University of Glasgow | School of Computing Science

Honours Individual Project Dissertation

Interactive Refrigerator Magnet To Reduce Food Waste

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Abstract

Approximately, one-third to half of all food produced globally is wasted. Around two-thirds of this waste comes from the household. Currently, no consumer technology exists that is effectively reducing the food waste coming from the household. Therefore, an interactive refrigerator magnet was built with the goal of influencing and enabling it's users to waste less. The magnet was evaluated by potential users in an experimental procedure to assess it's ability to alter user's existing habits, influence their intentions towards their wasteful behaviours and generally enable sustainable actions. It was found that the magnet's design was effective in reducing household food waste and a set of design recommendations were extrapolated and presented for future development.

Acknowledgements

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Signature: Joe Kadi Date: 03 April 2020

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1 Introduction

1.1 Overview

With pervasive computing as a globally growing trend, people are realising the increasing ability technology has as a means to self-regulate behaviour. Global food waste is at an all time high, with 2/3's of it coming from the household, and we are beginning to see catastrophic consequences on Earths environment. Governments are attempting to mitigate these threatening conditions through altered policy and enterprise technology (EU 2019), but as of yet no effective large scale, consumer technology that focuses on minimising household food waste exists.

This project aims to deduce how an interactive refrigerator magnet could be best designed to effectively influence a person's behaviour to reduce the amount of food waste they produce. The paper investigates this through conducting 2 studies. The first is a study with users, using a low-fidelity prototype, that aims to identify people's current waste habits, explore their initial attitudes towards the system and identify any design implications or changes for the final, high-fidelity prototype. The final evaluation is experimental and uses the high-fidelity prototype to gauge the potential capacity an interactive refrigerator magnet has in instigating behavioural change and influencing its users to act more ecologically. The results of the evaluation are discussed within the context of design principles which are established through reviewing various psychological models of behaviour and other persuasive technologies in Chapter 2. Design recommendation's are then proposed based on the insights gained.

This chapter will detail the motivation behind the development of the system and the subsequently present the aims and objectives of this paper. Further chapters in this paper will go on to detail specific areas of the project, including the background research, the system's design, implementation and evaluation.

1.2 Motivation

Roughly one third of food produced in the world for human consumption gets wasted every year: about 1.3B tonnes. This waste amounts to roughly £510B for producing, transporting, processing, and disposing of this unused food, and two-thirds of this lost economic value is due to household food waste (Leib et al. 2016). Moreover, the Earth's average temperature has been increasing at an unprecedented rate over the last decade. (NASA 2020). Professionals are calling this an environmental catastrophe with the potential consequences of adverse weather conditions that seriously threaten the livelihood of all humans and animals (WWF 2020). If consumers continue current consumption patterns, food production would need to increase by 70% to feed all 9 billion people in 2050 (Bond et al. 2013).

These statistics show that research in sustainability, specifically targeting household food waste, should receive critical attention. To prevent global food waste, there needs to be change at various levels of the global hierarchy including policy, education and media, but this paper will focus on a technological solution. Since consumers could be considered the main drivers of overall waste generation, with household waste responsible for 2/3's of global food waste, the household seems like an appropriate place to intervene.

In the last decade we have witnessed a pervasive presence of artificially intelligent sensors, cloud computing and powerful micro controllers that has fuelled the rise of the Internet of Things (IoT) paradigm. The IoT market is expected to grow by 32% in the next 5 years and cross the $1 trillion mark by 2025 , and is it presumed that domestic appliances are going to spearhead this movement: with the collective vision of a "smart home" in which all our home appliances are connected together and to the internet (Zanella et al. 2014).

Many of the flagship IoT devices share the collective goal of enabling healthy, conservative behaviours by sensing and reporting the user's behaviours back to them through various, cogent methods. The kitchen has became a favoured area for development with a specific focus on refrigerators. This is due, in large part, to its central location in the household, its spacious face and how it currently plays an important role in sharing information within a household. As such, the refrigerator seems an optimal location for a technological solution to exist.

