the prototyping tools will be reconsidered.

4.4.4 Design Choices

The first prototype was drawn up with the initial requirements and using designs inspired from previously visited applications, such as those seen in section 2.4.

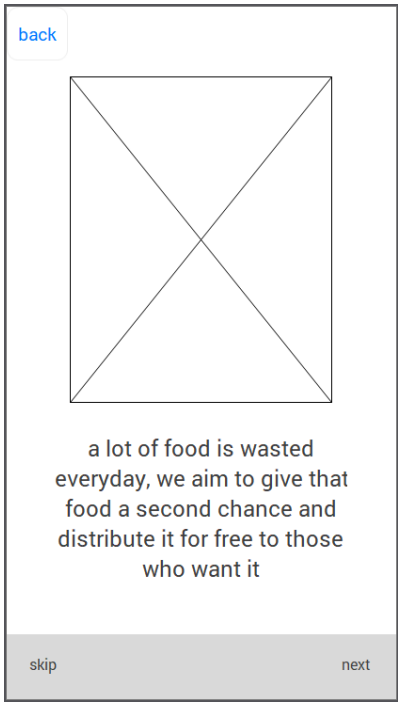

Figure 4.11: 1st Prototype: Intro Screen 3

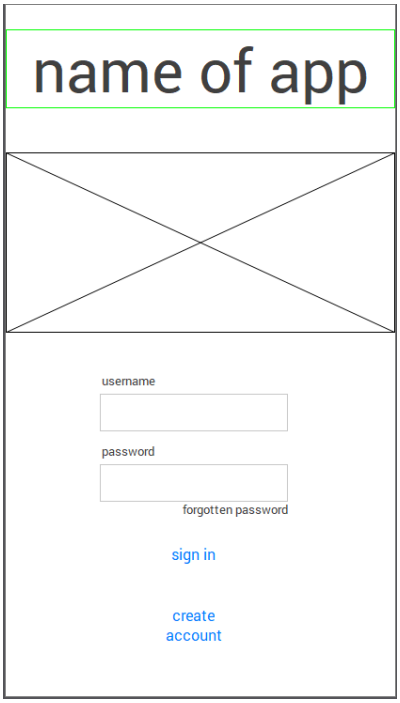

Figure 4.12: 1st Prototype: Login Screen

Introduction Screens

As previously discussed in section 4.2.2, following requirement FR 2.1 the app 'Should raise environmental awareness and explain the impact of food waste in the introductory pages to the application, for new users'. In the system hierarchy section, the use of 'one time use' introduction screens were discussed. Therefore, this method will be implemented as the design choice for this requirement, see figure 4.11 one of the three screens (see appendix for the other two). The prototype displays the text, attempting influence through language, that will be used as a persuasive method.

Furthermore, the screen is also complemented by a photo placeholder where a relevant photo can be used for the artistic side of the application. However, for this project, there is no need to decide on the photo to be used. The placeholder is depicted by a box with a cross going through it.

In addition, there have been some navigation buttons to navigate through the introduction screens and reach the actual system. The navigation bar at the bottom of the page will be used throughout the system to convey a section of the screen that is interactive, as a method of consistency (Krug, 2006).

Log in and Register Screen

The log in screen, seen in figure 4.12, has been heavily influenced by the research conducted in existing systems, see section 2.4. Since the structure of a log in and register screen has been standardised, there is not much room for improvement. The screen will just follow the house style of the application (Krug, 2006).

Moreover, a space has been allocated for an image. The space is depicted the same way as previously seen.

Homepage

To meet requirements FR 1.3 and 1.4, see section 3, which relate to being able to list and reserve an item on the system, respectfully; the following screen has been designed, see figure G.5. The user may list a new item by clicking on the 'list a new item' button, which will direct them to the new product entry page where the user can enter the details about the item they wish to list.

Furthermore, the user may interact with the 'recently listed near you' section, which can by expanded by clicking on the title of that section, directing the user to the listings page, as seen in figure 4.14.

These two features have been made prominent on the homepage as these are the two most important task in order to pursue the desired target behaviour.

Furthermore, the homepage will need to provide access to the rest of the app, as defined in the system hierarchy, figure 4.8. Therefore, the homepage

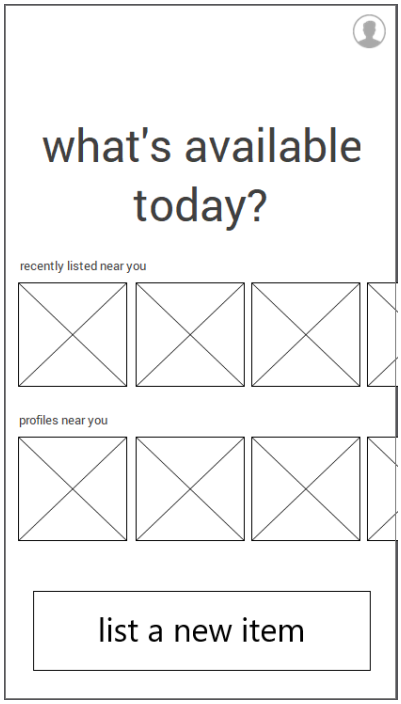

Figure 4.13: 1st Prototype: Homepage

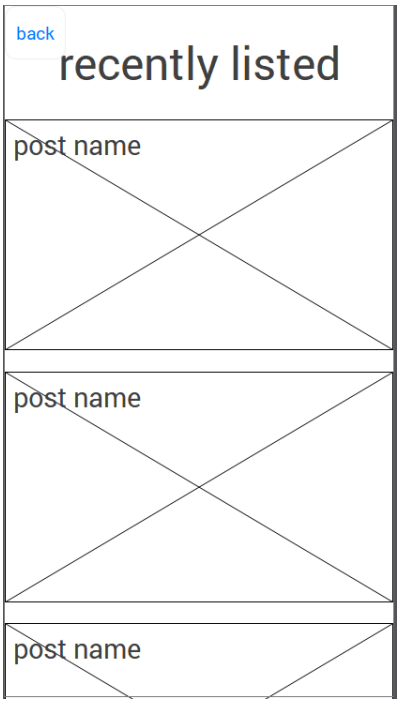

Figure 4.14: 1st Prototype: Listings Page

has a user icon at the top right hand corner, permitting the access to the rest of the app.

Listings Page

Seen in figure 4.14, the page allows users to interact with the available listings. Here the user can scroll through the available listings and click on one that could take the user's fancy which will direct the user to the product details page, as seen in figure 4.15.

Post Details

This page was created to meet requirement 1.4 'Must allow users to reserve products on the marketplace', as mentioned previously. This allows the user to see the post's photo and name as well as the reserve button.

In addition to the main feature of the page, there will be a link to the user's profile, their most recent rewards that they achieved and the walking distance to pick up the item. The walking distance felt appropriate as the objective of the app is to be environmentally friendly, therefore, walking should be the default method of transport as not everyone has a bike.

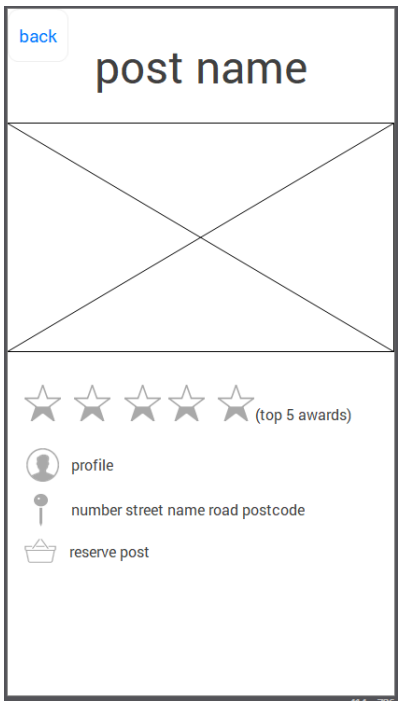

Figure 4.15: 1st Prototype: Post Details

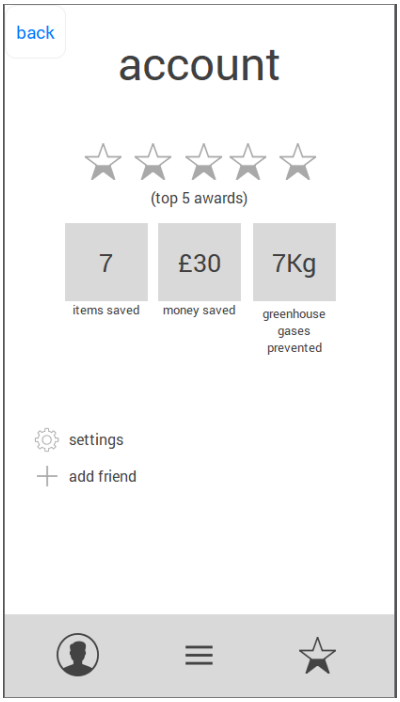

Figure 4.16: 1st Prototype: Account Page

Account Page

The account page has been designed as shown in figure 4.16. The three boxes in the middle have been designed as to meet requirement FR 2.2 'Should display the users food reduction stats (items saved,money saved and pollution prevented) so that users can perceive their control'. Hence, from left to right the boxes display the number of saved items, the amount of money the user has saved from not buying the equivalent items and the amount of pollution prevented due to saving those items. Above the three boxes, the user's 5 most recently unlocked rewards are also shown (represented by stars in the prototype).

Furthermore, the page uses a navigation bar at the bottom of the screen so that the user can access the leader-board and rewards (meeting requirements Fr 1.5 and FR 1.6, respectively, see section 3).

In addition, the settings and 'add friend' options are also present on the screen to access those features (the add friend option would be removed shortly after due to focusing on the app's core functionality).

Full Prototype

To see the entire prototype see appendix F.

4.4.5 Evaluate

To analyse the prototype, user engagement was used to gain feedback and to meet requirement NFR 2.1 'The system must have a large focus on user experience'

Participants

Independent interviews over 5 participants were conducted. These participants were aged between 21 and 24 and had 3 male and 2 female. The sample size was ideal as it was large enough to gain different perspectives and small enough to gain qualitative data from the questions, including follow up questions. The sample also reflected the target audience of the project.

Material

Each participant was provided a smart phone with the active prototype. The participants were also required to answer questions during the interview.

Procedure

After being explained that it was important that the answers be as honest as possible to be helpful, the participants were asked to complete a number of tasks to reach certain screens. After each task the participant was asked about how they received the interface. These questions took into account element placements on the screen as well as what they thought worked well and what did not.

4.4.6 Conclusion

The overall feedback was the following two points:

Accounts Page Navigation Button Layout

When testing the prototype with potential users, the feedback related to the user's account screen, see figure 4.16, mentioned that the settings felt to be in a weird place. Therefore, the account screen should be considered for a redesign. The settings cog could be placed in a different location. A possibility would be to reconsider the design on the navigation bar and include the settings cog.

User Score

The users asked how the ranking in the leader-board was going to be calculated and this raised the question of how the overall score of all the stats was calculated. Therefore, as the question was asked in the first place, the

Figure 4.17: 1st Prototype: Settings Page

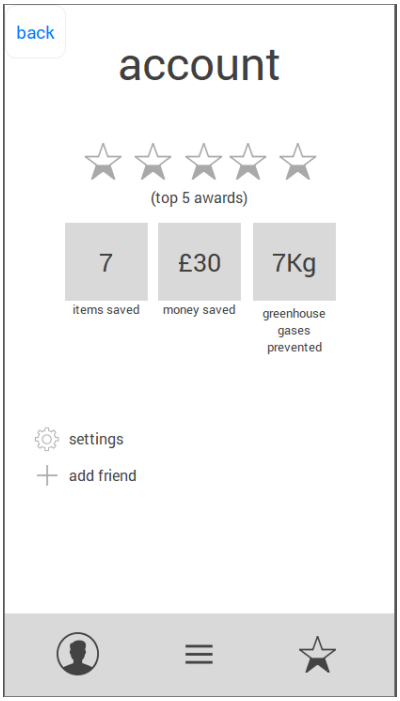

Figure 4.18: 1st Prototype: Profile Screen

user score will be displayed to ensure that the user knows what is taken into account to generate the leader-board.

4.4.7 Further Evaluation

The prototype was also evaluated by myself. Therefore, there is another aspect to consider in the next prototype.

Account Details Page

On revision of the settings page, see figure 4.17, the page was too cluttered and needed to be reorganised. Therefore, the placement of the account details needs to be reconsidered. This change is not needed due to feedback, however, the testing for the first prototype could not include changing any of the users details and therefore was not able to test data manipulation.

4.4.8 Redesign

Using the feedback gained in the evaluation of the 1st prototype, the appropriate redesign will be discussed in the the following section.

4.5 2nd Prototype

The 2nd prototype will building upon the 1st.

4.5.1 Aims

Using the feedback gained from the 1st prototype, redesign and update the prototype to ensure the best user experience as possible to meet requirement NFR 2.1 'The system must have a large focus on user experience'.

4.5.2 Prototyping Software

Following the use of JustInMind, new requirements for the prototyping tool became apparent. Therefore, Proto.io became an attractive solution (*Proto.io Prototyping Tool*, 2020). The tool allowed for more modern implementations and a import to mobile which was functional and seem more user friendly for potential users. However, the full access to the software only lasted 15 days. Hence, a fast implementation needed to be produced to be able to test with potential users. Therefore, the 2nd prototype was implemented using the new software.

4.5.3 Design Choices

The 3 points from the feedback received for the 1st prototype will be used to reconsider the design of the system's interface. The colour theme was applied to this prototype.

Account Details Page

As mentioned in section 4.4.7, the settings page was very cluttered as it grouped together all the settings on one page, see figure 4.19. Therefore, for the second prototype, the settings were broken up into multiple section, as shown in figure 4.20. The page was broken up to provide a better user experience as the structure became clearer, especially with the addition of universally accepted icons (Krug, 2006).

Furthermore, to follow requirement NFR 2.4 'Must be streamlined to be as efficient as possible, to keep users from getting bored by the process', see section 3, the feature to 'become a distributor' and the reserved product 'history' have been removed as features from the project. These features were not essential in the purpose of the project therefore should not be included in the most basis form of the solution.

In addition, 'feedback' and 'help' were grouped into the 'contact us' section to make the section more general and remove the number of possible options, to make the app more condensed. The notification settings were moved into their own section, separate from user data and a log out option was added

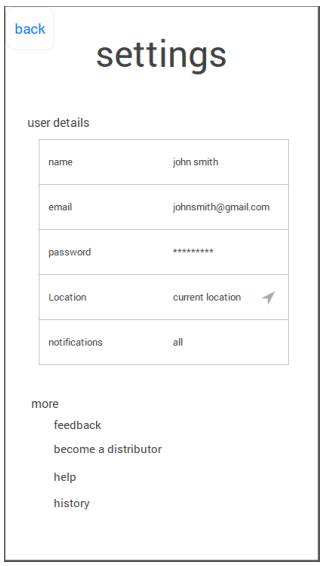

Figure 4.19: 1st Prototype: Settings Page

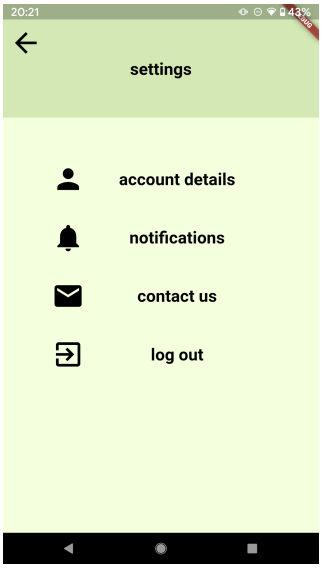

Figure 4.20: Example of Settings Page

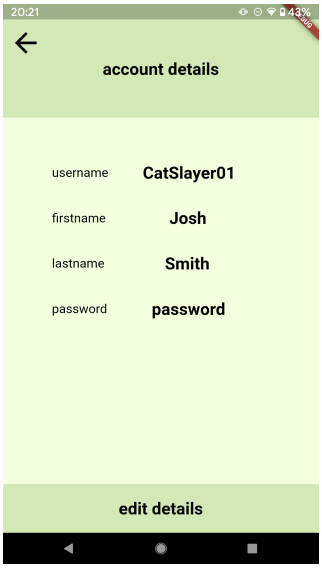

Figure 4.21: Example of Account Details Page

to meet the requirement FR 1.10 'User must be allowed to log out of the system', which was added to the requirements when a participant noticed it was missing.

Finally, The user details were moved into their own page as shown in figure 4.21.

Accounts Page Navigation Button Layout

From the feedback gained from evaluating the 1st prototype, the participants mentioned that they felt the 'settings icon was in a strange place', see figure 4.22. Therefore, the account button was removed from the navigation bar as it was not needed (as it is currently used as a back button with the current system hierarchy) and the settings cog was added to the navigation bar at the bottom of the screen, see figure 4.23.

User Score

To ensure that users were aware of how the leader-boards we generated, the user's score statistic was created and moved emphasis in favour of the score instead of the other three statistics, see figure 4.23. In addition, the requirement FR 2.2 was changed to add the score statistic: 'Should display the users food reduction stats (overall score, items saved,money saved and pollution prevented) so that users can perceive their control'.

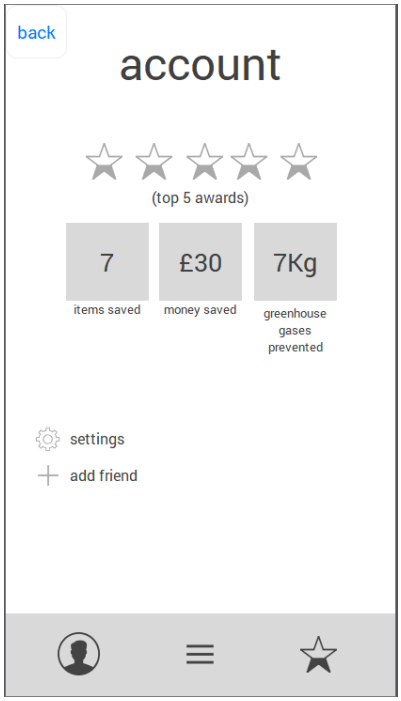

Figure 4.22: 1st Prototype: Profile Screen

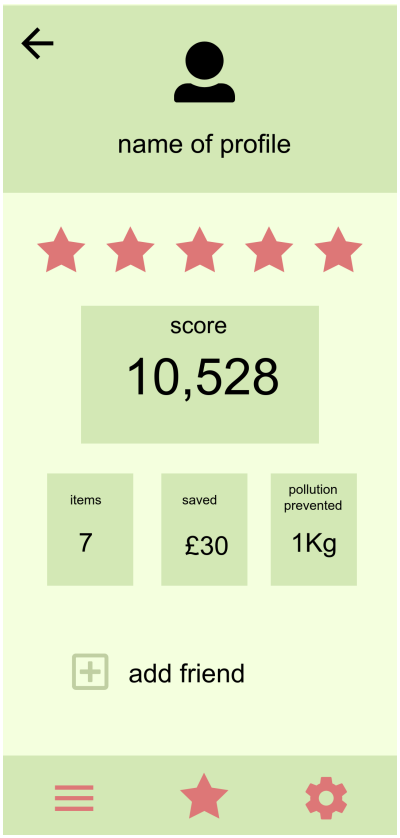

Figure 4.23: 2nd Prototype: Profile Screen

Full Prototype

To see the entire prototype see appendix G.

4.5.4 Evaluate

To meet requirement NFR 2.5 'Must test the usability of the system after any interface changes to ensure the user experience is keep to the best standard possible', the new changes need to be evaluated.

The sample will aim to be similar to the evaluation of the first prototype, by selecting students with a gender balance. The sample had an age range of 20 to 23 with 3 boys and 2 girls, with none of the participants being the same as the previous evaluation to avoid the training effect. However, the materials and procedures will be identical to that discussed in the evaluation of the first prototype, see section 4.4.5.

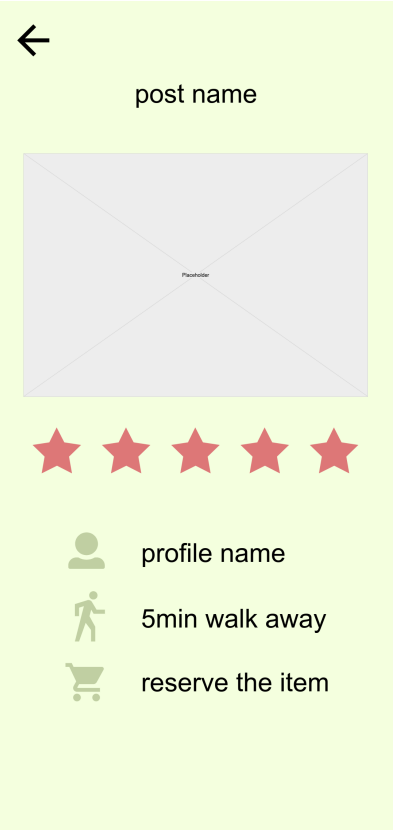

Figure 4.24: 2nd Prototype: Post Details

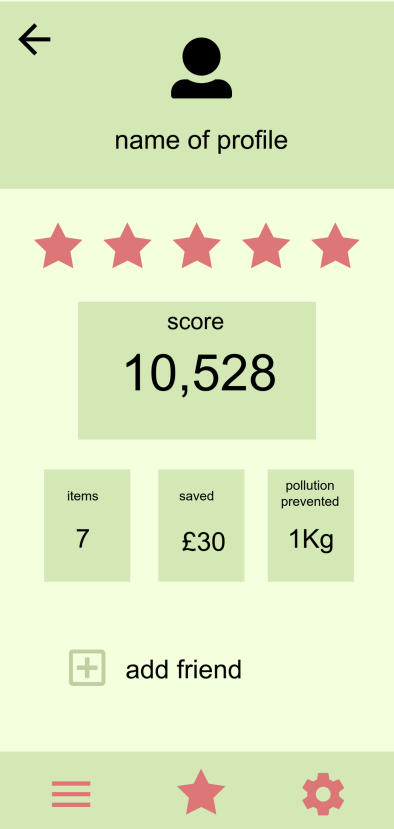

Figure 4.25: 2nd Prototype: Account Page

Listed Product Details

On evaluating the 2nd Prototype, it was brought to attention that the product detail page had no product description, see figure 4.24. Therefore, this feature will be added into the next version of the application.

System Hierarchy

During the testing of the second prototype, there were multiple comments, for the second time, about the logic of the button placements. They mentioned that the hierarchy of the pages from the did not provide a good user experience when navigating between the sections. The hierarchy in the 2nd prototype can be seen in figure 4.25. The participants in the user testing explained that it would be better if the navigation page did not take the users away from the profile screen but instead was included as one of the option on the navigation bar and all option were contained within the same level in the hierarchy.

4.5.5 Further Evaluation

The prototype was also evaluated by myself, as some aspects of the prototype may go unnoticed. Therefore, there are another 2 points to consider for the next version of the interface.

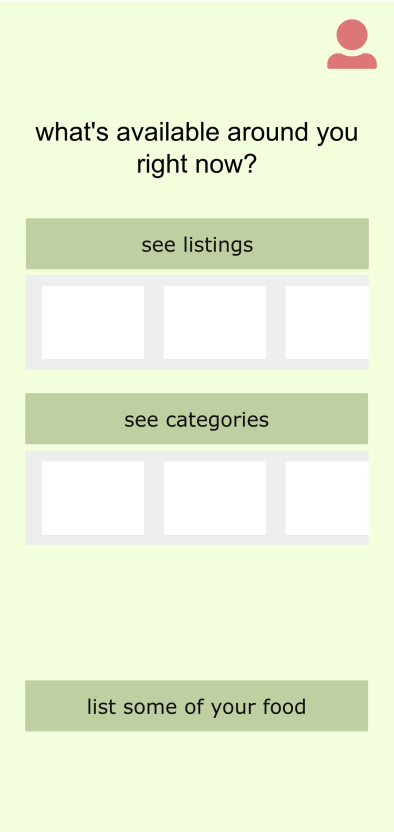

Figure 4.26: 2nd Prototype: Homepage

Streamline

The homepage has been broken down into two sections, see figure 4.26. The user is able to access a section for all the listing or is able to break down the listings into categories. However, this is not core functionality. To ensure the implementation of requirement NFR 2.4 'Must be streamlined to be as efficient as possible, to keep users from getting bored by the process', see section 3, the homepage will need to be reconsidered. Therefore, to make the system more efficient before adding 'accessory' features, the 'see listings' section could become the home page to reduce the number of steps needed to browse and reserve an item.

User Shop

As the participants were not able to add new items, they did not notice that there was no way to check on the items that the user has listed. Therefore this needs to be take into consideration when designing the next version of the interface.

4.5.6 Redesign

The interface will continue to be considered for redesign to meet requirement FR 2.3 'Must have an attractive interface to keep users from leaving the system'. The appropriate changes to the evaluation will be conducted in the next section.

4.6 Final Design

The final interface design will take into account all the work from the 1st and 2nd prototypes.

4.6.1 Aims

Building on the 1st and 2nd prototypes, the interface will continue to go through the iterative design process which will include the interfaces redesign and be developed into the final version of the solution. This further follows requirement requirement NFR 2.1 'The system must have a large focus on user experience'.

4.6.2 Design Choices

System Hierarchy

The feedback in the evolution of the 2nd prototype mentioned that the user experience when navigating between the sections in the user's profile section, was less than satisfactory and 'felt illogical'. The hierarchy in the 2nd prototype, of the user's profile section, can be seen in figure 4.27. The participants in the user testing explained that it would be better if the navigation page did not take the users away from the profile screen but instead was included as one of the option on the navigation bar and all option were contained within the same level in the hierarchy. Therefore, a new hierarchy was developed to reflect the new idea, seen in figure 4.28. In the new hierarchy diagram, the boxes with the dotted lines do not represent physical pages but instead a grouping of the pages linked to it.

For example, the 'User Area' starts on the 'Profile Screen' by default. Within the 'Profile Section', the user can flip between the 'Profile Screen' and the 'User's Shop', see figure 4.30. The 'Profile Screen' is indicated by the icon

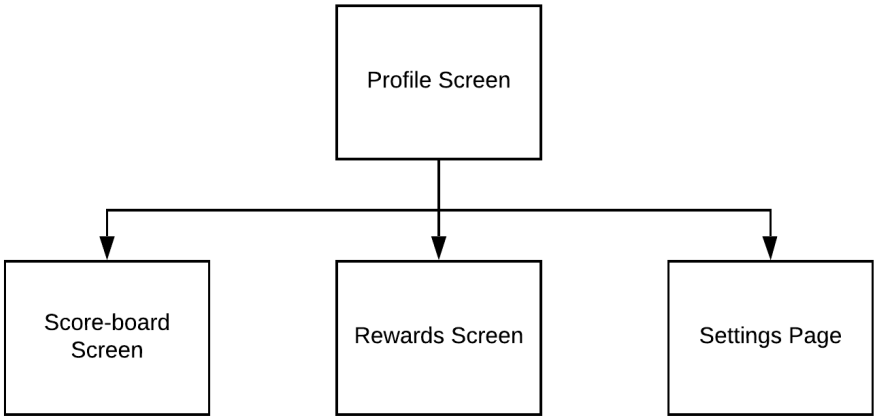

Figure 4.27: Profile Screen Hierarchy in the Second Prototype Diagram

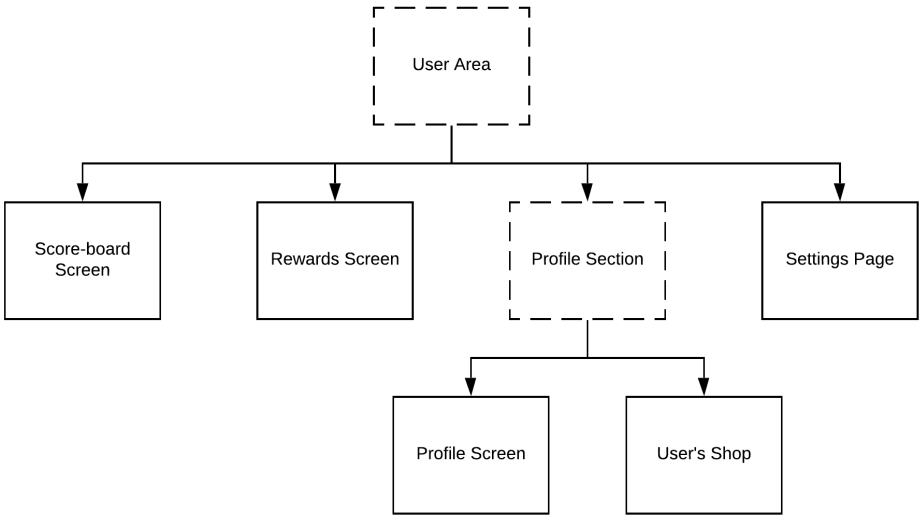

Figure 4.28: Profile Screen Hierarchy in the Final Design Diagram

grouped with the username (the light green box around the icon and username indicate that the profile screen is active) and the 'User's Shop' is indicated by the trolley and the word shop. Following that example, the 'Profile Section' is then contained in the navigation of the navigation bar at the bottom of the screen (the 'Profile Section' is indicated that it is active by the orange colour on the user profile icon).

Therefore, the system's hierarchy needed to be updated, see figure 4.32.

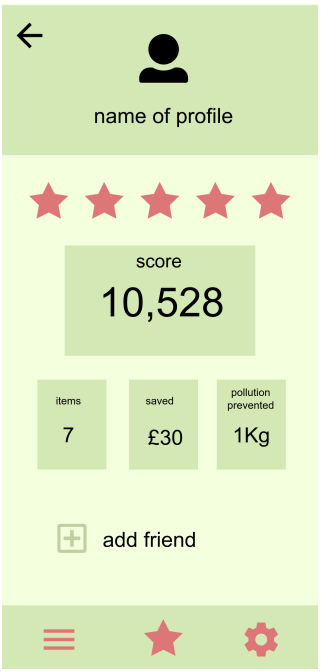

Figure 4.29: 2nd Prototype: Profile Screen

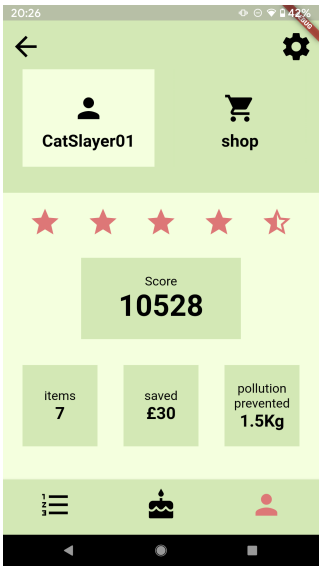

Figure 4.30: Final Prototype: Profile Screen

Figure 4.31: Final Design: User Shop Screen

Streamline

On review of the limitations of the scope of the system, the version of the Homepage as of the 2nd prototype, see figure 4.33, was not streamlined. Therefore, a more basic implementation of the homepage should be implemented. Hence, to make the system more efficient before adding 'accessory' features, the 'see listings' section could become the home page to reduce the number of steps needed to browse and reserve an item, see figure 4.34.

Listed Product Details

Previously, in both versions of the prototype, the product description was left out of the system, see figure 4.35. Therefore, new requirements were added:

1. FR 1.3.1: Must allow users to enter a description of the product they are listing
2. FR 1.3.2: Must allow users to view the description of a product that has been listing

Therefore, the two new features will be included in the final version of the solution, see figures 4.36 and 4.37.

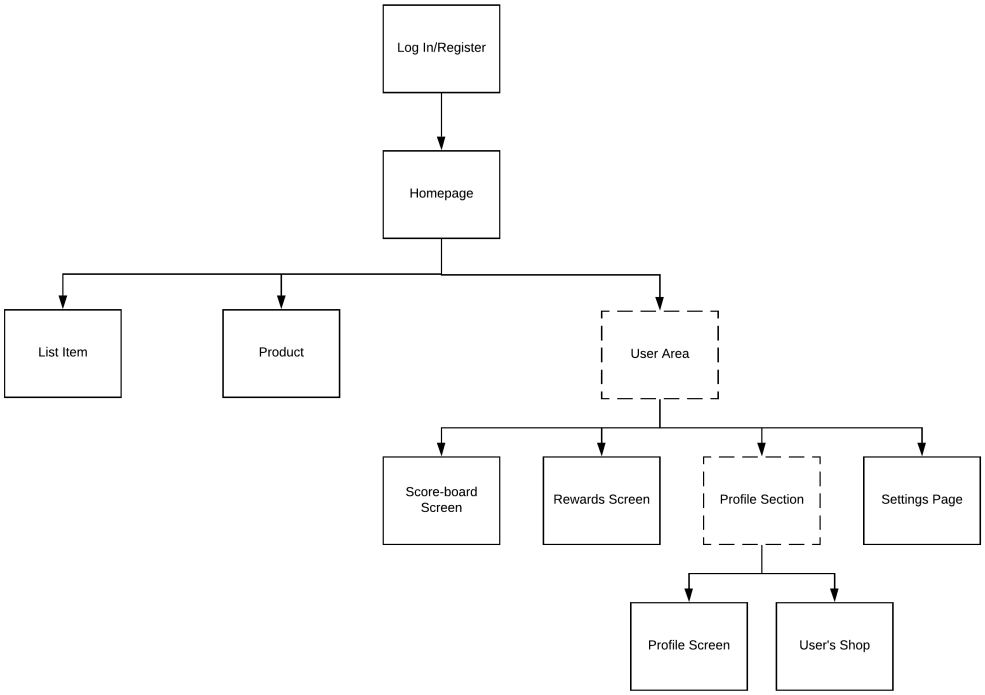

Figure 4.32: System Hierarchy

User Shop

As discovered in the evaluation of the 2nd prototype, see section 4.5.4, the user had no way of checking what items they had listed. Therefore, the requirement FR 1.7 'Should have a section for the products the user has listed, in the user section of the app' was added. Therefore, this required a redesign on the profile section of the application. Therefore, the top section of the profile screen where the user icon and the name of the profile, see figure 4.29 was redesigned into an interactive area. Therefore, the top portion of the screen was split into two buttons, highlighted when the corresponding page is active, as seen in figures 4.30 and 4.31. This change was also accounted for in the redesign of the system hierarchy, as seen in figure 4.28.

4.6.3 Evaluate

To meet requirement NFR 2.5 'Must test the usability of the system after any interface changes to ensure the user experience is keep to the best standard possible', the new changes need to be evaluated.

Repeating the same process as used for the evaluation of the 1st and 2nd prototypes, see sections 4.4.5 and 4.5.4, participants were asked to interact with the system.

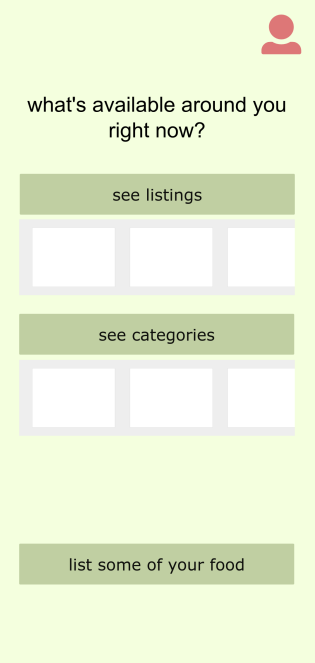

Figure 4.33: 2nd Prototype: Homepage

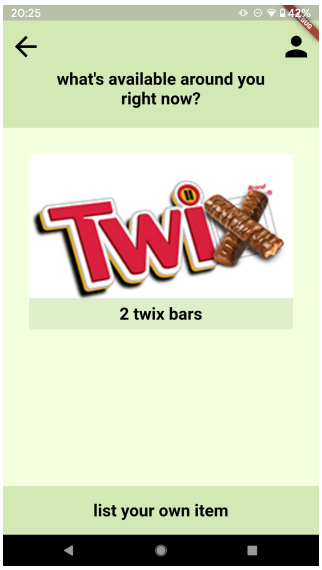

Figure 4.34: Final Design: Homepage

However, the 3 iterations of designing the interface did not receive any notable feedback. Therefore, this design will be implemented in the final solution and will be tested and evaluated to a higher degree in the following chapters, see chapters 5 and 6.

4.7 Exceptions to HCI principles

The app only uses universally accepted conventions to signify where the click of a symbol will take you. For example, as seen in figure 4.38, the back arrow, settings cog, user icon and shopping carts are all frequently used across all applications and pose a sense of familiarity. However, for the score-board and the rewards section, as they are not commonly used icons, a 'numbered list' icon and cake, respectively, like it would represent those sections appropriately. Furthermore, as those two section of the app are not critical functionality for the system, the users will be able to discover those sections on their own time.

Moreover, when designing the interface, the main idea was to keep it as simple as possible and only use words when needed and for reasons discussed in section 2.2.3. This is to follow the HCI principle 'less is more' (Krug, 2006). Everything should already be self-explanatory and not require any text instructions.

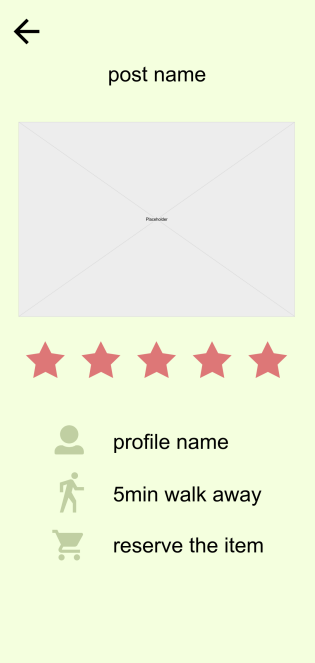

Figure 4.35: 2nd Prototype: Post Details

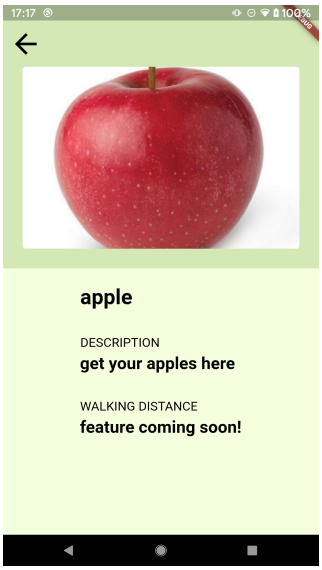

Figure 4.36: Final Design: Product Details Page

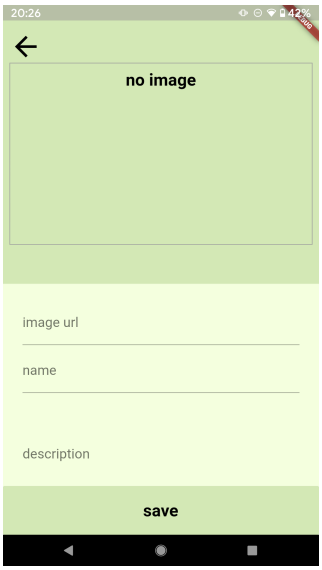

Figure 4.37: Final Design: List an Item Screen

However, there are exceptions to this implementation:

1. The page titles should be concise, following the 'less is more' rule. However, in the case of the homepage, the page's title is 'what's available around you right now?'. This choice was made to apply the use of the persuasive technology which persuades through the use of language, see section 2.2.3. The sentence was uses to display 'natural' language (written as if spoken language) to convey social presence.

2. On the homepage, see figure H.1 in the appendix, the 'list a new item' button uses text instead of an icon. This is because the ideal implementation of a floating button in the bottom right corner of the screen, as seen in many applications such as Google's Gmail app (*Gmail*, 2020), did not have a strong enough contrast with the items on the page. In user testing, potential users mentioned that it was hard to notice the first time. The only option was to use an extreme colour that did not fit in with the colour theme in place. Therefore, to resolve the issue a button was added to the button of the screen. The button was too wide to only have a 'plus' icon and hence was replaced with the text 'list your own item'.

3. On the product details page, see figure H.2 in the appendix, to reserve

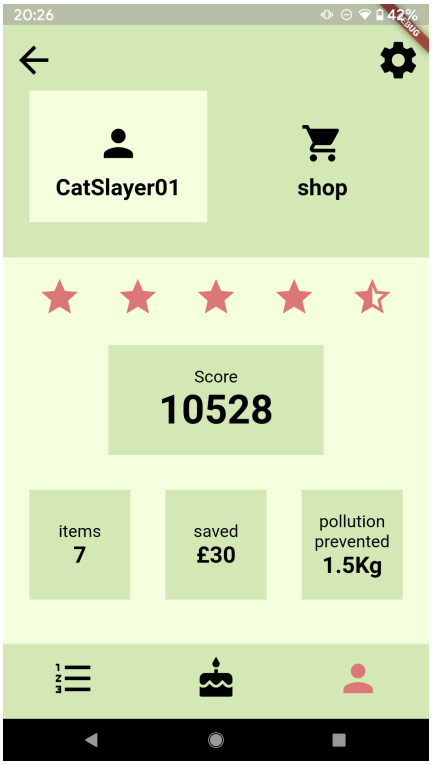

Figure 4.38: Final Design: Profile Screen

an item the user must click on the button located a the bottom of the page. This button uses text instead of an icon. The reason for not using an icon is that there is not an universally acknowledged symbol for reserving an item. The closest, well known icon, that could be used would have been symbols that represent buying a product (i.e. such as a symbol for a currency or a shopping cart). Hence, the choice was made to use the word 'reserve' instead as it felt more appropriate. However, the style of button is used in multiple places across the system, such as the 'list your own item' button, on the homepage, and the 'save' button on the 'list your own item' screen. Therefore, the use of these buttons is consistent.

4. The profile section, as seen in figure 4.28, the user is able to switch between the profile screen and the user's shop. The buttons to switch between these two screens use text, the user's username and the word 'shop'. This choice was made based on displaying the username and the need for the page to be symmetrical from a design point of view.

4.8 Limitations

As discussed in the requirements section, section 3, the parts which will not be included in the scope of the project are the design limitations. For example, the artwork of reward icons as well as 'accessory' functionality such as the categories section removed from the homepage, as seen through out the the iterative design process through the different prototype versions in sections 4.4, 4.5 and 4.6.

4.9 Conclusion

The iterative design process was useful as it allowed to work closely with potential users to understand their needs and how their needs can be achieved while using the system. Hence, providing a design that has a greater user experience than previous versions. To see the full prototypes see sections F and G in the appendix and to see the full final design, see section H.

Having completed the design process of the project, the design will now be implemented into the final solution.

Chapter 5

Implementation and Testing

Following the definition of the final design of the solution, the project will now enter development, implementing the established design.

5.1 Implementation

5.1.1 Development of Application

Choosing a Programming Language

When deciding how to build the application, the choice of language had to be considered. Usually there needs to be a choice between building the application for Android or iOS as they use different languages. However, Flutter, build by Google, was suggested as an option to consider (*Flutter*, 2020). The Flutter toolkit would allow to develop an app while can be compiled down to run on iOS and Android devices, therefore, using only one codebase.

Why Flutter?

The Flutter framework allows programmers to develop high-performance, high-fidelity applications. As mentioned above, Flutter is a tool which can be used to build native cross-platform applications, for iOS and Android, using only one language, Dart, and codebase. Moreover, Flutter provides building blocks, which include basic widgets such as buttons and text areas, which allow for rapid development and a small learning curve. These widgets are also customisable which is important to create a consistent theme for the app. This Dart code is then compiled into optimised and high performance native code for both Android and iOS. However, the Dart code does not translate directly to equivalent native code, or platform primitives, for each version. Instead, flutter builds the entire screen and therefore, has more control over the end result, as seen in figure 5.1.

Dealing with a Risk

Therefore, the risk 'R3.1', seen in figure 3.1, has become a reality as I do not have any experience with Flutter. Hence, a learning period is needed to take the online courses available to students studying at the University of Bath, O'Reilly (*O'Reilly*, 2020).

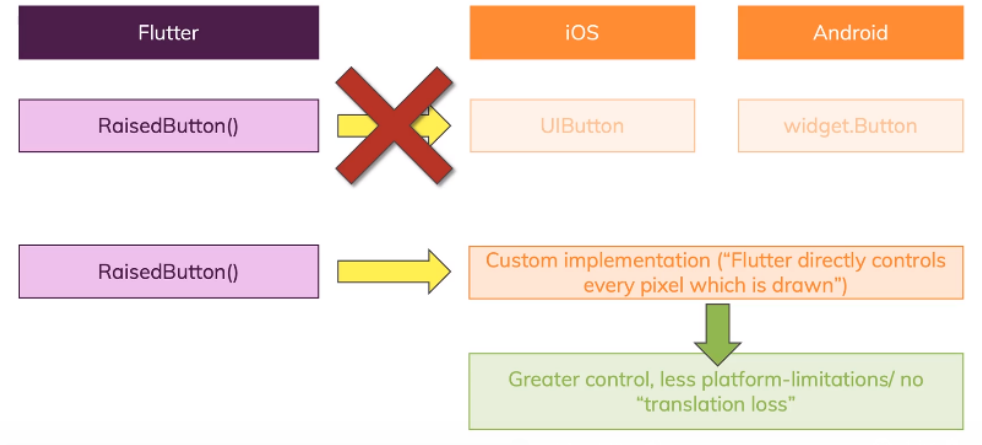

Figure 5.1: How Flutter converts Dart code

Other Tools

Furthermore, other tools were needed to fully utilise Flutter for the project. For the integrated development environment (IDE), Visual Studio was used as it was one of the recommended IDEs and the one which was most familiar. This choice was made to help mitigate the effects of having to learn a new programming language.

Furthermore, to be able to run the code and test while in development, a Google Pixel smart phone, running Android, was used. This allowed to gauge a deeper understanding of the usability of the app while developing as I could interact directly with the system, just as a potential user would. This was a viable option as I happened to have a spare phone and my personal computer had the limitation of having AMD processors which do not work well with running virtual devices.

Finally, Google Firebase was used to store the application's data (*Firebase*, 2020). Firebase offers a free service which offers all the services that are required for this project, an online database (allowing up to 5GB) and the use of cloud messaging. As this project is using behaviour-driven development, using a NoSQL database system such as Firebase is ideal as it allows for quick iterations. Behaviour-driven development focuses on system behaviour allowing the development and testing phase to be more efficient. Furthermore,

this database is flexible as most of the functions, already offered by Firebase, can also be created application side so that the choice of database can be altered in the future if needs be. Currently, if the application rolls out, Firebase offers a pay as you go service upwards of 5GB of storage, which is currently the best option. However, as the database functionality is currently application side, the database choice is flexible and can be changed if a better solution is available.

Building Process

The first 4 days of the development work were heavily guided by the O'Reilly, see section 5.1.1. O'Reilly provided a course that builds a basic application teaching how to build widgets and use them together to build a screen. Most of these initial days were spent understanding how the language is used and how the code is structured. This basic education was used to build the skeleton of my application and imitate the hierarchy established in figure 4.32, in section 4.5.3.

After completing the skeleton of the app, the basic shop feature were build using O'Reilly as there was lessons on how to build a shop. Therefore, was a useful guide to help implement the features defined when designing the system, see section 4.

Finally, the persuasive technology was implemented into the system. This did not require any support from O'Reilly resources as it was basic logic which was easier to implement as functions were similar to that of other languages, such as JavaScript.

A total of 38 Dart files were created to ensure the project was readable and maintainable. Therefore, the Dart files were abstracted as much as possible, as well as to ensure code was reusable. For example, as seen in figure 5.2, these *generic_widgets* are used across the entire system. This allows for the system to have consistent buttons and text formatting.

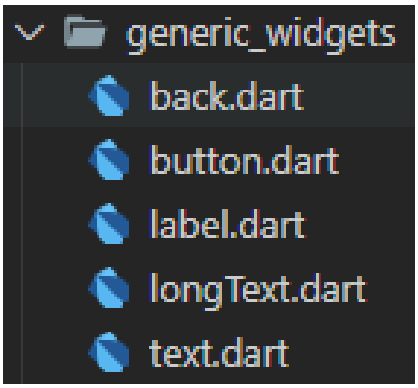

Figure 5.2: Abstraction Example

Furthermore, code was made private were possible to demonstrate when code was specific to a class and would never be needed across the application.

Important Code

The code unique to the requirements of this system are those which can directly reflect requirements made in section 3. Therefore, in this section, those sections of code will be demonstrated and discussed.