Although, this knowledge isn't new. We saw the first internet refrigerator in 1998 manifest as Alan Van E's Quantum Fridge, and since then we have seen them incrementally improve with flagship models coming mainly from LG and Samsung. The most recent flagship attempt is by Samsung, called the Family Hub and will set you back a costly £2,799 for the basic model. It sports many desirable features that promote conservative behaviours such as creating a shopping list, a food expiration date tracker and recipe recommendation but still embodies similar shortcomings as the previous attempts: it's lack of portability, high price point and arduous installation and maintenance. Also the date tracking and recipe recommendation is entirely dependant on you manually entering the foods and subsequent expiry dates. An automated, more compact, cheaper solution would obviously be more desirable and effective.

1.3 Aims and Objectives

In light of the above motivations, the central aim of this paper is to work towards designing a portable and cheap domestic appliance which effectively encourages and enables sustainable food practices within the household.

An experimental evaluation will then be conducted with users using the magnet, with the aim to address the central question: How can an interactive refrigerator magnet be designed to reduce household food waste?

Due to the broad nature of this question and the various potential paths to realising an effective design, it is unlikely that one optimal solution exists. As such, the key aims and objectives of this paper are:

- Understand how best to influence behaviour and promote ecological practices by researching behavioural change models
- Research and identify how these behavioural change models are and could be embodied in the design of interactive devices
- Establish refrigerator magnet's design principles based on findings
- Explore potential users current waste habits and initial attitudes towards the systems through a user study
- Design and implement a high-fidelity prototype
- Evaluate the prototypes effectiveness in reducing food waste through experimental evaluation

1.4 Summary

This chapter outlined both the motivations behind the development of the system and the high level aims and objectives of the paper. The remainder of this paper will discuss the process of

achieving each goal, how technology can be designed to influence behaviour, walk through the development process of the refrigerator magnet and present an experimental evaluation of the magnet's effectiveness in promoting conservative behaviours. The paper is structured as follows:

- **Chapter 2:** researchers and assesses various behavioural change models. It also looks at how these models have been and could be applied to technological design to reduce food waste by researching similar persuasive technologies.
- **Chapter 3:** outline the requirements analysis processes by developing a complete set of functional and non-functional requirements. These are presented using Consortium's MoSCoW method (Ahmad et al. 2017).
- **Chapter 4:** details the process of making design decisions. It begins by documenting a pilot study conducted with a low-fidelity prototype, and concludes by discussing design changes based on the studies' findings.
- **Chapter 5:** reviews the implementation of the magnet application and its architecture.
- **Chapter 6:** provides the experimental evaluation of the system, including an experiment with users, interview questionnaire questions then a discussion that draws from the experiment results and evaluates if the refrigerator magnet's design conforms to the established design principles.
- **Chapter 7:** provides the conclusion to the paper. A summary of the entire paper is given, as well as a future work section which extrapolates all the system's future improvements and summarises them.

2 Background

In this chapter I will examine prior research that is relevant to the core concept of this paper: persuasive technology. The aim of the research is to understand wasteful behaviours through looking at accredited psychologists' models of behaviour, then to understand how to effectively influence and change wasteful behaviour through scrutinising various behavioural change models and finally how to effectively incorporate these models into the design of an interactive refrigerator magnet by inspecting techniques used by similar persuasive technologies. A set of design principles, used to guide the refrigerator magnets design and main evaluation, are established based on the findings.

2.1 Understanding wasteful behaviours

Most people generally agree that they would like to act ecologically, and not contribute to the degradation of the environment, but this is not reflected in their behaviour (Quested. et al. 2013). Why? To answer this, we firstly must understand the factors influencing people's wasteful behaviours. The Triandis' Theory of Interpersonal Behaviour (Triandis 1977) is an integrated model of 'interpersonal' behaviour, developed in 1977 by the social psychologist Harry Triandis, and can be seen below:

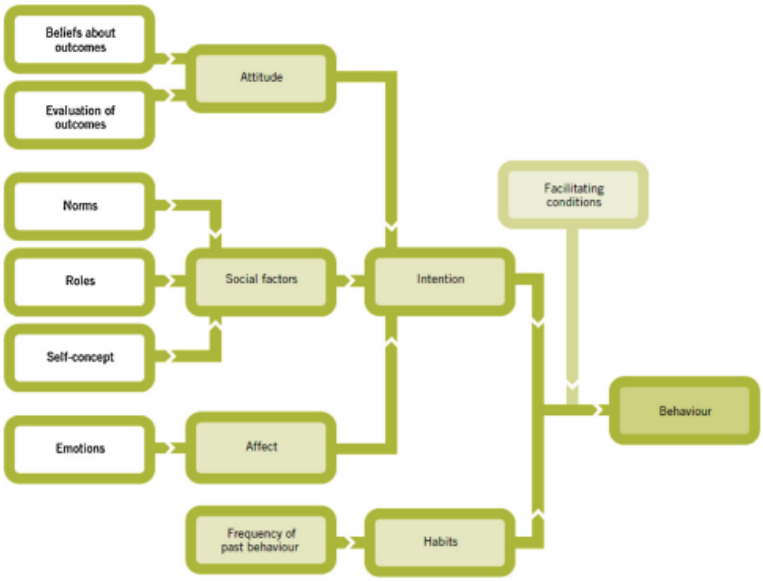

Figure 2.1: *Triandis' Theory of Interpersonal Behaviour depicting concepts that comprise behaviour* (Triandis 1977)

The model aims to demonstrate what factors (external and internal) comprise a persons behaviour. The core of the model, and the most important areas of behaviour to focus the refrigerator

magnets influence on, are the 3 boxes on the right hand side: Intention, Habits and Facilitating Conditions. Triandis originally ranked 1) Habits as the most significant factor determining a persons behaviour, followed by 2) Intentions and 3) Facilitating Conditions.

2.1.1 Understanding Habits

Habits are widely regarded as routine behaviour which occur without the individual consciously forming an intention. Triandis' model deduces that habits are based upon past behaviours and further research by (Bargh 1994) defines habitual actions as automatic; lacking awareness and being difficult to control. In the context of wasteful behaviours, many activities can be regarded as wasteful habits due to their frequent repetition. These include: buying too much food, consistently allowing the same food's to expire (due to over-purchasing, food being "bruised", simply not knowing what to do with it, to name a few), not planning meals, disposing of foods as soon as they look "off" and many more (Quested. et al. 2013). These un-ecological habits become engrained in people's behaviour largely due to the lack of awareness the individuals have about their consequences, and the perceived effort involved in actually changing them. Although it is presumed that, at least in the first instance, that the behaviour arose from rationally based intentions (Bargh 1994).

2.1.2 Understanding Intentions

(Triandis 1977) states that a persons intention represents their decision making process and represents what the individual consciously intends on doing. Figure 2.1 depicts a persons intention to be directly influenced by social factors: how the person sees themselves and their actions in relation to wider society, affect: their sub-conscious emotional factors including things like moods and value, and attitude: their beliefs and evaluation of the outcomes of the behaviour. In the context of wasteful behaviours, it is clear that many people do not have ecological intentions. This is due to many reasons, including that sufficient social pressures aren't in place to make individuals aware of how their personal waste can have a global impact (Quested. et al. 2013). Although we are seeing a global increase of social pressures surrounding the subject of waste, due to the impending environmental devastation that human waste has cultivated. Also, individuals could struggle to adopt an ecological attitude towards personal food waste as they are unaware of how much waste they actually produces, as usually food is thrown out in small quantities but frequently (ibid.). This unawareness tends to manifest itself as wasteful behaviour, with disregard to the environments health. Although, people tend to be much more vigilant when it comes to wasting their money. This can be reflected in a study conducted by (WRAP 2013) - Waste and Resources Action Programme - where only 13% of people said throwing away food bothers them because its bad for the environment, whereas 71% said it bothers them as it is a waste of their money. It was revealed in another qualitative study by WRAP that those who disengage with the issue of food waste prevention do so with the perception that nobody else is acting on the issue (Quested. et al. 2013).