When using an app on a smart phone users are likely to open the app more than one time. Therefore, an automatic login feature was developed to create a better user experience, without requiring the user to input their details again. Therefore, users are able to open and close the app without the impression that they have been logged out and need to sign in again, which can be a laborious task. An example of this code can be seen in listing 5.1. The listing shows a snippet of the main.dart file and hows what is build as the homepage when building the app when starting the app. This code is important as for a persuasive technology to be successful, the system needs to have a great user experience. In addition, it follows requirement NFR 2.1 in table 3.2 in section 3.

Listing 5.1: Auto-login Example Code

```
home: auth.isAuth
          ? OverviewScreen()
          : FutureBuilder(
              future: auth.tryAutoLogin(),
              builder: (ctx, authResultSnapshot) =>
                  authResultSnapshot.connectionState ==
                          ConnectionState.waiting
                      ? SplashScreen()
                      : Login(),
            ),
```

An important feature included in the app is the scoreboard, an example of the persuasive technology used, as defined in requirement FR 1.4 in table 3.4. The code, shown in listing 5.2, is an abstracted version of the code. Essentially the code saves an ordered list of the users on the system to be used in the leader-board. The "_isLoading" variable shown in the listing represents if the screen displays a loading screen if the data is not yet at the system's disposal.

Listing 5.2: Leader-board Example Code

```
class _ScoreBoardState extends State<ScoreBoard> {
  bool _isLoading = false;
```

```
List<User> _userAccounts = [];

@override
Widget build(BuildContext context) {
  createScoreboard();
  return ListView(
    children: <Widget>[
      _buildHeader(context),
      _buildBody(context),
    ],
  );
}

Widget _buildHeader(context) {
  return Container(
    padding: EdgeInsets.only(
      left: 10.0,
      right: 10.0,
      top: 15.0,
      bottom: 60.0,
    ),
    color: Theme.of(context).accentColor,
    child: Column(
      children: <Widget>[
        Row(
          children: <Widget>[
            BuildBackArrow(context),
          ],
        ),
        Row(
          children: <Widget>[
            Expanded(
              child: BuildText('scoreboard', null),
            ),
          ],
        ),
      ],
    ),
  );
}

Widget _buildBody(context) {
  return _isLoading
      ? Center(
          child: CircularProgressIndicator(),
        )
      : GridView.builder(
          shrinkWrap: true,
          physics: ScrollPhysics(),
```

```
                padding: const EdgeInsets.all(40),
                itemCount: _userAccounts.length,
                itemBuilder: (ctx, i) =>
                    ChangeNotifierProvider.value(
                  value: _userAccounts[i],
                  child: ScoreBoardItem(_userAccounts[i], i),
                ),
                gridDelegate:
                    SliverGridDelegateWithFixedCrossAxisCount(
                  crossAxisCount: 1,
                  childAspectRatio: 5,
                  crossAxisSpacing: 0,
                  mainAxisSpacing: 0,
                ),
              );
      }

      Future<void> _getUsers(BuildContext context) async {
        await Provider.of<Accounts>(context, listen:
            false).getUsers();
      }

      Future<void> createScoreboard() async {
        if (_userAccounts.length == 0) {
          setState(() {
            _isLoading = true;
          });
          await _getUsers(context);
          _userAccounts =
              Provider.of<Accounts>(context, listen:
                  false).usersOrdered;
          setState(() {
            _isLoading = false;
          });
        }
      }
    }
  }
```

Furthermore, another important feature of the use of persuasive technology, is the display of user stats on the user' profile page, see requirement FR 2.2 in table 3.5. The listing 5.3 shows how all of the different stats (score, items saved, money saved and pollution prevented) are calculated when an item is reserved, saved to the database and saved to local memory.

There are 3 different weights used in the algorithms. *itemWeight* was defined as the average portion size in North America was 0.3Kg and *pollutionPerKilo* was calculated based on the figures of amount of food wasted in North America (in Kg) and the amount of pollution produced directly linked

to food waste in grams, leading to finding 9.43g per Kilo of food (Gustavsson et al., 2011). Finally, the *costPerItem* was a number allocated at random to allow the formulas to be used for testing.

Furthermore, for the formulae, when reserving an item, the user will gain 10 points to their score, their item count will increase by 1 and their total money saved will increase by the amount allocated by *costPerItem*. As for the more complex formula, the pollution is calculated by multiplying the number of items saved by their weight multiplied by the amount of pollution it produces per kilo.

Listing 5.3: Stats Example Code

```
Future<void> updateStatsReserve() async {
const itemWeight = 0.3; //0.3Kg of a portion
const pollutionPerKilo = 9.43; // 9.43x10^(-6)g per kilo
    of food
const costPerItem = 4.67; // random number decied to get
    the system functionning

final score = (int.parse(accountDetails.score) +
    10).toString();
final items = (int.parse(accountDetails.items) +
    1).toString();
final saved = (double.parse(accountDetails.saved) +
    costPerItem).toString();
final pollution = (double.parse(items) * itemWeight *
    pollutionPerKilo).toStringAsFixed(2);

final url =
    'https://food-waste-reduction-system.firebaseio.com/users/$userId.json?au
       // $dbAccountId not needed anymore? (database
       bugs)
try {
  final response = await http.patch(
    url,
    body: json.encode({
      'score': score,
      'items': items,
      'saved': saved,
      'pollution': pollution,
    }),
  );
  accountDetails = User(
      score: score,
      items: items,
      saved: saved,
      pollution: pollution,
```

```
        );
      notifyListeners();
    } catch (error) {
      throw (error);
    }
  }
```

Notifications were not included in the code as Google's Firebase has a cloud messaging feature (*Firebase Cloud Messaging*, 2020). This allows the developer to send notifications on demand by accessing the online database where a could message can be created and pushed to all (or a selection of) users on the system. Using this feature will allow for the most flexibility when testing because there was no need to implement notifications in code therefore, can tailor the timing and message of the notifications.

Finally, there were no prominent technique choices that were made during the development of this project. During the learning process, the most efficient code style was followed as recommended by the courses from O'Reilly.

5.2 Testing

Testing alongside the development of the system is an important part of the System Life Cycle. Testing ensures that the implemented features are all behaving as expected.

5.2.1 Ensuring Efficient and Accurate Testing

Testing is essential to ensure a reliable system as well as quality software (Mathur, 2010). Testing removes as many bugs as possible and guides the developer(s) to correctly build the system.

Readability and Maintainability

To ensure readability and maintainability, some coding conventions have been followed. This encompassed thoughtful naming of functions, variables, widgets and classes as well as code abstraction and commenting on code that may need a little more explanation of its functionality. Hence, leads to higher code legibility, avoids bugs that arise from disorganised code, higher code quality and ultimately a more reliable system. The system has also been developed with testabilty in mind. Due to the code practiced in development the system has both high cohesion and low coupling which allows the system to be easier to test.

Testing the System

Prior to system evaluation, regression will be conducted to cover both validation and verification testing to ensure that the software does what the user really requires as well as conform to the specification.

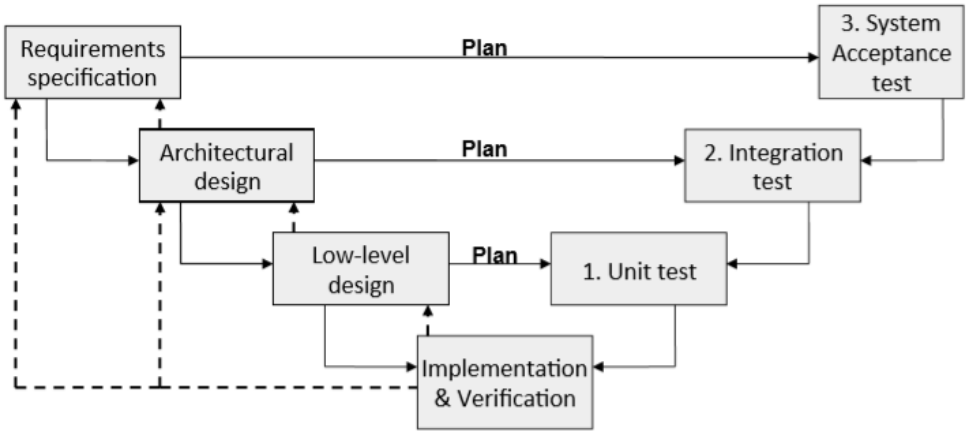

Figure 5.3: V-Model

During development, a combination of unit, integration and system acceptance testing will be conducted manually, see table 5.1 and figure 5.4. These tests will be conducted when a unit's development has been part/fully completed going from unit to system acceptance, as seen in figure 5.3 inspired by (Rook, 1986), before moving on testing previously build parts of the system and continuing with developing the next feature. Using this method, allows for a more efficient development process (Mathur, 2010). Most of the work has been completed during the design of the testing and code development is more effective.

Furthermore, software inspection will not be possible as there will not be any supporting actors beside the project supervisor, who is only supervising the project from a higher level.

Unit Testing

For unit testing, software will not be used. Instead when appropriate the tests will be completed by attempting to use invalid data, as seen in 5.4. This testing will use the test cases created.

Integration Testing

When completing a unit test, the new part will be tested with the functionality attached to the new feature. For example, in the unit test case of testing if login accepts an email with a 'space' character in the string, the entire log

in functionality will be tested. This includes the effect the code has on the interface and deal with any issue that arise, to ensure the functionality is correct as well as the structure of the interface. This testing will utilise use cases.

System Acceptance Testing

The system acceptance testing will compromise of both alpha and beta testing. Alpha testing is in house testing which has an objective of ironing out obvious bugs before testing with real users, beta testing. Following the completion of the alpha testing, the application would be sent out to 10 potential users, under observation, to identify any other bugs or issues with the apps functionality. However, due to COVID-19 pandemic and the lock-down measures in place, the beta testing will be reduced to one potential user, my flatmate. This will limit the variability of a potential user using the app but, due to these specific circumstances a larger sample cannot be used. This testing will be based on scenarios such as the one created in section 4.2.1.

5.2.2 Testing Strategy

Behaviour-Driven Development

The requirements set, in section 3, were translated into specific test cases, on behaviour, to insure that the requirements were met (Solis, 2011). Behaviour-driven development was used in this project's development to build a reliable, bug free application while implementing the desired behaviour.Behaviour-driven development tests system behaviour instead of explicit functionality which allows the testing phase to be more efficient. This involved the behaviours of a basic digital shop as well as the behaviour of the persuasive technology features that were implemented.

The following table presents the basic behaviours that need to be provided by the system similar to what would be used in test driven development (Astels, 2003). The behaviours listed in table 5.1 were tested after any change to the system during development to ensure that all potential user goals were still supported. However, the behaviours in the table are only a basic representation of the testing that occurred as, for example, error handling testing also occurred along side the tests in table 5.1. For instance the case of test T 8.2 'Register a new user', the data entry form was tested with invalid data to ensure the system would not accept the inputs and return a handled error message for the user without crashing the system, see 5.4. These extra test cases account for more specific testing and include both positive and negative testing, where the behavior is tested with cases with correct (positive) and incorrect (negative) data is provided.

5.2.3 Outcomes

The development of the system has been completed and fully tested, to the extent of the above discussed. However, there will most likely be bugs that have gone unnoticed. Hopefully, they will come to light in the evaluation of the system, if they exist.

As of the project submission, one test has failed. After completing the development of feature FR 1.6 'Should have a section for user gained rewards', see section 3, and successfully passing the tests 7.1 to 7.4 in table 5.1, the functionality of feature FR 1.10 'User must be allowed to log out of the system' developed previously failed the behaviour test T 8.3 'Log out of the account'. Currently, no fix has been found. However, this functionality is not crucial to the evaluation of the persuasive impact of the system as the user will only be using the solution for a week and has no need to sign out during that time. This bug fix will be mentioned in future work.

Test Cases			
ID	Test	Requirement	Success
T 1.1	List an item on the marketplace	see FR 1.3	Pass
T 1.2	List an item within 3-4 steps from opening the app	see NFR 2.4	Pass
T 1.3	The Listed item should appear on the marketplace	see FR 1.3	Pass
T 1.4	The Listed item should appear on the user shop	see FR 1.7	Pass
T 2.1	Reserve an item listed on the market place	see FR 1.4	Pass
T 2.2	The reserved item should no longer be on the marketplace	see FR 1.4	Pass
T 2.3	Post reserving the item, the user should be displayed a pop-up with praise from the system	see FR 2.5	Pass
T 3	List an item within 3-4 steps from opening the app	see NFR 2.4	Pass
T 4	Reserve an item listed on the marketplace within 2-3 steps from opening the app	see NFR 2.4	Pass
T 5	Access the user's stats in the profile section of the app	see FR 2.2	Pass
T 6	Check the live version of the leader-boards	see FR 1.5	Pass
T 7.1	Check the rewards section (currently with fake data)	see FR 1.6	Pass
T 7.2	Receive an award for creating an account	see FR 1.6	Pass
T 7.3	Receive an award for listing an account's first item	see FR 1.6	Pass
T 7.4	Receive an award for reserving an account's first item	see FR 1.6	Pass
T 8.1	Register a new user	see FR 1.8	Pass
T 8.2	Login with a registered user	see FR 1.9	Pass
T 8.3	Log out of the account	see FR 1.10	Fail

Table 5.1: Test Case: Core Feature Testing

Test Scenario	Test Case	Pre-conditions	Test Steps	Test Data	Expected Result	Actual result	Pass/Fail
A. Register a new user	Verify valid email and password is accepted by the system		1. Launch the app 2. Click Register 3. Enter data 4. Click Register	Email: 'test@gmail.com' Password: '123456' Confirm Password: '123456'	Logged in to the system and forwarded to the homepage	Logged in to the system and forwarded to the homepage	**Pass**
	Verify invalid email is not accepted by the system accompanied by a valid password			Email: 'testgmail.com' Password: '123456' Confirm Password: '123456'	Error message: 'invalid email'	Error message: 'invalid email'	**Pass**
				Email: 'test gmail.com' Password: '123456' Confirm Password: '123456'	Error message: 'invalid email'	Error message: 'invalid email'	**Pass**
	Verify invalid password is not accepted by the system accompanied by a valid email			Email: 'test@gmail.com' Password: '123 456' Confirm Password: '123456'	Error message: 'invalid password'	Error message: 'invalid password'	**Pass**
	Verify that email field is not accepted if left empty accompanied by a valid password			Email: '' Password: '123456' Confirm Password: '123456'	Error message: 'enter an email'	Error message: 'enter an email'	**Pass**
	Verify that password field is not accepted if left empty accompanied by a valid email			Email: 'test@gmail.com' Password: '' Confirm Password: ''	Error message: 'enter a password'	Error message: 'enter a password'	**Pass**
	Verify password must contain more than 5 characters accompanied by a valid email			Email: 'test@gmail.com' Password: '12345' Confirm Password: '12345'	Error message: 'password too short'	Error message: 'password too short'	**Pass**
	Verify that both passwords must match accompanied by a valid email			Email: 'test@gmail.com' Password: '123456' Confirm Password: '12345'	Error message: 'passwords do not match'	Error message: 'passwords do not match'	**Pass**

Figure 5.4: Extra Test Cases: Example

Chapter 6

Evaluation

The system must be evaluated to gauge the components of usability: effectiveness, efficiency and satisfaction, as defined by ISO (ISO, 2018). We must also evaluate the implementation of the persuasive technology against the aims and objectives set out in section 1.3. The system will be evaluated following the methods discussed in this section.

6.1 Aspects to be Evaluated

The aim of this evaluation is to determine the usability and persuasiveness of the solution. The evaluation will look into understanding choices made by users to reach a desired goal, for example, the goal of listing a new item on the marketplace. This reflects the goals of this project, as defined in section 1.2.

6.1.1 Usability

The evaluation needs to consider the components of usability, as mentioned above:

1. Effectiveness: the time it takes to complete tasks, mistakes made before completing the task and the feedback from the user about the system's effectiveness.

2. Efficiency: counting how many events (interactions such as a button click), time it takes to complete a task (based on the speed of the application) and a questionnaire for more feedback on this.

3. Satisfaction: from engagement with the participants focusing on usability.

6.1.2 Persuasiveness

The solution needs to be evaluated to determine whether the solution is a persuasive system as intended. To measure the persuasiveness of the system, the amount of participants that reach the target behaviour will be analysed. The target behaviour, as defined in appendix E, is to use produce which has been left over by other students (by me for the purpose of the test), 3 times in a week. Therefore, to evaluate if the target behaviour has been reached, the database will be checked to verify if the users have made 3 item reservations.

6.1.3 COVID-19

Due to the impact of COVID-19, there have been restrictions on movement and social distancing, see appendix B. Therefore, the planned studies were not able to be completed. This section will discuss the planned studies and how they were changed to comply with the restrictions due to COVID-19.

The evaluation will use a field study which will allow for real life variables which cannot be replicated in a lab environment. Therefore, reflecting the real world and produce more useful results.

Participants

In order to gain the most accurate results possible, the sample will aim to be representative of the target audience, see section 4.1.2, with a sample size of 10-20 people. The sample will have a balance of both male and female participants and are students (typically aged between 18 and 24).

Due to COVID-19, there will only be one participant for this study. The participant is a Physics student, male and 22 years old. The participant is familiar with the technology channel discussed in section 4.1.4. Therefore, the participant fits perfectly in the target audience discussed in section 4.1.2.

Materials

Before, the start of the study, the participants must be informed that the study requires honesty over anything else. This will hopefully reduce the risk of social desirability bias.

For this study, the participants will need access to a mobile phone with the application installed as well as a connection to the internet to have access to the database. This material will still be provided for the actual study therefore, there is no need for adaption.

The participants will also need to have access to the relevant questionnaires, discussed throughout the evaluation chapter, as well as information sheets and consent forms to participate in the study. The information sheet will explain the purpose of the evaluation as well as information on how the

data will be used, when they can ask for help and remove themselves from the evaluation process.

6.2 User Experience

6.2.1 Analytical Evaluation

Heuristic Evaluation

This section is where the system will be evaluated, by myself, using the updated Nielsen's Heuristic Evaluation. This part of the evaluation was not effected by COVID-19 and therefore will have no adjustments.

The aims of the heuristic evaluation is to assess the usability of the system internally to ensure that the general principles have been applied to the solution.

To produce accurate findings a large budget is required. However, Nielsen's Heuristic Evaluation has no requirement for a large budget and produces valuable results. Furthermore, Kientz et al. produced a more useful list of heuristics which are more appropriate for persuasive systems (Kientz, 2010). Therefore, this evaluation will be preferred over the original version, see the list of heuristics accompanied with the completed evaluation below.

- Appropriate Functionality: in the system's current state, it only has the core functionality needed in order to keep it streamlined and meet the requirements.
- Not Irritating or Embarrassing: as of testing the system, there are not regular notifications implemented into the codebase. Therefore, the notifications cannot be irritating. In addition, there are no bugs that have been found, with user testing, to irritate the user. The system also does not use any feature that could be considered embarrassing.
- Protect Users' Privacy: The testing did not use any of the user's data as it was kept anonymous. However, the data is protected by security from Google's Firebase. Therefore, the testing represented a secure environment that the app would have in the future, see section 7.4.
- Use of Positive Motivation Strategies: The app implemented the motivation strategies defined in the requirements, see section 3. For example, the use of praise when the user reserves an item.
- Usable and Aesthetically Appealing Design: The interface was designed using HCI principles as discussed in section 4.3. In addition, the feedback gained from the observation section of the evaluation mentioned that the interface was consistent and easy to navigate.

- Accuracy of Information: The information is kept up-to date. For example, when an item is reserved, it is updated so that the item cannot be reserved again.
- Appropriate Time and Place: Information is provided in a timely manner. For example, if there were an error saving data on the server, the user will receive a handled error message as soon as the server throws the error. However, it is unlikely all the possible errors have been accounted for. Hence, any future issues will be dealt with as they are noticed, see section 7.4.
- Visibility of User's Status: The status of the user is available in its own section of the app, displaying the user's score and other statistics. This section is always available to the user. However, this could be improved further. For example, providing information about what the user needs to unlock a reward and their progress towards that goal, see section 7.4.
- Customisability: The project does not allow for any customisability. However, this could be implemented in future designs, see section 7.4.
- Educate Users: The users are briefed about the impact of food waste and why the amount of food wasted needs to be reduced. However, this could be improved. The user could be educated with more detailed information while engaging with the system on a daily basis. For example, on unlocking a reward, the system could provide a useful fact, see section 7.4.

In conclusion, all of the heuristics have been implemented, excluding being able to customise the system. Something that could be expanded upon in future designs. However, Based on this evaluation, the system could be considered a persuasive system. However, it is difficult to confirm this with the level of evaluation which was conducted for this project.

6.2.2 Empirical Evaluation

Self-Report Evaluation (SUS)

The participants will be asked to complete a SUS questionnaire to gauge the experience the user has had while using the solution (Tullis and Albert, 2013). In addition, the user will have to complete a questionnaire on two separate occasions, after the first session and after the week of beta testing to assess if the solution has an effective memorability and learnability (Smith, Morrow and Ross, 2015).

The System Usability Scale was chosen above other methods as it is a reliable tool for measuring a system's usability. SUS is a Likert scale where the participant rates the response to a statement on a scale of how much they

agree or disagree (Brooke, 1996). One of the important benefits of using this method is that it produces reliable results regardless of the sample size (*System Usability Scale (SUS)*, 2020). Hence, there was no need to adapt the SUS due to the impact of COVID-19. The statements are shown below:

- I think that I would like to use this system frequently.
- I found the system unnecessarily complex.
- I thought the system was easy to use.
- I think that I would need the support of a technical person to be able to use this system.
- I found the various functions in this system were well integrated.
- I thought there was too much inconsistency in this system.
- I would imagine that most people would learn to use this system very quickly.
- I found the system very cumbersome to use.
- I felt very confident using the system.
- I needed to learn a lot of things before I could get going with this system.

After collecting the data, the results must be calculated before they are analysed. To calculate the score for the SUS, the questions are each worth 0 to 4 points with 4 being the positive response to a statement. For instance, if the statement is negative, the statement is marked in reverse with completely disagreeing with the statement, worth the maximum of 4 points. The points are then totaled and multiplied by 2.5 to provide a score out of 100.

After the 1st Session:

The participant scored 85 on the first SUS which suggests that the user experience is over average. Research has shown that the average score on a SUS would be 68 (Brooke, 1996). Hence, with the score being greater than 68, the system could be considered to have a good usability. However, due to the study only having one participant, it is possible that these results do not reflect an accurate usability of the solution.

After the Week of Beta Testing:

On the ultimate SUS, the participant had a higher score of 95. Suggesting that the usability also improves with continuous use. Hence, parts of the system which may not be immediately obvious will become second nature after using the solution multiple times. As mentioned previously, the results are from one participants and may not reflect the system's usability accurately.

Observational Evaluation

The participant was observed on two separate occasions. The first time was when the user had no experience with using the app and the second time was after completing the week of beta testing, to reassess if there has been an effect on the user's ability to use the app due to memorability or learnability of the system.

The participants will be instructed to complete all the tasks that cover the scope of the system, in random order as to not produce a bias due to the training effect or fatigue. After completing each task, the time the user takes to complete tasks and the errors made will be recorder. The participants will also be each asked questions individually, after each task, to gain quick and fresh thoughts about the solution. The questioning will be unstructured with the aim of discussing the task's efficiency, effectiveness and satisfaction. The following tasks will be asked to be completed:

- Reserve an apple
- List a bag of peanuts
- Find your profile's shop
- Edit the item listed
- Delete the item listed
- Find your user details
- Find the leader-board
- Find the rewards you can unlock

Planned:

The participants will be split into two groups, maintaining the diversity of the whole sample, with the 1st group using the solution with none of the persuasive features and the 2nd group with the persuasive technology included. Therefore, the 1st group will have an application without the following features:

- Introduction screens with information about the problems with food waste
- Praise when reserving an item
- Score/statistics page
- Leader-board

Figure 6.1: Final Design: User Shop Screen

Figure 6.2: No Persuasive Technology Example

- Rewards

The following changes will also have an impact on the user's profile section. Instead of the default page being the user's score and statistics screen, the user will be directed to the user shop, with the new layout, see figure 6.2. As seen in the comparison the figure 6.1, the page no longer has an option to navigate to the score/statistic screen or a navigation bar as the pages will not be used by the 1st group.

This will allow the results to directly reflect the impact of having the persuasive technology implemented in the solution. The two groups will be asked to meet the target behaviour.

Actual:

However, due to COVID-19, this study was not able to be completed. The study had to be reconsidered as there was only one participant. Hence, the system with the removed persuasive features will not be used and the study will focus on the final version of the solution, as seen in figure 6.1. There was also no benefit to be gained from randomising the tasks. As there is only one participant, there will be no method to mitigate the bias due to the training effect or fatigue. Otherwise, the observational section of the evaluation will

be conducted as planned.

The participant will be asked to complete a list of tasks. This will measure how much time it takes the participant to complete a task along with any errors made during that process. Therefore, will be able to infer what the user is thinking. The participant will then be left to complete the target behaviour: using produce which has been left over by other students (by me for the purpose of the test), 3 times in a week. The participant will then be observed a final time to compare the results collected in the first session. This information will be helpful to understand the usability of the solution as well as how fast the user learns, over the week of evaluation, and how to interact with the system efficiently.

First Observation

The first table, see table 6.1, shows the list of tasks that were asked of the user, followed by the time it took the user to complete this task from the neutral starting point of the homepage. As well as the number of errors the user made completing that task and the number of events it should take the user to complete the required task without any errors.

First Session Using the App			
Task	Time (s)	# of Errors	# of Events
Reserve an apple	14	0	3
List a bag of peanuts	58	3	8
Find your profile's shop	4	0	2
Edit the item listed	22	1	5
Delete the item listed	5	0	3
Find your user details	5	0	4
Find the leader-board	3	0	2
Find the rewards you can unlock	6	0	2

Table 6.1: First Session Using the App

Time

Looking at the times recorded in table 6.1, most tasks are recorded between 3 and 6 seconds. Hence, for those tasks, the pathway to complete the task must have been obvious as it took a small amount of time. However, for the three remaining tasks, with times between 14 and 58 seconds, this could be due to the tasks being significantly longer. For the more extreme time of 58 seconds for the task 'list a bag of peanuts' the participant made 3 errors and asked for help which would be the reason the task took longer to complete. Therefore, the solution is effective but could be improved by reducing the number of errors.

Errors

During the task 'List a bag of peanuts', the participant made three errors. The first error related to the usability of the app. The participant automatically tried to click on the image placeholder to add an image. This feature is present in many applications and is a natural assumption to make. Therefore, this will be an important feature to implement in the future to enhance the user experience. The second was an Android usage error, as the user had to paste some text into the image URL text field and had to ask for help. The final error made by the participant was that they assumed the listing would be automatically submitted and saved when clicking enter on the keyboard of the final text box. Adding this feature would be a quality of life change which could have a positive effect on the user experience. Hence, should be added in future versions of the solution. Therefore, the solution is effective but could be improved by dealing with the errors discussed.

When the participant was asked to edit the item they had previously listed, they made an error previously seen.

The edit an item section also did not submit the data upon clicking the enter button, of the keyboard, when on the final text box. The participant for the second time paused before realising they needed to close the keyboard and click the 'save' button.

Feedback

Overall, the participant felt that the system was effective at completing the given tasks. As there were limited pathways, it was easy to find anything they were after. The only negative comment about effectiveness was concerning the way to upload an image. The upload was restricted to an image URL upload as to reduce the development time of the project. Hence, the feature in final solution was not as effective as possible. The feature will be expanded to allow for the user to upload a photo or take a photo directly with their camera in future designs, see section 7.4.

Furthermore, the system was said to be efficient as the paths to each task were short and did not take long to complete any task. However, there was a comment about implementing a search bar to look for items the user could be searching for.

The participant mentioned that they were satisfied with the system as a whole because the system had a clean interface and a consistent layout. Therefore, there were no complaints beside the method to upload an image.

Final Observation

following the same structure as the first observation, the following results were obtained:

Second Session Using the App			
Task	Time (s)	# of Errors	# of Events
Reserve an apple	6	0	3
List a bag of peanuts	35	1	8
Find your profile's shop	3	0	2
Edit the item listed	11	1	5
Delete the item listed	4	0	3
Find your user details	4	0	4
Find the leader-board	3	0	2
Find the rewards you can unlock	6	0	2

Table 6.2: Second Session Using the App

Time

Looking at the times recorded in table 6.2, most tasks are recorded between 3 and 6 seconds. Hence, as discussed in the first observation session, the small amount of time spent on those tasks represents that the tasks were easy to complete without much cognitive strain. However, for the two remaining tasks, with times between 11 and 35 seconds, this is due to the tasks requiring more time than the other. This is because there were more events in order to complete the task, for example adding text to a text box.

Errors

Only two errors occurred during the session. They were both the same error at different points in the system. When completing the form when listing a new item or editing an existing item, the user instinctively clicked the enter button on the keyboard and waited a couple of seconds. It can be inferred that the user was expecting an action to occur. For example, the keyboard to close or the form to automatically submit.

Feedback

The positive feedback was that the app was efficient as there were limited pathways, event sizes for a task was kept low and was effective in completing tasks, only requiring the needed features to complete the task. The participant was satisfied with the solution and mentioned that the system had a clean and consistent interface. On the other hand, the participant mentioned that the method to upload an image was still a feature they would be interested in.

Comparison of the Two Observation Sessions

Time

The times per task were cut down significantly, with some taking half as

much time to complete. Therefore, the user experience is of a good enough level to have a training effect after only a week of use. Furthermore, the biggest drop in time were from the list an item and edit an item tasks. These tasks both had similar functionality with editing/inputting text and accompanied with the issue the participant had with clicking enter on the ultimate text box. The participant had therefore, learnt how to deal with the impracticality of the enter button on the keyboard. Hence, there is room for improvement on those two tasks to further drop the task completion time by adding the assumed functionality of the enter button automatically submitting/saving the data.

Errors

There were no reoccurring errors beside when the user clicks on the enter key on the keyboard expecting the system to automatically save a new listing or save an edit. However, the participant did not seem overly bothered by the functionality, it was purely observational.

Feedback

Overall, the user was satisfied with the system. However, the method to upload an image was still an issue throughout both sessions.

Events

Finally, the number of events, that have been identified in the tables, range between 2 and 8 with an average of 3.625. The only lengthy task is when listing an item, with 8 events because the user needs to input data into the required fields. Therefore, the task still only uses the lowest amount of events to complete the task as possible. This is a low number of average events to complete a task, therefore, the solution is efficient.

Psychophysiological Evaluation

Furthermore, another method to test the success of the solution could be to use implicit user responses which are not controlled intentionally by the user. Psychophysio-logical measures, such as pupil dilation (Fazio, 2003). However, the project lacks the resources (technological and financial) to be able to accomplish such evaluation. Hence, this will not be considered for this project.

Conclusion

The evaluation of the solution's usability has been completed. All of the heuristics have been implemented within the system, providing a strong basis for the solution's usability. Furthermore, the user has scored high results in both SUS questionnaires. These high scores reflect the system's usability as well its memorability and learnability with the score increasing on the

second collection of results. Moreover, the solution was evaluated in terms of effectiveness, efficiency and satisfaction during the evaluation, as shown below:

1. Effectiveness: The time to complete a task was low and decreased after the week long beta testing. The number of errors were minimal and were reduced as well after the week of beta testing. The user also mentioned that the system was effective at directing the user to the task they require.

2. Efficiency: The number of events for a task was kept to a minimum and all actions were completed in a timely manner ensuring that the system was efficient. The user made no comments and was not observed waiting for long periods of time.

3. Satisfaction: The user mentioned that they were satisfied with the system and that the interface was clean and consistent.

However, due to COVID-19 and there only being one participant, the results may not be an accurate representation of the system.

6.3 Persuasiveness

6.3.1 Empirical Evaluation

The Target Behaviour

The participant completed the target behaviour, which was: use produce which has been left over by other students (by me for the purpose of the test), 3 times in a week. The database was checked and 4 reservations had been made. To confirm this, I gave away the 4 products the participant requested to ensure the experience was as realistic as possible. Therefore, for the purpose of this study, the food was not wasted and was used by the participant. Hence, the system demonstrated that it meets one of the aims of this project, 'Persuade the user to reduce the amount of food they waste' as defined in section 1.3.

Self-Report Evaluation

The participants' self-efficacy is an important factor to reach a target behaviour (Fogg, 2002*b*). To ensure that the results are useful, the self-efficacy of the participants needs to be evaluated to determine if they are able to be persuaded (Fogg, 2002*a*). Hence, the GSE will be used as a screening process to ensure participants have the potential to reach the target behaviour. Participants scoring under average results on the GSE, 29.55 out of 40 (*PsyToolkit - GSE*, 2018), will be discarded from the evaluation process.

Evaluating the participants with the GSE will be a reliable method to collect the relevant data. The results should help gauge if the participants are

more likely to reach the target behaviour. Similarly to the SUS, the statements use a Likert scale to evaluate the participant. The statements are as follows:

- I can always manage to solve difficult problems if I try hard enough.
- If someone opposes me, I can find the means and ways to get what I want.
- It is easy for me to stick to my aims and accomplish my goals.
- I am confident that I could deal efficiently with unexpected events.
- Thanks to my resourcefulness, I know how to handle unforeseen situations.
- I can solve most problems if I invest the necessary effort.
- I can remain calm when facing difficulties because I can rely on my coping abilities.
- When I am confronted with a problem, I can usually find several solutions.
- If I am in trouble, I can usually think of a solution.
- I can usually handle whatever comes my way.

Due to COVID-19 there will only be one participant. There should be no impact on this section of the evaluation as the participant must still answer the GSE with an over average score to continue with the evaluation.

Results:

The participant scored 32 out of 40 on the GSE scale which if is over the international average of 29.55 (*PsyToolkit - GSE*, 2018). Hence, the user was of sufficient self-efficacy to continue with the study. The full GSE can be found in appendix I.

Food Waste Questions

The section will be evaluating the effectiveness in changing attitudes and behaviours regarding food waste.

These questions were asked 3 times through out the evaluation. The first time was after the GSE, the second after completing the first session and SUS (two the same day) and the final at the end of the week trial following the SUS.

The scales of the questions differed depending on the question, these can be seen in the example in figure 6.3.

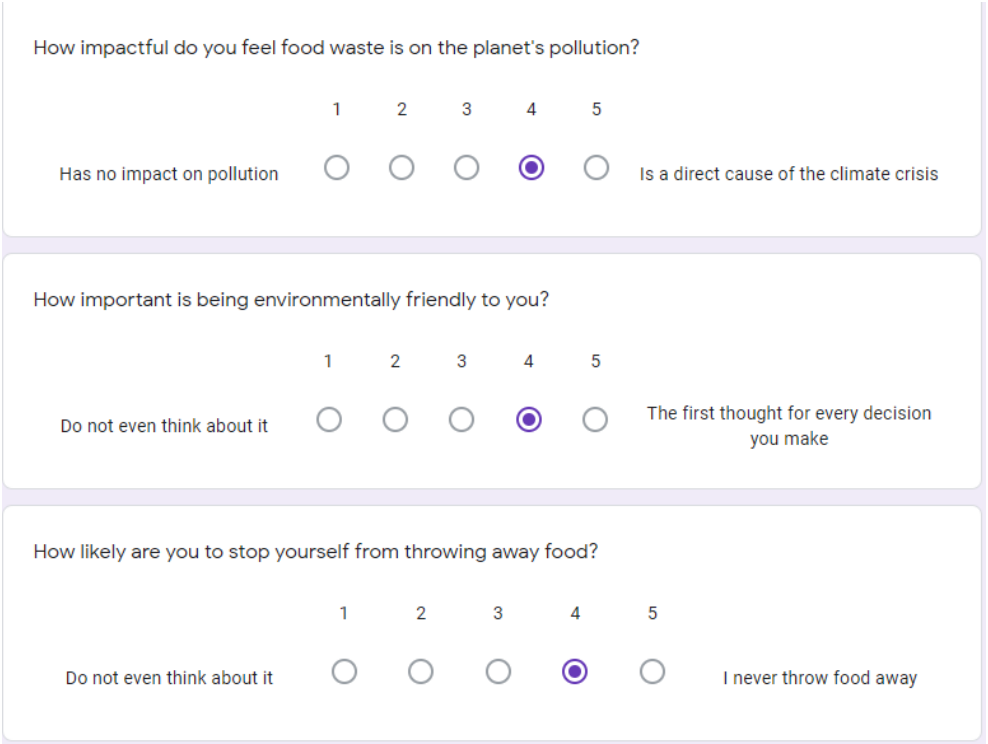

Figure 6.3: Food Waste Questions Example

Food Waste Related Questions			
Question	1st	2nd	3rd
How impactful do you feel food waste is on the planet's pollution?	4	4	4
How important is being environmentally friendly to you?	4	4	4
How likely are you to stop yourself from throwing away food?	2	3	4

Table 6.3: Food Waste Related Questions

The participant's opinion did not change over the week concerning their opinion on food waste's impact on the environment or being environmentally friendly. However, due to there being only one participant it is possible that the participants opinion could have become stronger if they had initially started on a lower scored opinion. For example, if the participant initially answered 3 to those questions, the system could have persuaded the user about the importance of those two opinions and increased the answers to a 4 or 5 in the following questionnaires.

However, there was a positive trend on the final question, 'How likely are

you to stop yourself from throwing away food?'. This could be an initial positive indication the participant could be persuaded by the app. The app aimed to show that avoiding food waste can be easy and aimed to support users that just lacked the ability and motivation to reach the target behaviour. The ability was demonstrated by having an app that links people that want to give away and receive food and the motivation by educating and praising the user. However, due to there only being one participant, the ecological validity and generalisability of these results is limited.

Persuasive Features

Due to COVID-19, the study of individual persuasive features implemented in the system could not be evaluated to an extensive degree. The user was asked about the effectiveness of each feature at the end of the evaluation process. Below is a table of the results of those questions:

Evaluating the Persuasive Features		
ID	Feature	Answer
F1	Raise awareness in the introduction pages	"It was informative but I felt I already had a clear idea of the impact of food waste on the planet"
F2	Praise when reserving an item	"Felt like I was doing a good deed and slightly proud of my actions"
F3	Use of natural language	"Did not notice, but it does seem to make the process less formal which is more attractive for daily use"
F4	Score and Statistics	"I found the statistics interesting as it felt like i was making a contribution to the planet, however I did not pay much attention to the score"
F5	Rewards	"I did have a quick look but as it did not have many real options, it was not as interesting as it could have been"
F6	Leader-board	"Being the only person using the app, I payed no attention to the leader-board"

Table 6.4: Evaluating the Persuasive Features

Overall, the persuasive features were well received. Features F1 and F5 were not able to be fully tested, see table 6.4. This was due to the user already being educated about food waste for F1, as observed in the food related questions in section 6.3.1, and due to the lack of created rewards the user was not interested in feature F5.

Moreover, the user mentioned that they "felt like [they were] doing a good

deed" for feature F2. This reinforces the theory from Fogg (2002*a*), as the solution ensures that the user believes that their actions are correct, as discussed in section 2.2.3.

Furthermore, as also discussed in section 2.2.3, a user can be persuaded if they perceive the control they have in regards to the impact on the environment. The participant mentioned that they felt like their action "[made] an impact on the planet". Therefore, feature F4 has been successfully implemented.

Finally, for feature F3, there was no notable feedback to use and will require further evaluation and the competitive aspect of the solution was not able to be fully tested, therefore, no usable feedback was provided for feature F6.

Conclusion

The participant met the target behaviour and became less likely to contribute to wasting food. Therefore, the solution could be considered persuasive.

However, due to COVID-19 and only having one participant, the results may not accurately reflect the persuasiveness of the system.

6.4 Evaluation Summary

These methods of measurement have been chosen as they collect relevant and realistic information that is needed for the system to be evaluated correctly. The questions have been built from well defined research and therefore is reliable and effective. Furthermore, the methods do not exceed 10 questions. Hence, the user will be able to complete them in a timely manner and produce more accurate results as the questions can be answered immediately after the completion of the tasks.

Main Findings

From a usability perspective, the system seems to provide a great user experience and allowed the participant to reach the target behaviour. Following the evaluation conducted it is possible that the system is persuasive. However, more research is needed produce more accurate results. COVID-19 has made evaluating the system difficult. However, these preliminary data seem to suggest the solution's usability is favorable and the solution could indeed be a successful persuasive system.

Meeting Aims of the Project

Therefore, this project has met 2 of the aims of this project: 'Persuade the user to reduce the amount of food they waste' as the user was able to meet the

target behaviour, and 'Develop a system that facilitates the user reducing their food waste' as the user increased there. However, for the third aim: 'Increase user awareness on the impact food waste has on the planet', the participant already had a significant awareness of the impact of food waste on the planet and therefore, cannot be tested if the system was able to raise awareness of the user.

Meeting Objectives of the Project

The project has met objectives 6 and 7 of this project: 'Develop a system to support a community style marketplace. Users need to be able to find and exchange products through software' and 'Integrate persuasive features which have been found to be successful', see section 1.3.

Chapter 7

Conclusions

7.1 Dissertation Overview

7.1.1 Literature and Technology Survey

Food Waste on Pollution

Food waste is an important source of pollution that needs to be addressed, contributing to water, soil and air pollution. If compared to a country, food waste ranks third internationally as a country producing the most harmful emissions after USA and China.

Consumers on Food Waste

Consumers in industrialised countries waste up to 20 times the amount of food as developing countries (Gustavsson et al., 2011). Therefore, there is room for a change to reduce the amount of food that is wasted by consumers in industrialised countries. The waste is due to lack of awareness, not realising its cause for environmental concern or poor planning leading to the food expiring and therefore, being wasted. Hence, there should be a solution to deal with poor planning.

Persuasive Technology

The persuasive technology to be used in the solution was established, supported by existing work.

Existing Systems

In this section, similar systems were analysed bring to attention the importance of a positive user experience. Furthermore, the review of existing systems confirmed that the idea of being environmentally friendly and recycling food waste is already well received by the public.

7.1.2 Requirements

Following the information gathered from the literature and technology review, the base requirements were defined. However, throughout the project, the requirements continued to be updated to ensure that the system meets the user needs.

7.1.3 Design and Prototyping

Using qualitative and quantitative research methods has allowed to capture the needs of users and translate the information in to a system which meets those needs. The user engagement during the prototyping phase was especially important for the development of the system as quick feedback was received allowing for a rapid development process. The participation of potential users helped identify issues with the system which was not evident when developing design in order to continue improving the solution and reach the final implementation.

The focus on the design was to make the system persuasive. Hence, the aim of the solution was to ensure a great user experience, paying attention to the system's usability, and implementing persuasive features which were deemed successful in other technologies and literature. For, example the use of praise in the system have been used successfully by many technologies, such as seen in figure 2.4 from TooGoodToGo's app.

7.1.4 Implementation

Using flutter was a good learning experience as it was a completely unknown language to me. Furthermore, its ability to compile down to both Android and iOS code makes it an ideal and flexible language that will be useful in the future. The implementation was fairly efficient due to the work and planning from the solution's design stage.

7.1.5 Testing

Testing was conducted throughout the implementation process using unit, integration and system acceptance testing. Finally reaching the final stage of only one bug being unresolved, regarding logging out of the system.

7.1.6 Evaluation

Due to COVID-19, a limited version of the evaluation was effectively conducted, with only one participant. This hindered the evaluation process considerably, allowing for results that may not accurately reflect the solution. However, the results were treated as initial insights while making it clear that the claims are based on an incomplete evaluation. Due to these limitations,

the evaluation was reduced to focus on the one participant, using both qualitative and quantitative methods to gain as much information as possible with the limited resources. From the evaluation conducted, the solution was found to have a good usability, helped the user achieve the target behaviour and increase the likelihood of them not wasting food.

7.2 Contributions

7.2.1 Application

This project helped produce an application which is both user friendly and persuasive which has the potential to help reduce the amount of food that is wasted everyday. The app is a direct solution to support potential users looking to reduce the amount of food waste as well as receive food for free. Therefore, contributing to the individual and the benefit of the planet, helping users be more environmentally friendly.

7.2.2 Persuasive Technology

Not enough evaluation was able to be conducted during the course of the dissertation. Therefore, the degree to how much each persuasive feature impacts the users of the system has not been uncovered. Without future work the project will not have made valuable contributions to designers in persuasive technology. However, current work on persuasive technology has been insightful and practically useful for scoping and development of this project. This project is another example of successful persuasive technology and can be used and improved upon in the future.

7.2.3 Empirical

As suggested by Fogg (2002*a*), the use of targeting a specific audience has helped produce useful results, increasingly important with the impact of COVID-19 and reducing the sample size of participants used in the evaluation. This project is another example of Fogg's work being successful and should be considered when building similar solutions. However, following this, raises the question of how to persuade the parts of the population who are not as likely to be persuaded.

7.3 Limitations

Some features originally planned to be included in the project were left out. A portion of these features were deemed out of scope for this dissertation due to the knowledge gained from the literature review, about how to create a persuasive technology (Fogg, 2009*c*), as Fogg discusses the importance of

starting small and expanding on success. A smaller portion of features were deemed out of scope due to a lack of resources (mostly time) due to the impact of COVID-19 and therefore, would delay the evaluation and therefore, delay gaining useful results for the project.

Furthermore, due to the impact of COVID-19 the evaluation process was considerably stunted and as a result was not able to produce significant results. This section needs to be reestablished in future work. In addition, COVID-19 also had an important impact on productivity when working on the project, as discussed in appendix B.

Finally, due to the nature of the project, some aspects are not able to be tested. For example, it was impossible to evaluate how uses respond to a real reflection of the marketplace. This is because ideally new items should be frequently appearing on the marketplace at random times, from different users in different locations. This cannot be achieved unless there are a significant amount of users using the system in its entirety on a daily basis.

7.4 Future Implications for Future Iterations

After completing the evaluation of the system, some design issues were brought to light. These features should be assessed for future work on the system.

7.4.1 Important features

Uploading Images

One of the most important features that needs to be implemented in future work is how the user is able to upload an image when listing an item. During the observational evaluation in the evaluation section, see section 6.2.2, the participant made an error when trying to upload the image that was provided. Therefore, a feature needs to be implemented to account for this universally accepted behaviour. The user must be able to click on the image placeholder and be able to upload a photo from the camera roll or taking a photo.

Picking Up the Reserved Item

Furthermore, the section of the system which allows the user reserving the item to meet with the user who listed the item is not built as that role, for the purpose of the evaluation was filled by myself. Therefore, there needs to be a messaging service allowing the two users to discuss a meeting point. Furthermore, the walking distance feature was not implemented either as it was deemed out of scope for this dissertation. Therefore, this feature could be implemented as an extra feature.

Contact Us Section

The contact page is currently not developed. Therefore, to avoid user frustration when needing help with an issue, the user should be able to reach someone who they can talk to. A possible solution for this would be to ask the user to enter a their email and a message which will then be directed to someone who can handle the issue.

Edit User Data

The user currently cannot edit their user information from the application. This is basic functionality that needs to be included before release to the general public.

Security

As security wasn't a concerning factor for evaluation, the security of data traveling to and from the server need to be accounted for in future work.

7.4.2 Features to Consider

These features are not needed for the core functionality for the system. However, could be considered to improve how effective the persuasive system is. Therefore, some testing for these extra features should be considered.

Adding Friends

As the system becomes larger, users may wish to have a scoreboard of their friends. Therefore, an "add friend" feature could be implemented and then filter the scoreboard tables at the click of a button.

Points for Other Actions

Furthermore, points are currently only awarded for becoming a new user and for reserving an item. Therefore, other methods of earning points should be considered. For example, to persuade users to list items or when an item of theirs is reserved, the user could be awarded points. On the other hand, the point system could also be used in favour of education. For example, gain a certain number of points from watching a documentary style video concerning food waste. Using the method to educate the user could further persuade the user, as seen in section 6.2.1.

Praise for Listing Items

Currently, the system only praises the user for reserving an item. The user could also be praised for listing and item, having their item reserved by another

user, achieving rewards or reaching a significant score regarding their statistics.