2.1.3 Understanding Facilitating Conditions

This term refers to any external factors that help or hinder a person converting their intention and habits into a behaviour. A lot of work in this area has focused on the attempt to remove "barriers" that prevent people from acting in an ecological manner (Darnton 2008). A good example of this barrier removal would be when "enablers" are supplied, such as door-step recycling collections. It wasn't that prior to this people weren't able to recycle, but it took some level of effort. Door-step recycling removed this effort, thus massively increasing the amount people recycled globally (Chatterton 2011). A similar approach could be taken in an augmented refrigerator magnet's design where it acts as an enabler by providing useful and actionable information, such as recipe recommendation to prevent individuals disposing of the nearly-expired food.

In conclusion in order for an augmented refrigerator magnet to influence somebodies behaviour, it must influence their intention, change their habits and remove any "barriers", thus acting as an "enabler". In the next section I will discuss some widely regarded methods in doing so.

2.2 How to change wasteful behaviours

Here I will introduce and discuss behavioural change models. I will look at models to change habits and intentions and analyse them in the context of promoting ecological behaviour.

2.2.1 Changing Habits

There are many social-psychological approaches to changing habitual behaviours that stress the importance of situational factors. (Bandura 1988)'s Mastery Modelling is a technique which involves practicing behavioural cues that are in line with new intentions. These are rehearsed repeatedly such that when particular situations are encountered, the practiced response becomes instinctive. This technique of repetition as a method to change habits is also seen in (P. M. Gollwitzer and Sheeran 2006)'s Implementation Intentions which dictates a conditioning process involving a rehearsal of scenarios. Many studies have shown that in cognitive terms, rehearsal of new behaviours is sufficient to override existing habits (Haddock and Maio 2007). An augmented refrigerator magnet could assist an individual in rehearsing ecological responses to expiring foods by showing the person what to do with the food, instead of merely disposing it. The magnet could also provide an effective system which enables a person to rehearse the practice of cooking with foods that are closest to expiring first. If practiced for long enough, these new environmental friendly behaviours could replace old wasteful habits within individuals.

2.2.2 Changing Intentions

(P. Gollwitzer and Heckhausen 1987)'s 4 stage model for of self-regulated behavioural change, deduces that when an individual becomes aware that their current behaviour has harmful consequences, they accept personal responsibility and self-awareness begins to form. In this state of self-awareness, the individual usually showcases a tendency to compare their current behaviour with personal standards they hold (e.g "I am somebody who cares for the environment"). This awareness is usually enough for the individual to re-evaluate the outcome of their behaviour and act according to their personal standards (personal norm). This belief that a heightened awareness of the consequences of ones actions can influence a their intentions is echoed in (Schwartz 1977)'s Norm Activation Theory. This finding is also in line with Trianid's Model of Behaviour, seen in figure 2.1, as it showcases how an altered attitude can influence an intention, thus influencing the behaviour itself. An augmented refrigerator magnet could incorporate this method into its design by visualising the users wasteful behaviours, thus making the harmful consequences of the users current behaviours apparent.

(P. Gollwitzer and Heckhausen 1987)'s 4 model for behavioural change also highlights that the fear of social disapproval may also be an influencing factor to activating an individuals personal norm and altering their intentions. Again, this in nicely in line with (Triandis 1977) model of behaviour as it reinforces how social factors can directly influence intentions. (Blamey 1998) did further research into (Schwartz 1977) Norm Activation Theory and found that when the obligation to behave within personal standards is felt, the individual perceives a feeling of satisfaction thus motivating them to actually carry out the action. Although the likelihood of this action actually being taken depends on how feasible the individual perceives it to be. An augmented refrigerator magnet could incorporate a similar method into it's design by deploying various eco-feedback techniques that increase the users awareness of the harmful consequences of their current behaviour (these are discussed in the next section) and by leveraging social pressures.

For example, incorporating a digital competition with a friend to see who can produce the least food waste.