Reward Information

The rewards section has room for improvement. For example, allowing the user to look up what is needed to achieve a specific reward and the progress the user has made towards gaining that reward. Furthermore, the rewards section could be used to educate the user further about food waste. For example, on gaining a reward, the user could then have access to that reward's fact card containing a fact about food waste.

7.4.3 Performance

Performance concerns need to be reconsidered. Some logic could be moved server side to allow for the app to be lighter and less dependent on the user's device specifications. The application needs to be able to run on as many different devices as possible. Therefore, should not handle any logic which is not required by the front end of the system.

Furthermore, there is an existing bug in the system. The log out functionality has a bug, see section 5. Therefore, this needs to be addressed as well as any other bugs that may be discovered or unhandled.

7.4.4 Quality of Life Improvements

For the user's quality of life on the app, there should be a refresh feature implemented into the user's shop section, such as the implementation on the homepage, see appendix K. Furthermore, as noticed in the observational section of the evaluation, see section 6.2.2, the user may automatically assume that when listing an item, the enter button on the keyboard, when editing the final text box, should automatically submit the data. Therefore, the keyboard should react accordingly.

7.4.5 Artistic Features

The rewards system needs to have a design for the icon of each of the possible rewards. These are currently displayed as stars in the current version of the system.

7.4.6 Customisability

Finally, following the heuristics adapted by Kientz et al., customisability was not included in this version of the solution (Kientz, 2010). Therefore, this feature should be considered in future versions of the system, ensuring that the feature is further persuading the user. For example, the user could be given the option to customise their user icon, or design their personal shop.

7.5 Future Works

7.5.1 Improvement on Conducted Studies

In future work the studies should be improved upon.

COVID-19

COVID-19 has an important impact on this project. Therefore, the planned studies described throughout section 6 were not conducted. Therefore, in future works similar studies should be conducted to complete the necessary evaluation. Due to only having one participant, some information was not able to be deduced. For example, there could have been a relationship between the amount of time spent on the system and how much that user is dedicated in being environmentally friendly which could in turn create a focus for the need to educate the user using persuasive technology.

7.5.2 Additional Studies

Psychophysiological Studies

Psychophysio-logical measures were not able to be accounted for in the evaluation, see section 6.2.2. Therefore, in future works, if the budget allows it, consider evaluating with psychophysio-logical measures. For example, assessing involuntary responses, such as pupil dilation, to determine the user's interest in the solution. Furthermore, conducting psychophysio-logical studies could be beneficial to the future of this project as it avoids sanitised answers from the participants and therefore, their results would be a raw reflection of the solution.

Longitudinal Studies

Research into studies for long term effects of persuasive systems should be looked into. During the course of this study, the option to conduct a longer scale was not possible due to time constraints. Therefore, these studies were excluded. However, conducting a similar study over a longer period of time could be a good start. As mentioned in section 4.1, once the iteration has been deemed a success the target behaviour can be scaled up. Hence, increasing the time scale of the target behaviour from one week, to two weeks and potentially one month depending on the new findings. These studies could permit a grant a greater understanding of the persuasive effects of the solution.This solution expects to remain persuasive and continue to help users pursue the target behaviour. Longitudinal studies are important as the target behaviour is not a one time occurrence. The target behaviour needs to be pursued to ensure an environmentally sustainable behaviour. Therefore, the solution's long term effects are relevant and future work must conduct studies on the effects.

Large Sample Studies

As discussed in the limitations, Due to the nature of the project, the systems needs a lot of active users to have an accurate representation of the marketplace. Therefore, a study should be conducted with with a large enough sample to replicate a real world marketplace. There will need to be tasks involving listing items as well as reserving others. Hence, could produce interesting results as it looks at the behaviour of users listing items in a real world environment, which has not been researched during this project.

Persuasive Technology Evaluation

Evaluating persuasive technology can be challenging, therefore a possible evaluation could be to conduct studies with usability professionals (Kientz, 2010). This method may increase the chances of finding potential issues with the system with the experience of these usability professionals. The goal should be to identify as many issues as possible and determine their severity. Hence, this study could be one of the most useful and accurate due to the support of these experienced professionals.

Evaluate Changes From Future Designs

Following section 7.4, many changes could be considered to potentially improve the persuasiveness and the usability of the solution. Hence, any changes to the system should be followed with additional evaluation.

7.6 Final Remarks

Using this solution and improving it further could benefit the individual and lead to a more sustainable future for the planet.

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Appendix A

12 Point Ethics Checklist

This form must be attached to the dissertation as an appendix.

Department of Computer Science

12-Point Ethics Checklist for UG and MSc Projects

Student Thomas Wooliston

Academic Year or Project Title Year 3

Supervisor John Bernardis

Does your project involve people for the collection of data other than you and your supervisor(s)? YES / NO

If the answer to the previous question is YES, you need to answer the following questions, otherwise you can ignore them.

This document describes the 12 issues that need to be considered carefully before students or staff involve other people ('participants' or 'volunteers') for the collection of information as part of their project or research. Replace the text beneath each question with a statement of how you address the issue in your project.

1. *Have you prepared a briefing script for volunteers?* YES / NO
   The participants will be given a brief description of the session as well as the context surrounding it, the reason why I am conducting the session.

2. *Will the participants be informed that they could withdraw at any time?* YES / NO
   There will be a disclaimer at the beginning of each session I conduct.

3. *Is there any intentional deception of the participants?* YES / NO

4. *Will participants be de-briefed?* YES / NO
   The participants will be explained, at the end of the session, how the results will be used.

5. *Will participants voluntarily give informed consent?* YES / NO
   The signatures of the participants will be collected as to confirm their consent.

6. *Will the participants be exposed to any risks greater than those*

encountered in their normal work life (e.g., through the use of non-standard equipment)? YES / NO

7. *Are you offering any incentive to the participants?* YES / NO

8. *Are you in a position of authority or influence over any of your participants?* YES / NO

9. *Are any of your participants under the age of 16?* YES / NO

10. *Do any of your participants have an impairment that will limit Their understanding or communication?* YES / NO

11. *Will the participants be informed of your contact details?* YES / NO
All participants will have my email address and are able to contact me at any time.

12. *Do you have a data management plan for all recorded data?* YES / NO
All data is stored on my personal computer, as well as all of the data being completely anonymous and having no potential for sensitive content to be compromised.

Appendix B

Impact of COVID-19

COVID-19 had the following impact on the project:

1. Impact on the evaluation studies: Due to the restriction of movement and social distancing, it has become impossible to conduct studies with more than one participant. Therefore, the results are unlikely to reflect the population's position.

2. Mental well-being: with the impact of COVID-19 everyone is forced to stay at home. This has lead to an unhealthier life style as there is less socialising, fewer outdoor activities and general fun which leads to being less productive and less motivation to continue with the project. Therefore, it has been harder to put the time needed into the project.

3. Interactions with the project supervisor: Due to the restriction of movement and social distancing, there have been fewer meetings with the project supervisor as Students and University staff have much less time due to there being much more work to complete due to the effect of COVID-19. Hence, there is a strain on time allocated to the supervisor's projects. Therefore, less feedback and no more scheduled meetings.

4. Connection to the internet: due to the increase of people staying at home, there is more stress on the internet. This has had a slight impact on the project as the connection to the internet has often cut off completely. This is cause for concern as the write up for this project is completed with the use of Overleaf, a Latex editor, which can only be used with constant connection to the internet.

Appendix C

Questionnaire

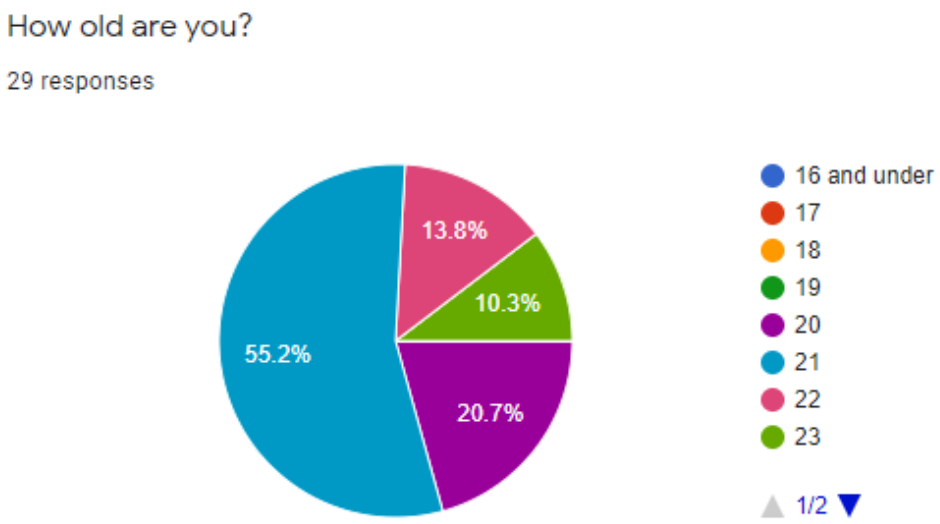


Figure C.1: Demographic: Age

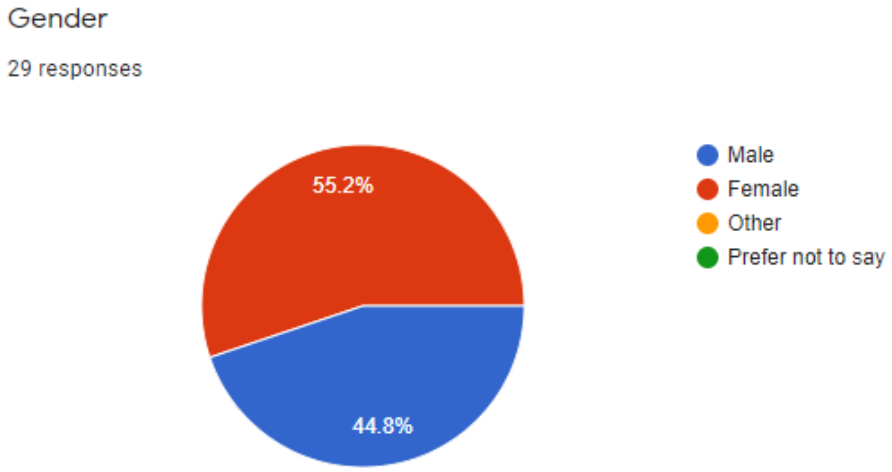


Figure C.2: Demographic: Gender

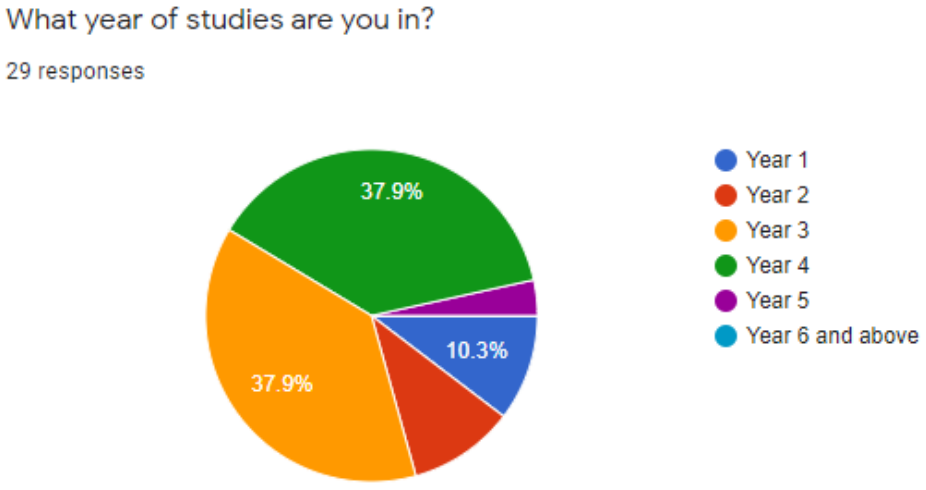


Figure C.3: Demographic: Year

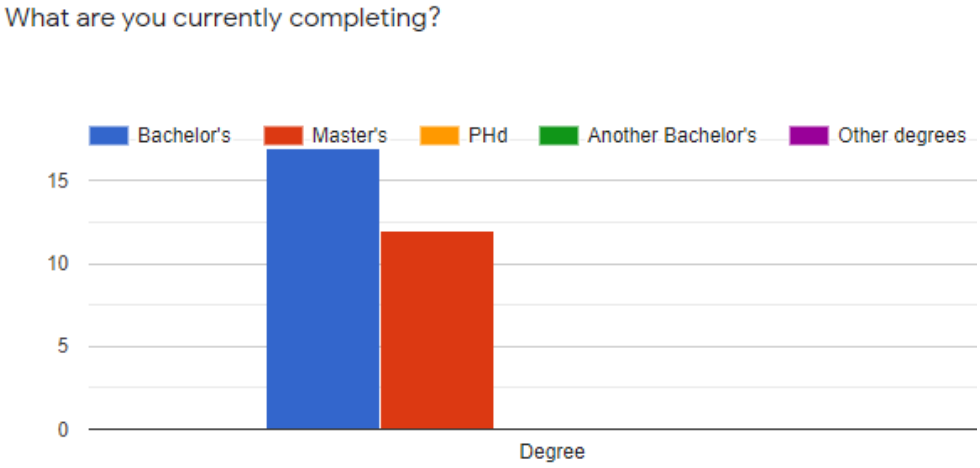


Figure C.4: Demographic: Degree

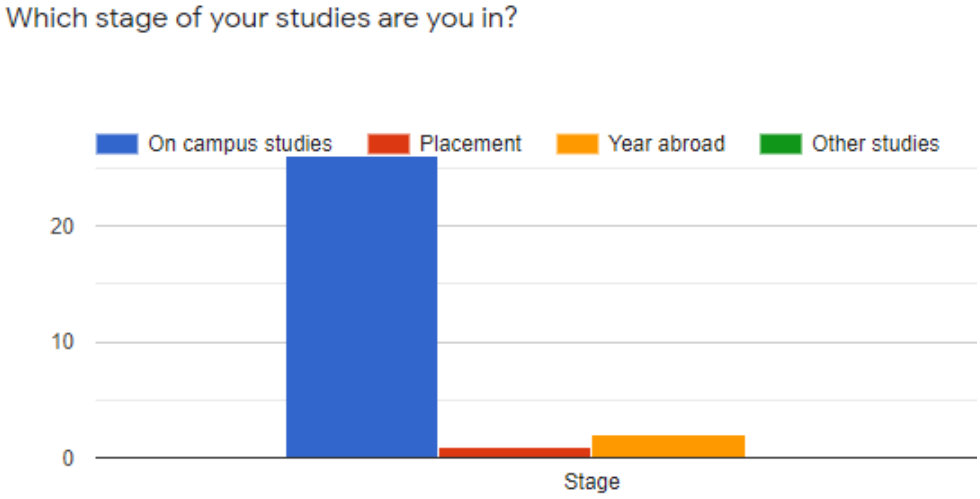


Figure C.5: Demographic: Stage

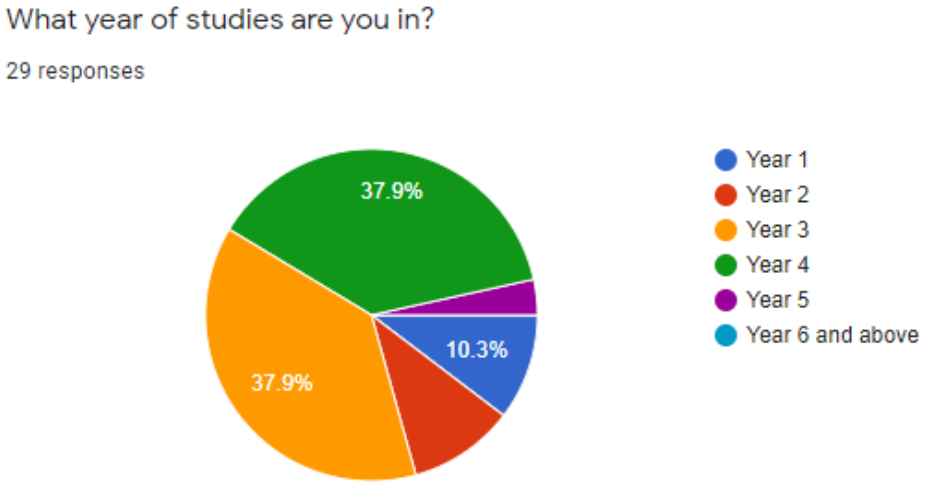


Figure C.6: Demographic: Year

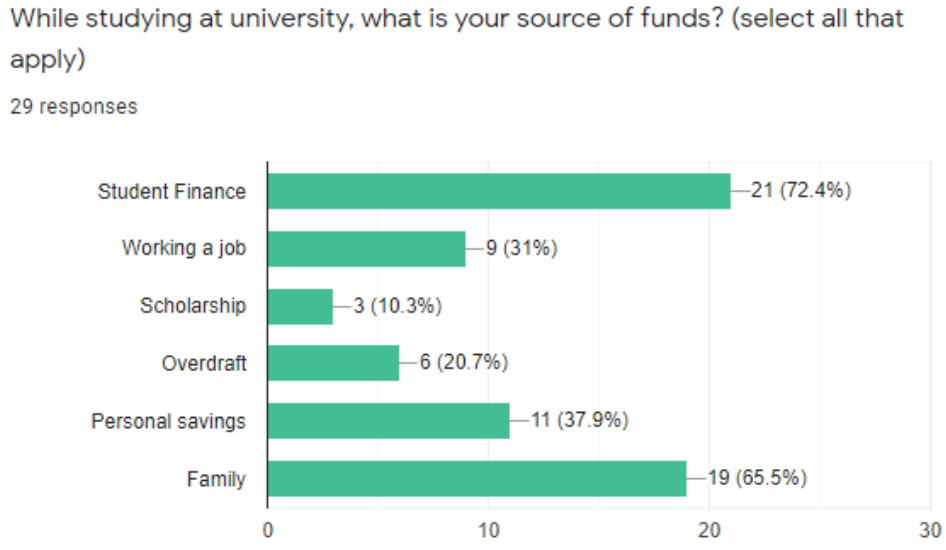


Figure C.7: Financial Background: Funds

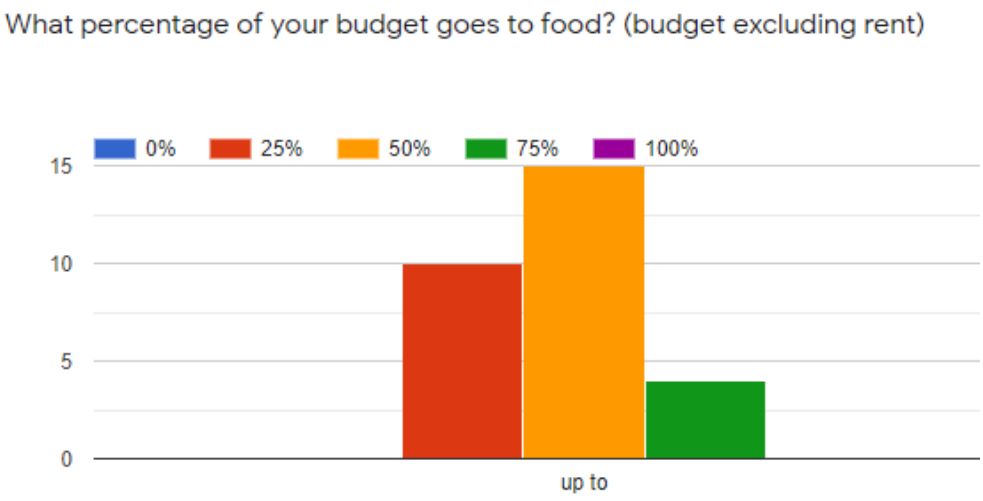


Figure C.8: Financial Background: Food Budget

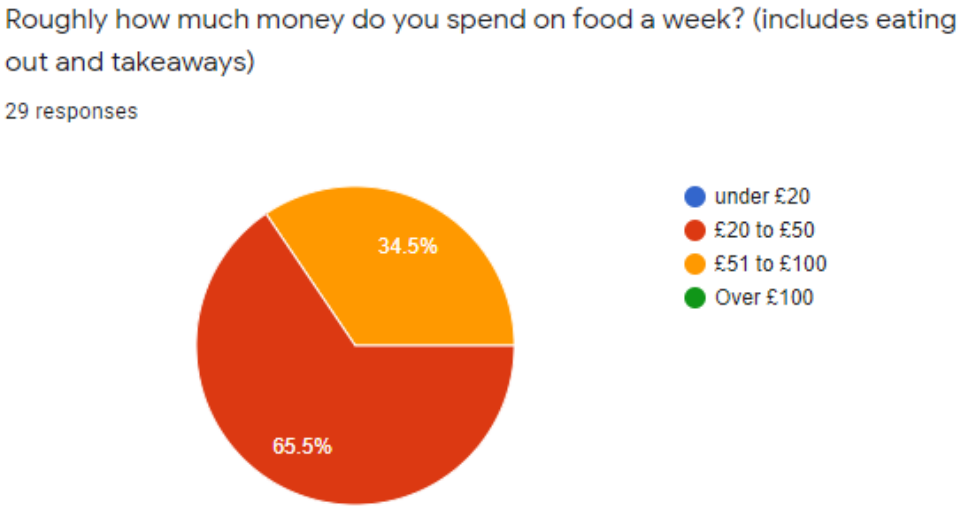


Figure C.9: Food Related Behaviour Background: Weekly Food Budget

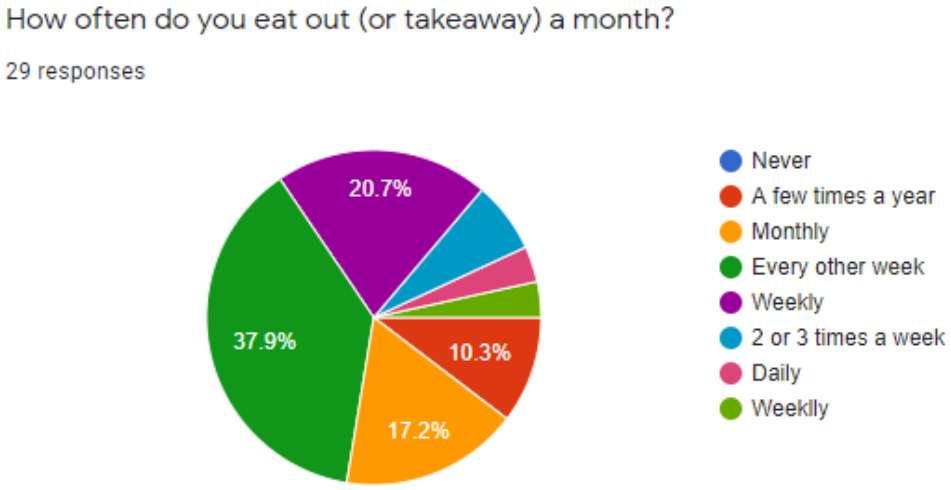


Figure C.10: Food Related Behaviour Background: Takeaway

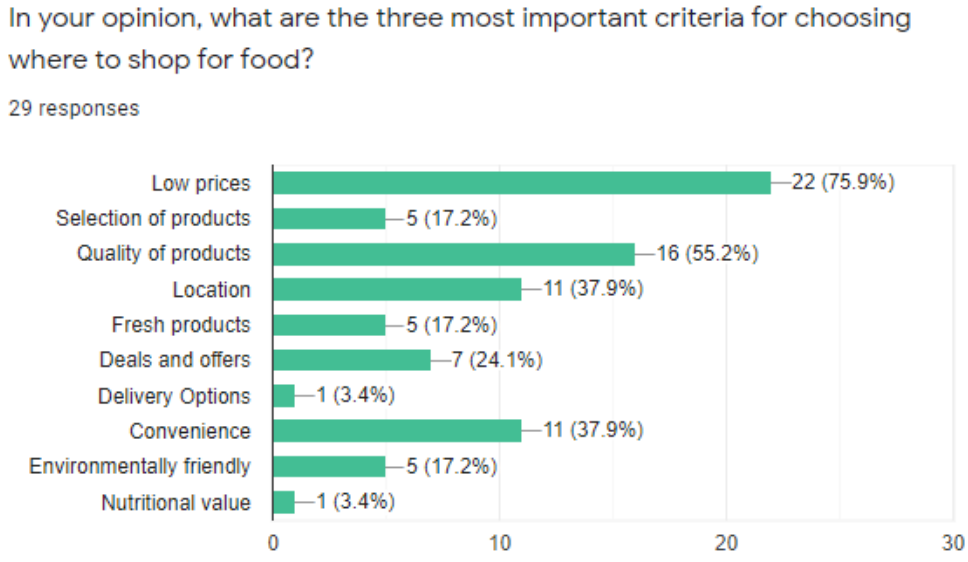


Figure C.11: Food Related Behaviour Background: Shop Criteria

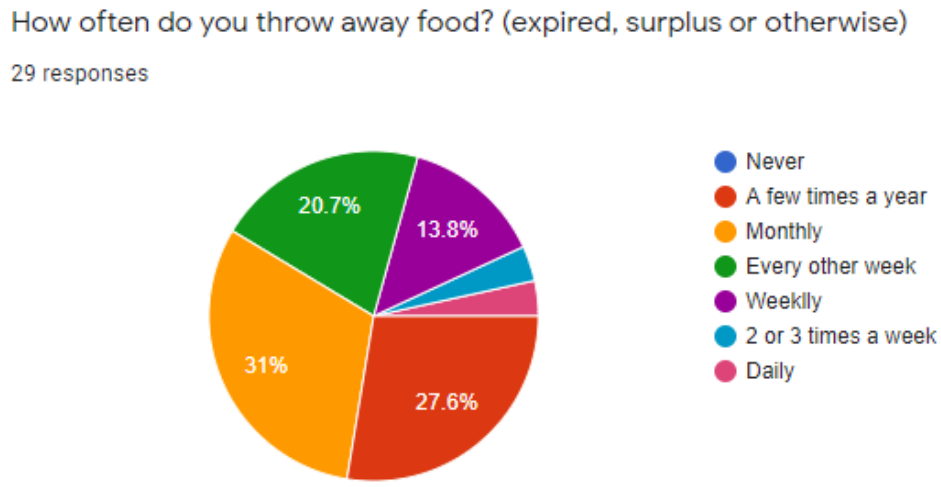


Figure C.12: Food Waste Behaviour Background: Food Waste

Figure C.13: Food Related Behaviour Background: Marketing Influence

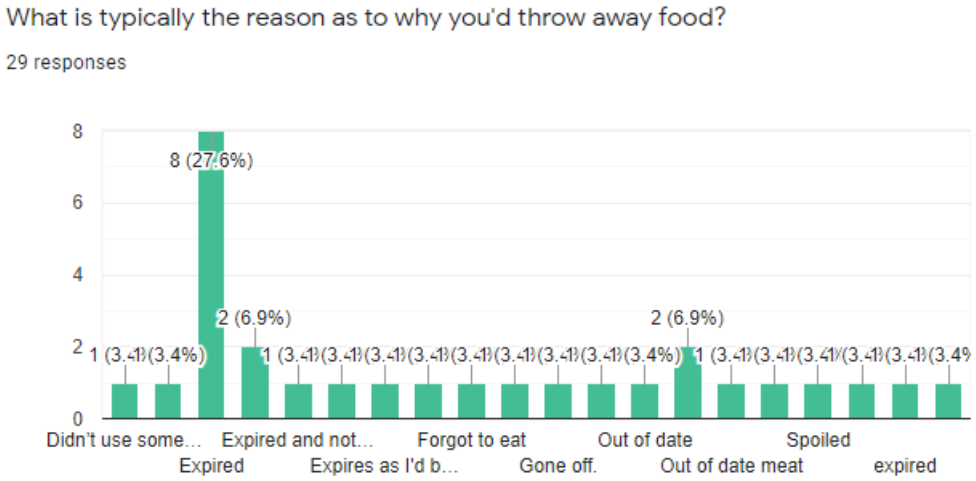


Figure C.14: Food Waste Behaviour Background: Food Waste Reason

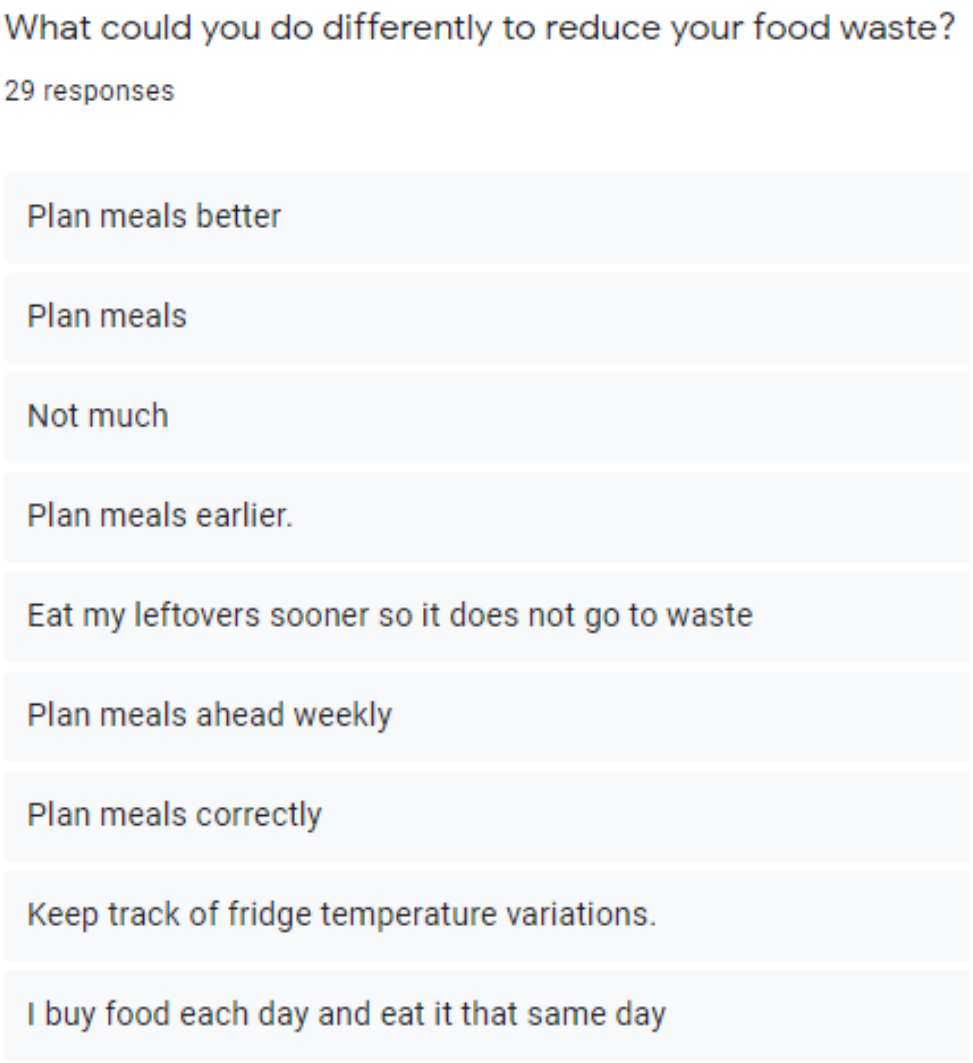


Figure C.15: Food Waste Behaviour Background: Reduce Waste

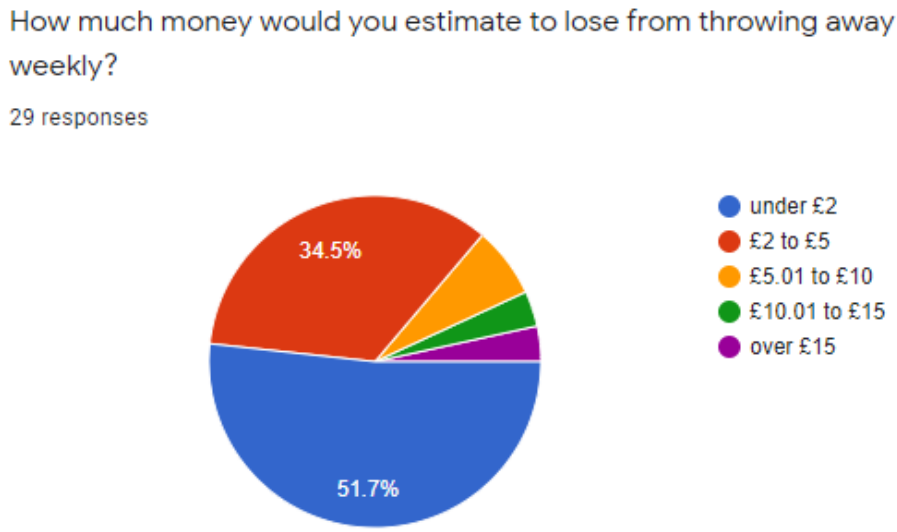


Figure C.16: Food Waste Behaviour Background: Money Lost to Food Waste

Figure C.17: Food Waste Behaviour Background: Thoughts when wasting food

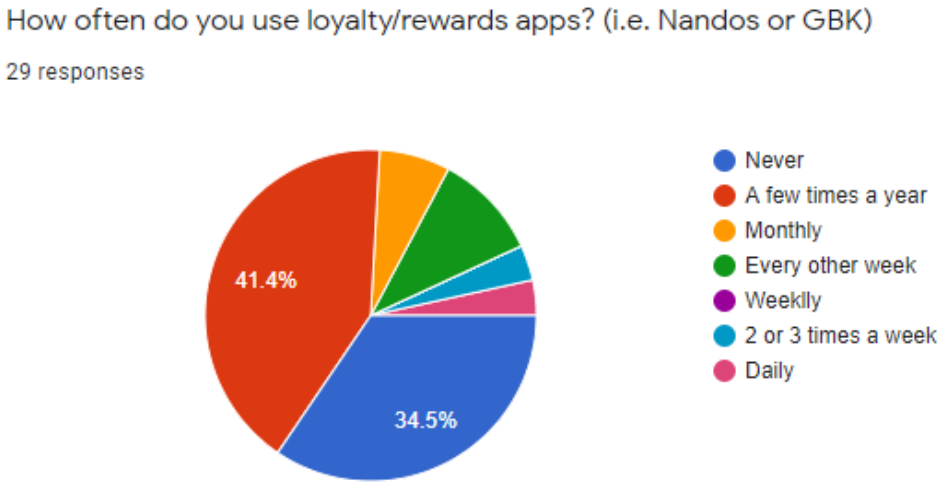


Figure C.18: Using Related Applications: Loyalty

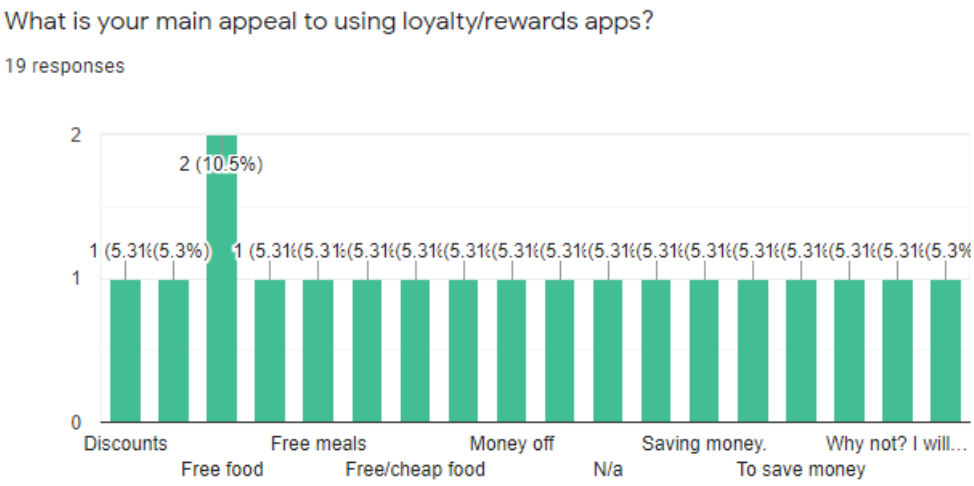


Figure C.19: Using Related Applications: Reason to Use Loyalty Schemes

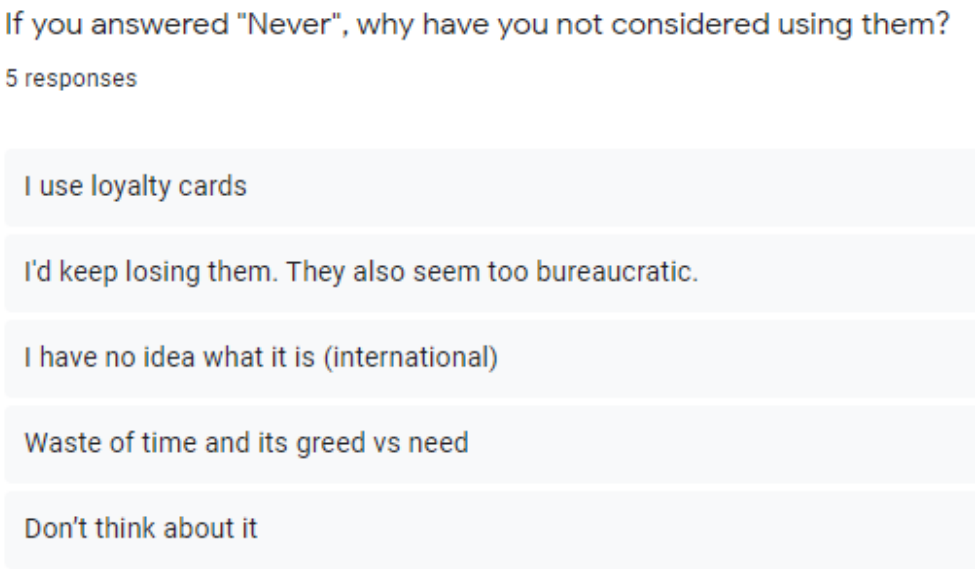


Figure C.20: Using Related Applications: Reason for Not Using Loyalty Schemes

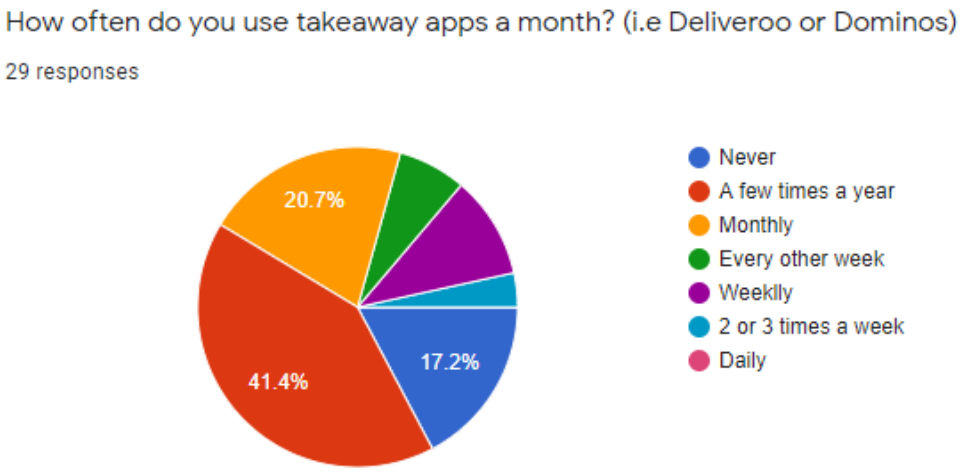


Figure C.21: Using Related Applications: Takeaway

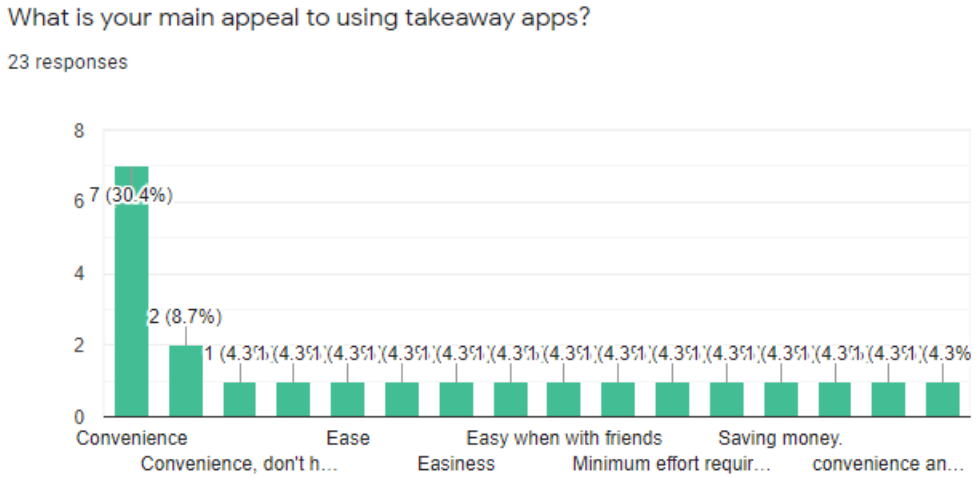


Figure C.22: Using Related Applications: Reason to Use Takeaways

Figure C.23: Using Related Applications: Reason for Not Using Takeaways

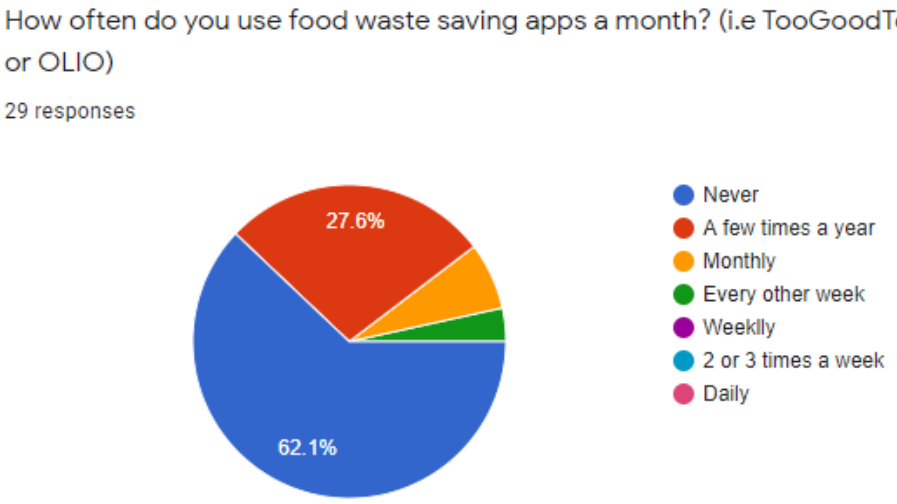


Figure C.24: Using Related Applications: Food Waste Saving Applications

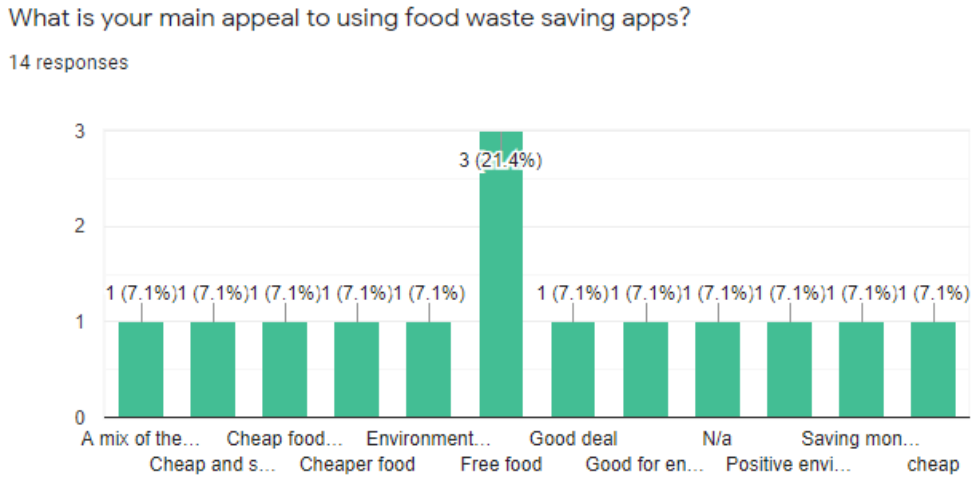


Figure C.25: Using Related Applications: Reason to Use Food Waste Saving Applications

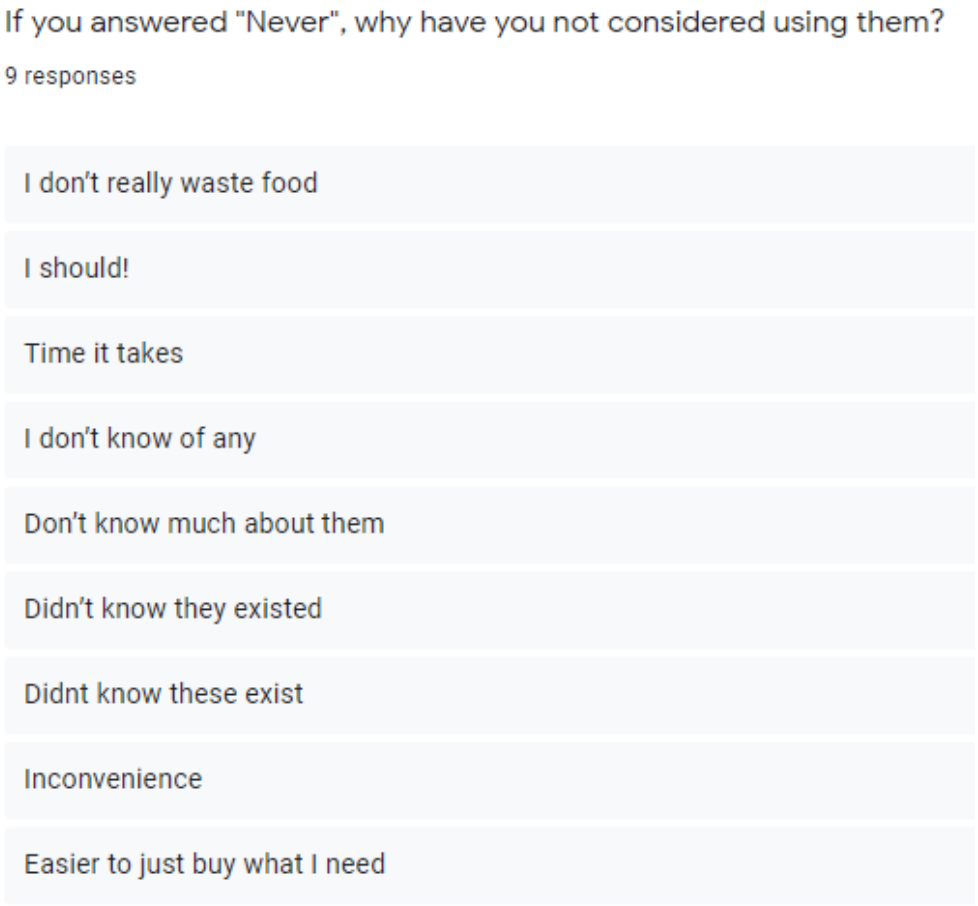


Figure C.26: Using Related Applications: Reason for Not Using Food Waste Saving Applications

Appendix D

Interview with a Food Bank

After the interview with Genesis Trust's food bank in Bath, the findings were summarised to utilise the data more efficiently. Here are those findings:

- Where does the food come from?
  - Donations from customers of supermarkets (weekly pickup)
  - Personally grown food product which have been donated
- How much food is donated?
  - Random (can lead to surplus or need for volunteers to buy food to substitute)
  - Always take long life product
- How much food is wasted?
  - From surplus left at the supermarkets
  - Not much waste in house as given away
- How are the supplier relations?
  - Personal relationship if the store operates on a smaller scale
  - For larger companies, the food bank communicates with a middle-man company that represents the supermarket
- How does the food bank advertise their services
  - Using boards in public places
  - With the use of social media

Appendix E

Focus Group

After the focus group with 5 students at the University of Bath, the findings were summarised to utilise the data more efficiently. The overall goal of this Focus group is to find the target behaviour that is achievable, while contributing to food waste reduction. Here are those findings:

Target Behaviour

The target behaviour decided upon during the focus group would be the following: Use produce which has been left over by other students (by me for the purpose of the test), 3 times a week. This target behaviour will be discussed in greater depth during the remainder of the session.

- What is the ideal situation?
  - Student are better able to control their portion sizing
  - Plan ahead of time make sure it is all eaten
  - Trust instinct on expiry dates and not rely on the one printed on the packaging
- What How would people get rid of food they won't eat, without polluting?
  - Offer the food to people around the students (i.e. other students and flatmates)
  - Donate the food to a local food bank
  - Use up the food by simply eating more
  - Feed the leftover food to pets
- What leads to food being wasted?
  - Food expires or is not needed

  - People they live with do not want the food either
  - The participants mentioned that they do not know who else to give the food to (besides people they live with) and may throw it away as a result

Obstacles that the Target Behaviour Faces

Motivation:

- Pleasure/pain:
  - Would incorporate food that "needed to be eaten", because it was close to expiry and would turn into waste, into their meals. It would be a pleasure as students prefer to save money and not buy new ingredients.
  - Could see the benefit of an app helping find ingredients close to expiry if the app was not intrusive and was not a lengthy process.
- Hope/fear:
  - The act of positive behaviour directed towards saving the planet could have a hopeful impact to reduce pollution.
  - Thinking of people who do not have access to food could have an fear impact on the user.
- Social acceptance/rejection:
  - The students in the group felt like they would like to reduce their waste and eventually reach a zero waste lifestyle.
  - The participants mentioned that they would be more inclined to reduce their waste if a friend (or other person) brought the issue to their attention.

Ability:

- Time:
  - The activity on the app would preferably need to take little to no time and be able to blend in the activity into everyday life.

Triggers:

- Spark:
  - Motivational prompts such as saving the planet.
  - Put forward topics of well being.

Appendix F

1st Prototype

Figure F.1: 1st Prototype: Intro Screen 1

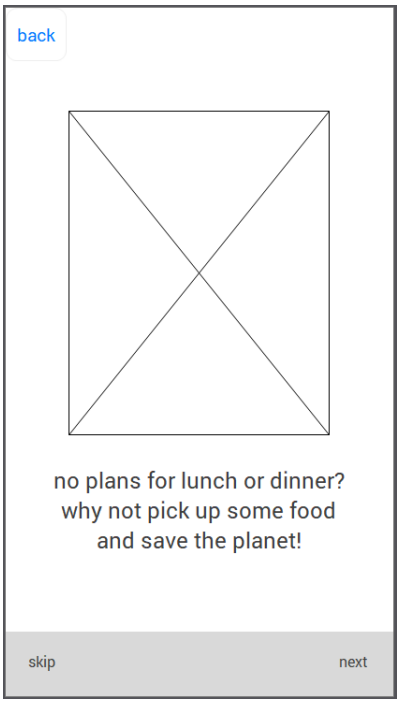


Figure F.2: 1st Prototype: Intro Screen 2

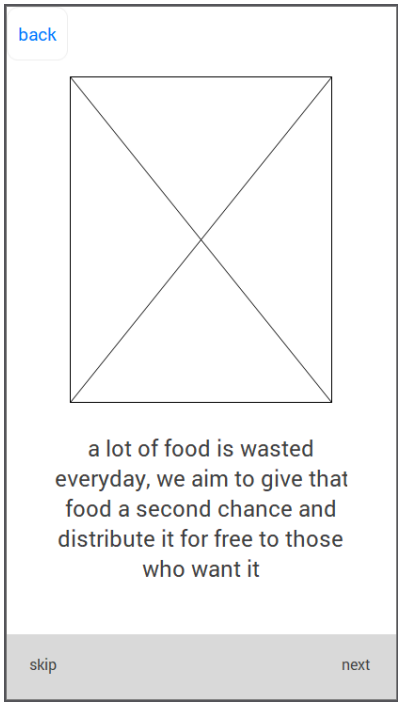


Figure F.3: 1st Prototype: Intro Screen 3

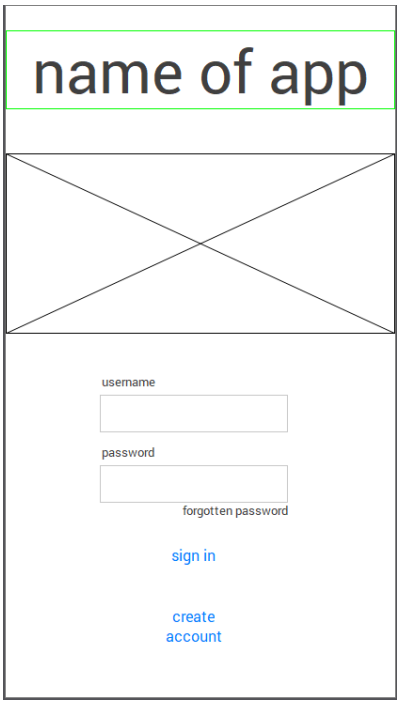


Figure F.4: 1st Prototype: Login Screen

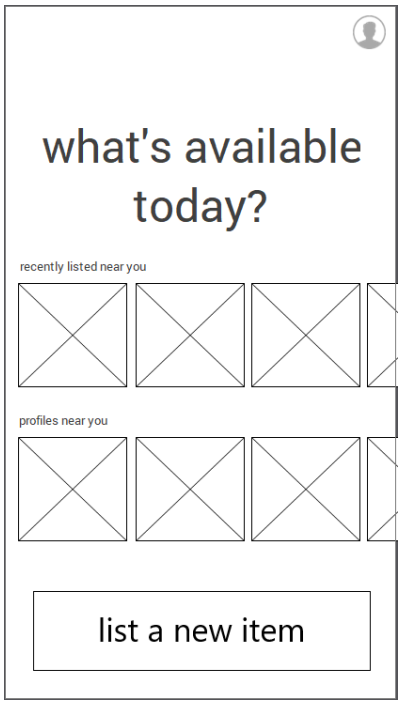


Figure F.5: 1st Prototype: Home Page

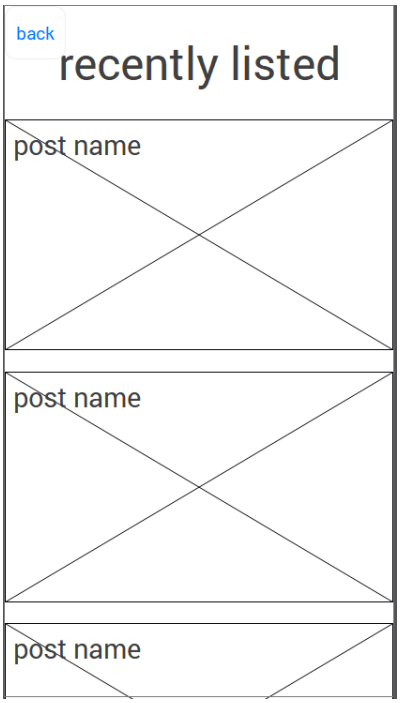


Figure F.6: 1st Prototype: Listings Page

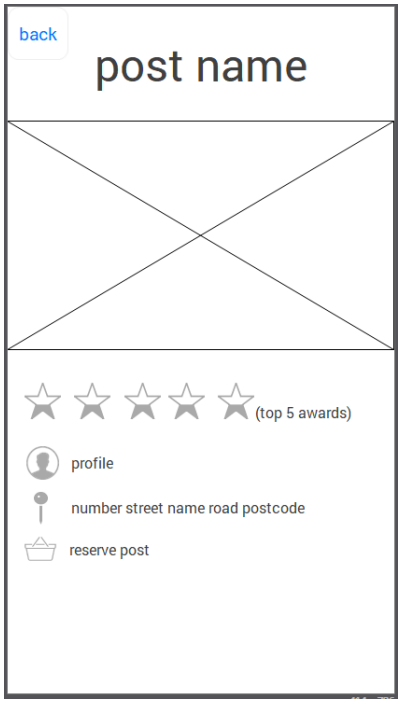


Figure F.7: 1st Prototype: Post Details

Figure F.8: 1st Prototype: Post Details with Praise Message

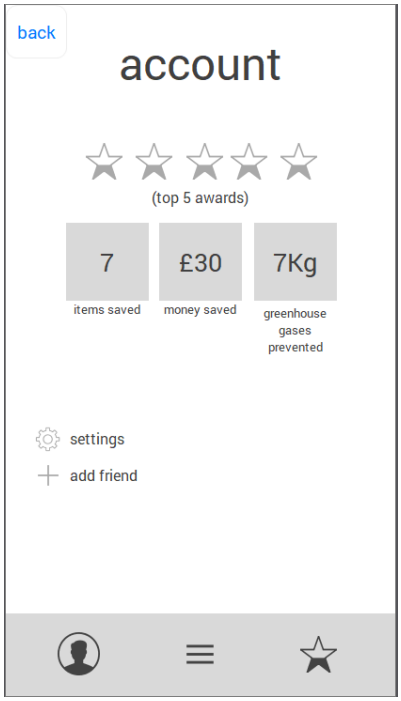


Figure F.9: 1st Prototype: Account Page

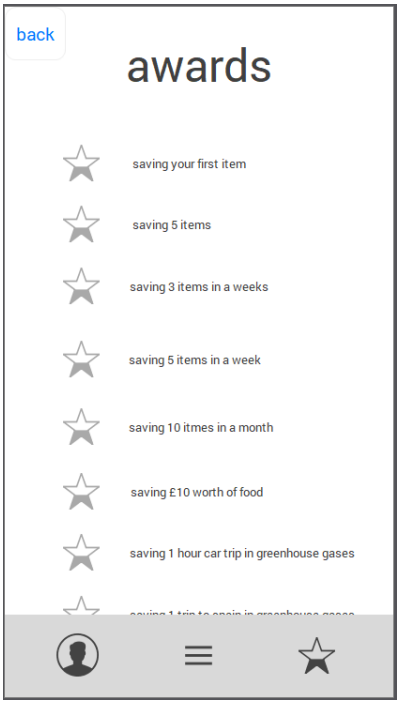


Figure F.10: 1st Prototype: Awards Page

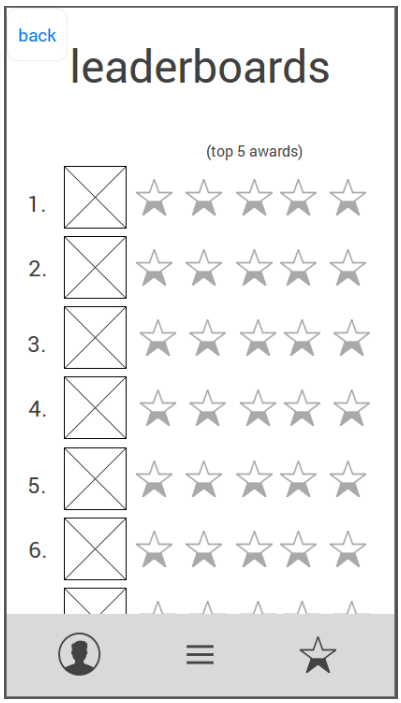


Figure F.11: 1st Prototype: Leader-boards Page

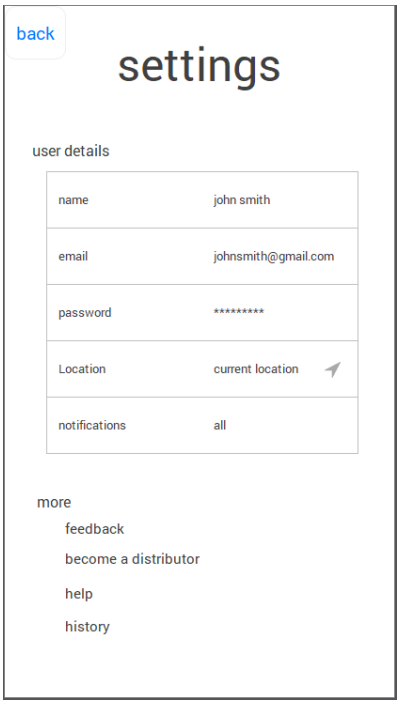


Figure F.12: 1st Prototype: Settings Page

Appendix G

2nd Prototype

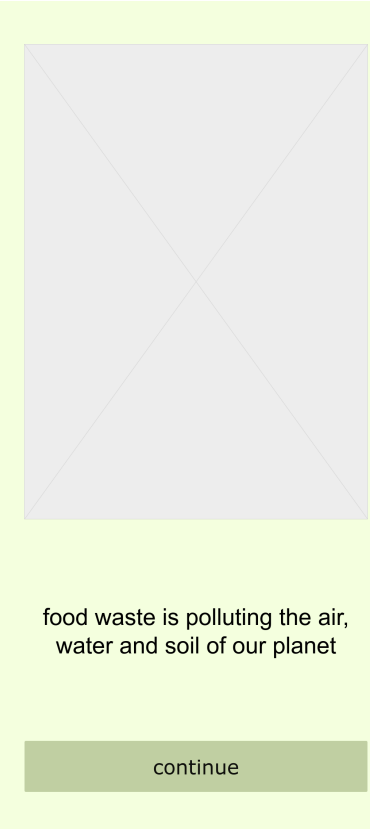


Figure G.1: 2nd Prototype: Intro Screen 1

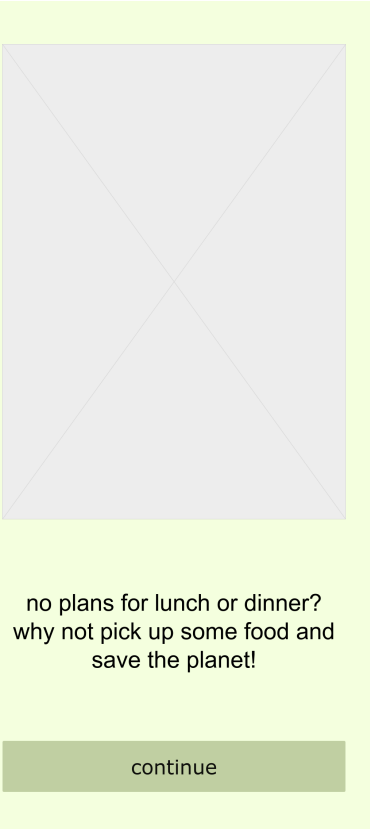


Figure G.2: 2nd Prototype: Intro Screen 2

Figure G.3: 2nd Prototype: Intro Screen 3

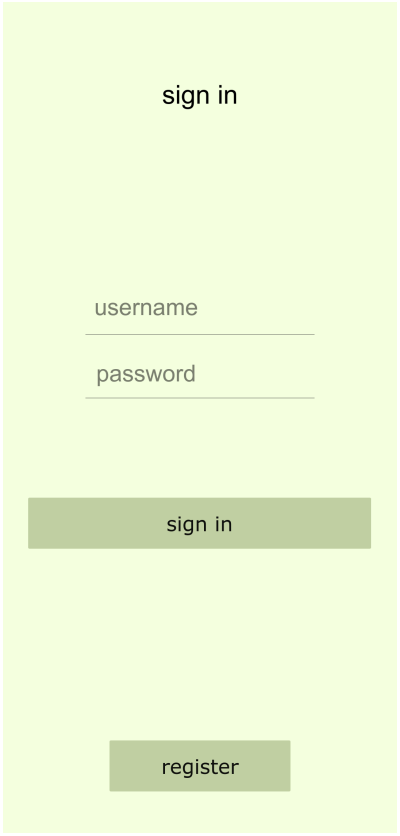


Figure G.4: 2nd Prototype: Login Screen

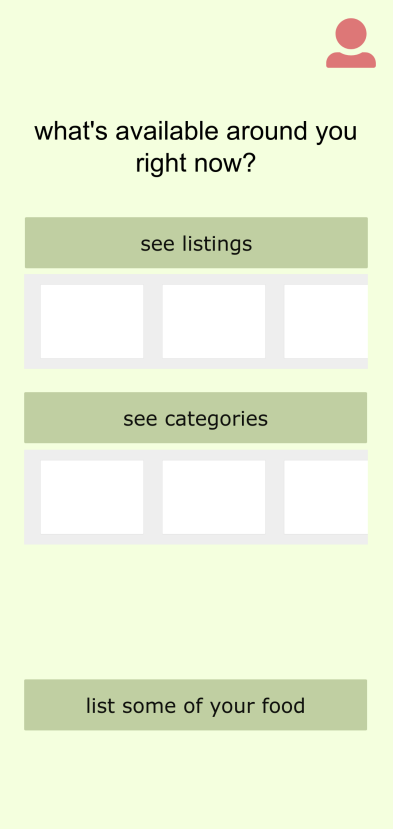


Figure G.5: 2nd Prototype: Home Page

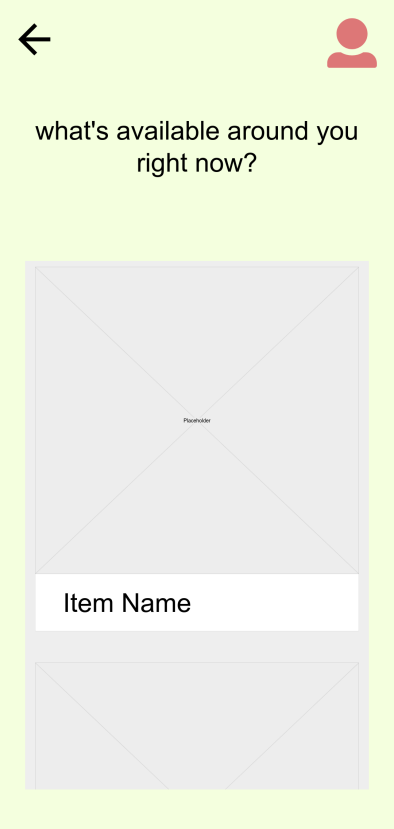


Figure G.6: 2nd Prototype: Listings Page

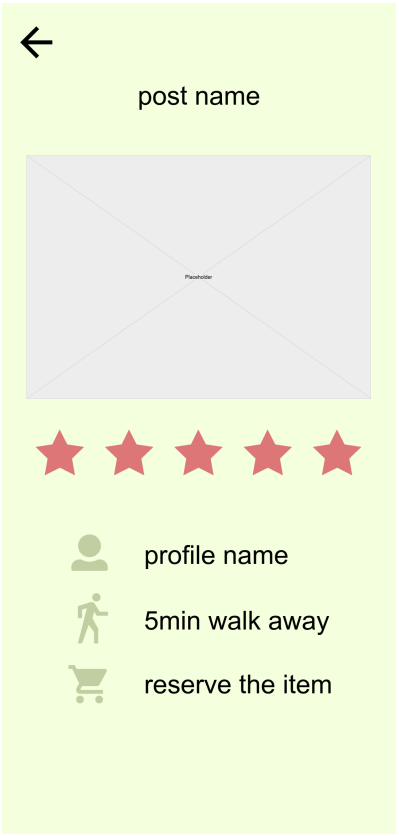


Figure G.7: 2nd Prototype: Post Details

Figure G.8: 2nd Prototype: Post Details with Praise Message

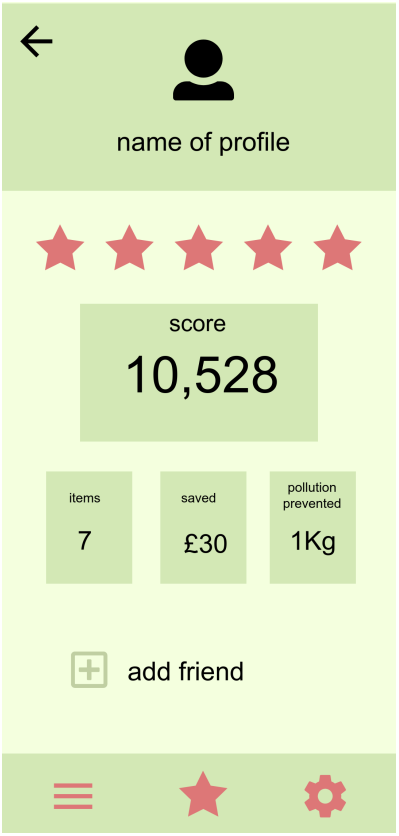


Figure G.9: 2nd Prototype: Account Page

Figure G.10: 2nd Prototype: Awards Page

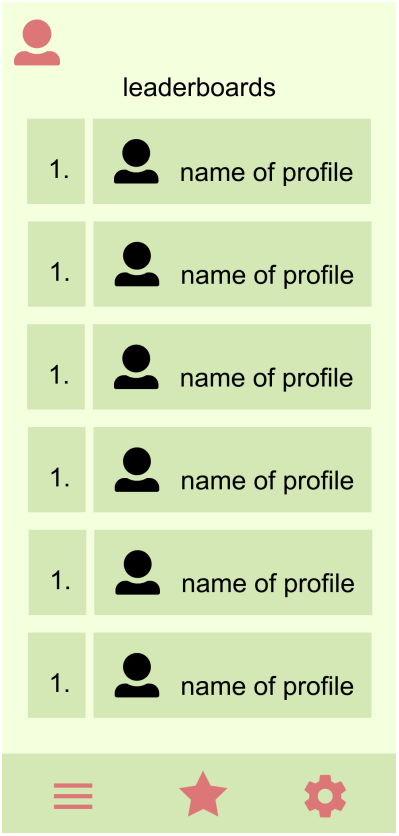


Figure G.11: 2nd Prototype: Leader-boards Page

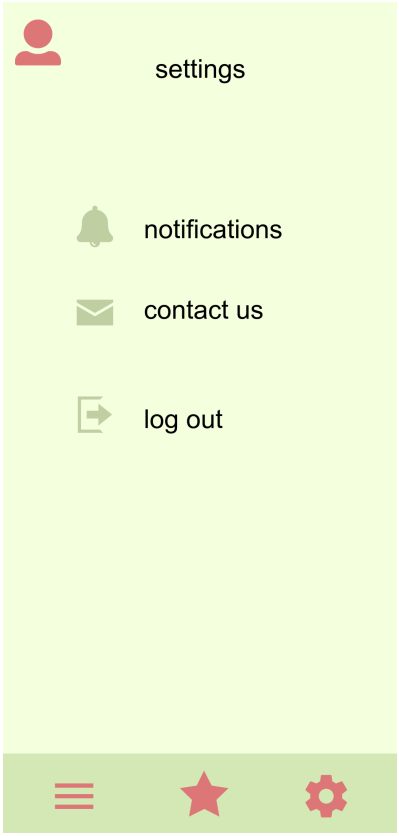


Figure G.12: 2nd Prototype: Settings Page

Appendix H

Final Design

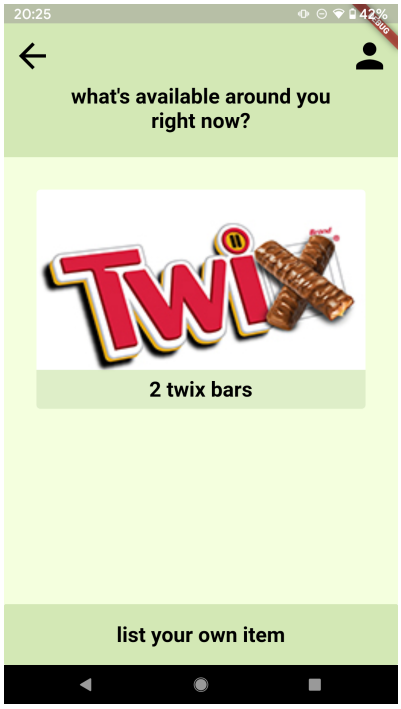


Figure H.1: Final Design: Home Page

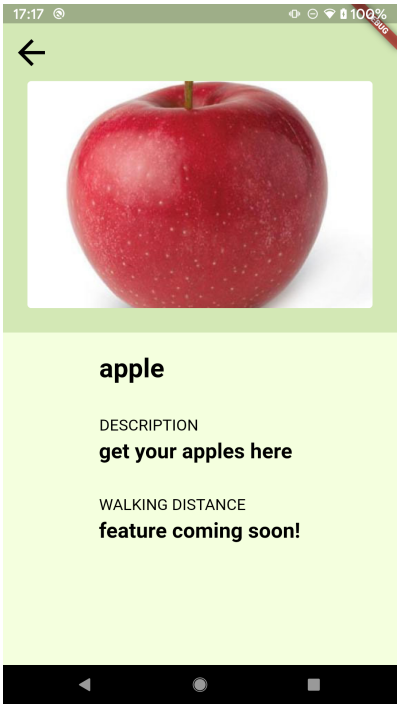


Figure H.2: Final Design: Product Details Page

Figure H.3: Final Design: List an Item Screen

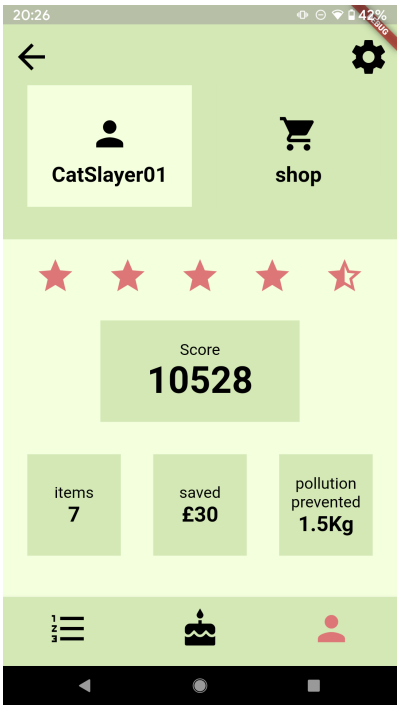


Figure H.4: Final Design: Profile Screen

Figure H.5: Final Design: User Shop Screen

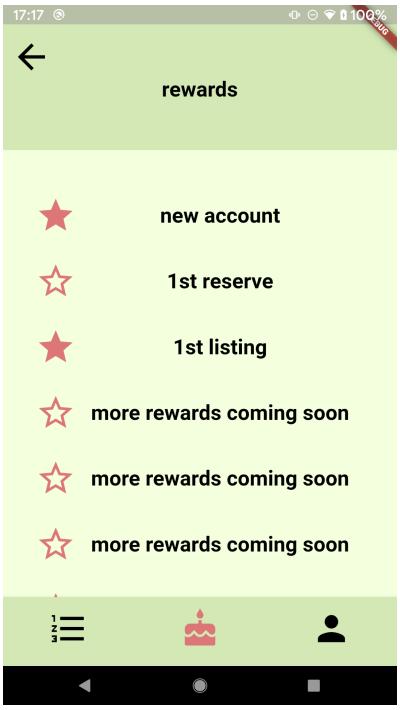


Figure H.6: Final Design: Rewards Screen

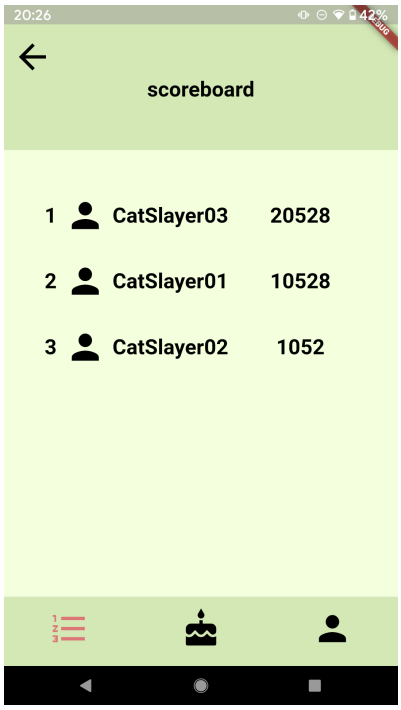


Figure H.7: Final Design: Score-board Screen

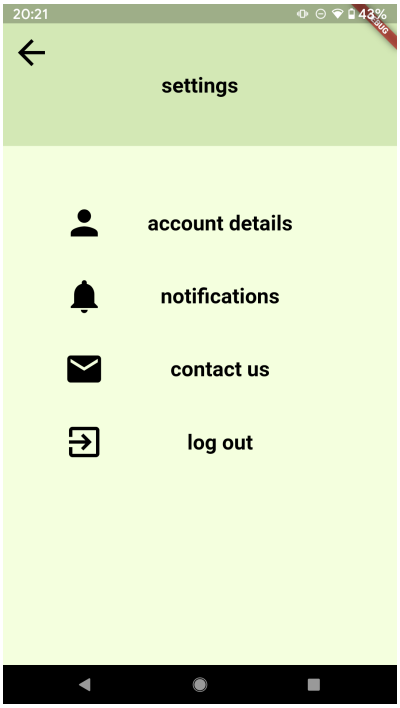


Figure H.8: Final Design: Settings Page

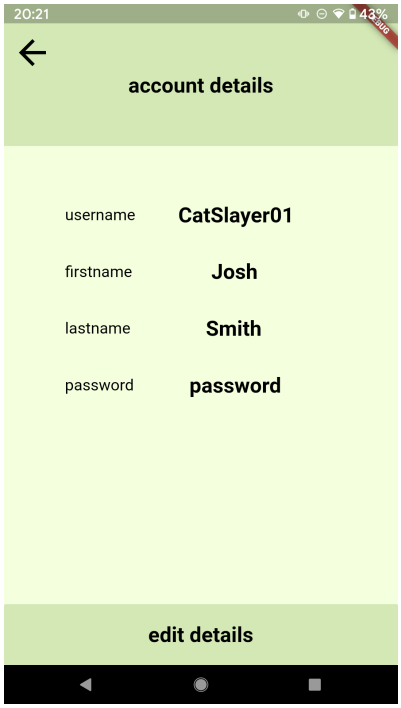
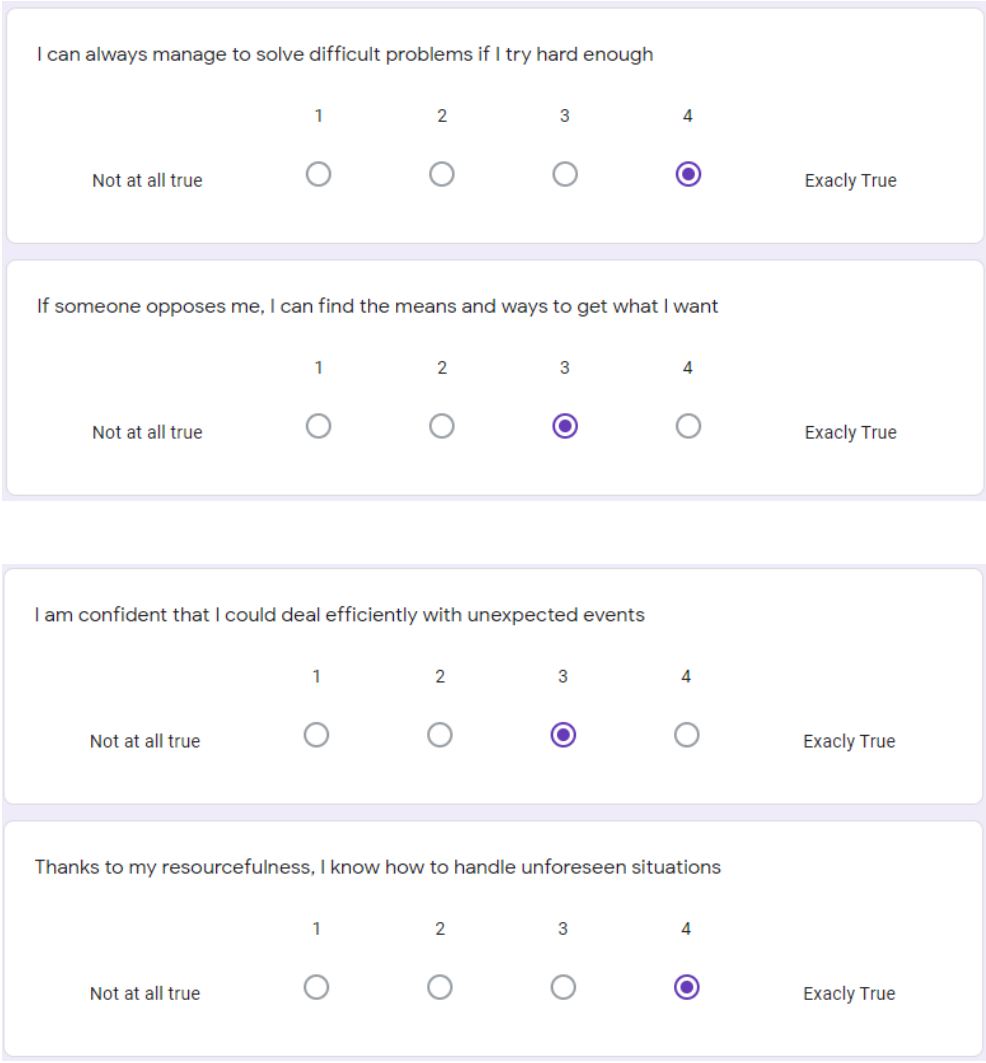
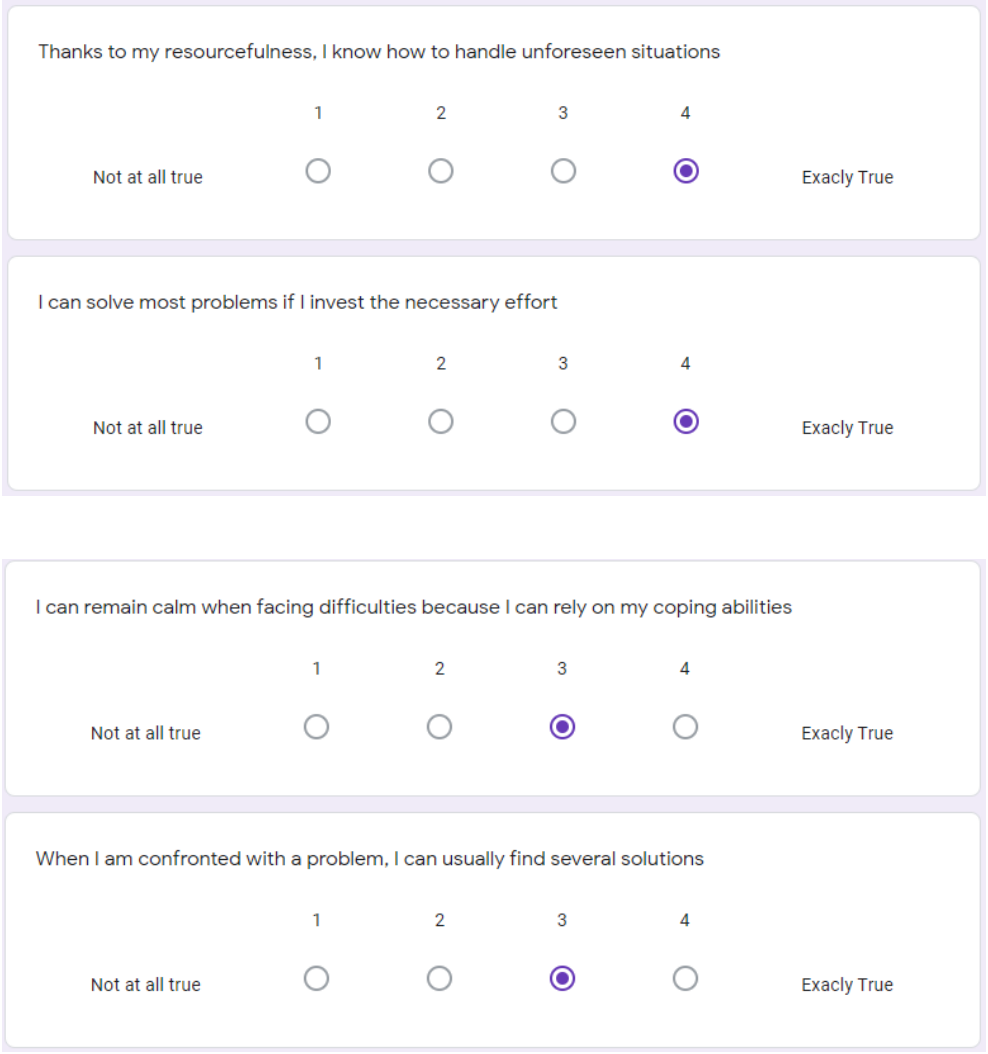


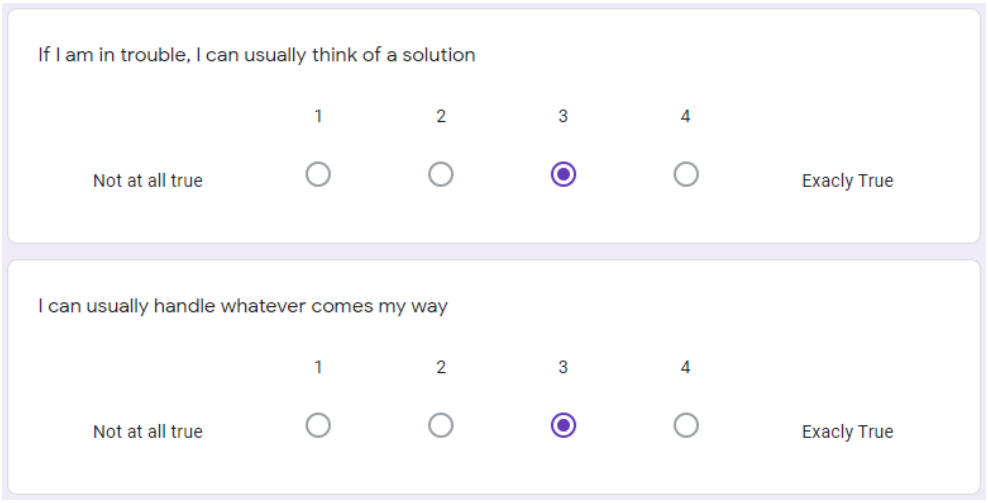
Figure H.9: Final Design: Account Details Page

Appendix I

General Self-Efficacy Scale



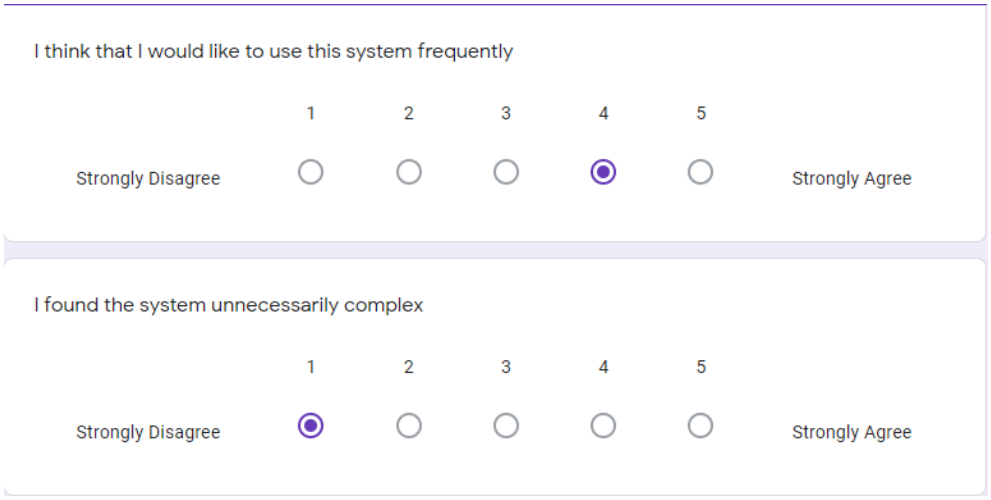

Thanks to my resourcefulness, I know how to handle unforeseen situations
1
2
3
4
Not at all true
Exacly True
I can solve most problems if I invest the necessary effort
1
2
3
4
Not at all true
Exacly True
I can remain calm when facing difficulties because I can rely on my coping abilities
1
2
3
4
Not at all true
Exacly True
When I am confronted with a problem, I can usually find several solutions
1
2
3
4
Not at all true
Exacly True

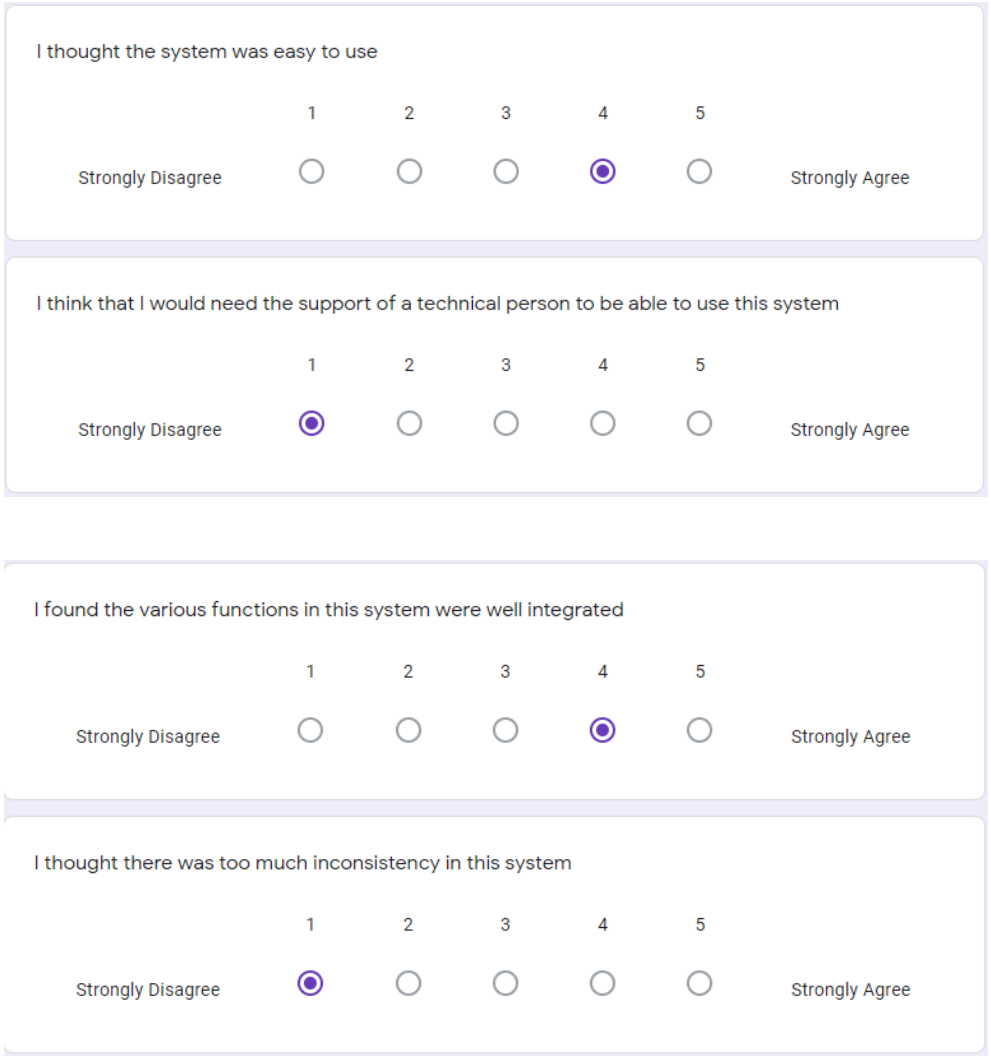

If I am in trouble, I can usually think of a solution
1
2
3
4
Not at all true
Exacly True
I can usually handle whatever comes my way
1
2
3
4
Not at all true
Exacly True

Appendix J

System Usability Scale

J.1 Post 1st Session Evaluation




I thought the system was easy to use
1 2 3 4 5
Strongly Disagree
Strongly Agree
I think that I would need the support of a technical person to be able to use this system
1 2 3 4 5
Strongly Disagree
Strongly Agree
I found the various functions in this system were well integrated
1 2 3 4 5
Strongly Disagree
Strongly Agree
I thought there was too much inconsistency in this system
1 2 3 4 5
Strongly Disagree
Strongly Agree

I would imagine that most people would learn to use this system very quickly

	1	2	3	4	5	
Strongly Disagree	○	○	○	◉	○	Strongly Agree

I found the system very cumbersome to use

	1	2	3	4	5	
Strongly Disagree	◉	○	○	○	○	Strongly Agree

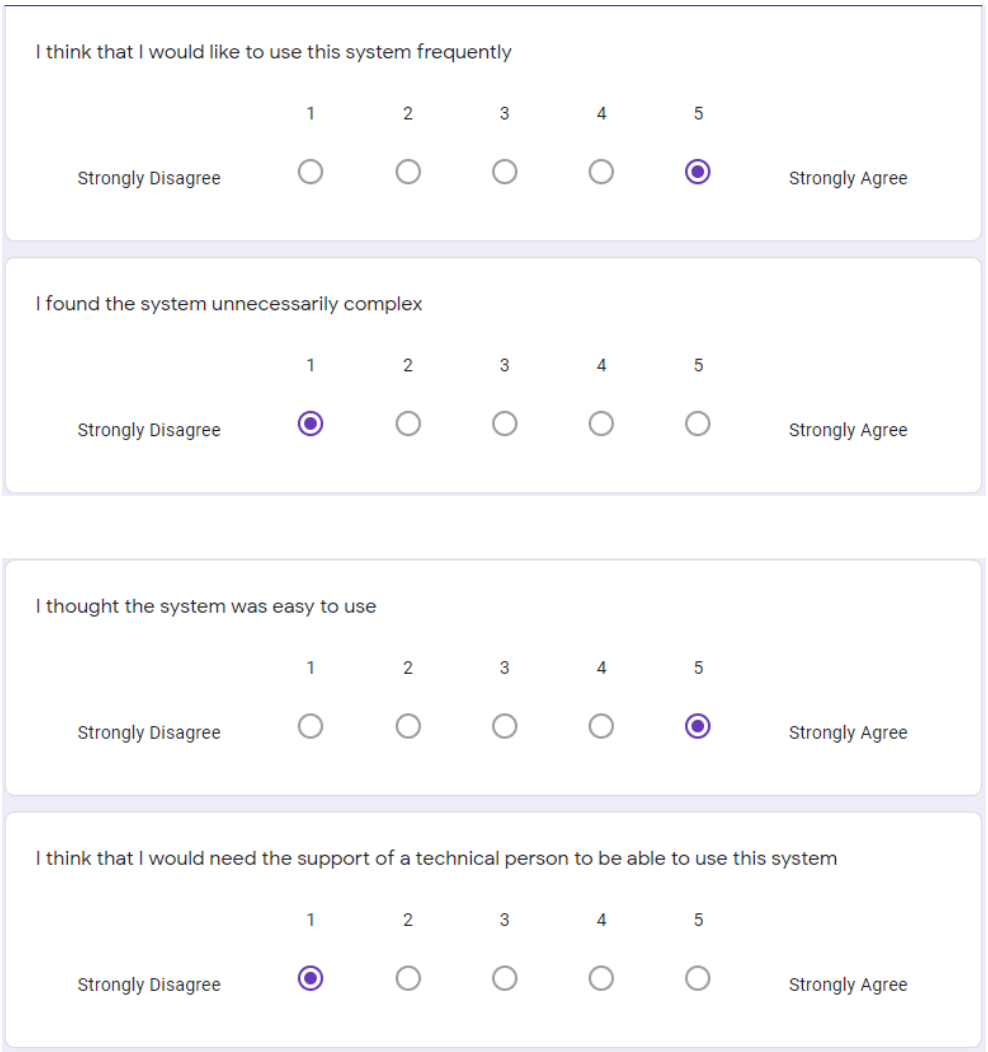
I felt very confident using the system

	1	2	3	4	5	
Strongly Disagree	○	○	○	◉	○	Strongly Agree

I needed to learn a lot of things before I could get going with this system

	1	2	3	4	5	
Strongly Disagree	○	◉	○	○	○	Strongly Agree

J.2 Post Week Evaluation



I found the various functions in this system were well integrated

	1	2	3	4	5	
Strongly Disagree	○	○	○	◉	○	Strongly Agree

I thought there was too much inconsistency in this system

	1	2	3	4	5	
Strongly Disagree	◉	○	○	○	○	Strongly Agree

I would imagine that most people would learn to use this system very quickly

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	◉	Strongly Agree

I found the system very cumbersome to use

	1	2	3	4	5	
Strongly Disagree	◉	○	○	○	○	Strongly Agree

I felt very confident using the system

	1	2	3	4	5	
Strongly Disagree	○	○	○	○	◉	Strongly Agree

I needed to learn a lot of things before I could get going with this system

	1	2	3	4	5	
Strongly Disagree	○	◉	○	○	○	Strongly Agree

Appendix K

Code

The codebase is available here: https://github.bath.ac.uk/taw43/food_waste