2.2.3 4E's Model for Sustainable Lifestyles

(DEFRA 2011) - the GOV Department for Environment, Food & Rural Affairs - published a framework, in October 2011, which lays out a system to understand and influence behaviour. The insights from (ibid.)'s model are based on evidence and act as an overview on waste prevention. It aims to inform us why some people are acting, and some are not and can be seen below:

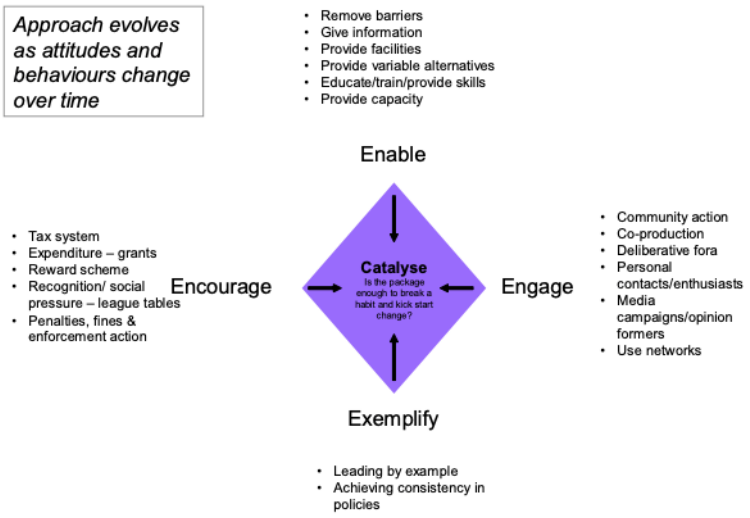

Figure 2.2: *GOV Department for Environment, Food & Rural Affairs proposed Framework for Sustainable Lifestyles which sets out an approach to understanding and influencing behaviour.*

This model links well with the models discussed previously since (Triandis 1977)'s Model of Interpersonal Behaviour enables me to identify what areas of persons behaviour the refrigerator magnet should focus its intervention on. The various behavioural change models, (P. Gollwitzer and Heckhausen 1987); (Schwartz 1977); (P. M. Gollwitzer and Sheeran 2006); (Bandura 1988), describe methods to change a persons current habits and intentions that should be incorporated into the refrigerator magnets in order in order to maximise its efficacy in preventing waste. Finally, (DEFRA 2011)'s model - seen above in figure 2.2 - provides a framework to reference, that is specifically related to waste prevention, when implementing the various change methods into the magnets design.

DEFRA's model accepts that there is no single solution to influence behaviour, and offers a tool to promote a mix of solution. It is split into 4 main areas of focus: Enable, Engage, Exemplify, Encourage. Based on DEFRA's studies, influencing behaviour is most effective when the technique is split between these 4 main categories. This model for behavioural change is also in line with the findings and recommendations of (Dolan, Halpern, and King 2014). When applied to the design of the refrigerator magnet's , with the aim to reduce personal food waste, it can be said that the magnets design should enable conservative behaviours by removing the barriers (such as uncertainty around how to use expired food) and provide clear information as to what foods are available/nearly expiring. It should engage the user by being having an easy-to-use and attractive design. It should also engage by helping the user develop a sense of personal responsibility through involving other people (tapping into social pressures) and educating them on their impact to the global environmental crisis. It should exemplify ecological behaviours by clearly

showing the user how little personal waste they should aim for. This could be done through goal setting. It should finally encourage the user by providing regular feeding back and visualising the expiry dates of the food so that they are known the user, with the aim of instilling a feeling of personal responsibility to act upon the knowledge. The magnet could accomplish this through deploying various techniques such as: praising conservative behaviours; condemning wasteful behaviours; providing incentive to act ecologically through competition and goal setting.

2.2.4 Summary of Change Models

To summarize the above, in order for the refrigerator to reverse an individuals wasteful habitual behaviours the magnet should promote a rehearsal of ecological responses to expiring foods. If rehearsed for long enough, these responses could replace existing habits ((Bandura 1988);(P. M. Gollwitzer and Sheeran 2006);(Haddock and Maio 2007)). (P. Gollwitzer and Heckhausen 1987)'s Model for self-regulated change and (Schwartz 1977)'s Norm Activation Theory dictate that in order for the magnet's to successfully change a person's intention to be more ecological it must promote self-awareness, thus instigating an individual to re-evaluate their current wasteful behaviour against their personal norms. This is an example of encouraging and enabling action - key components of (DEFRA 2011)'s 4E model to self regulated behavioural change. The magnet should also utilize social pressures to motivate a person to act ecologically. It could do this through competition with a friend or goal setting. Both of these are examples of "exemplifying" the correct actions, another key element of (ibid.)'s model. The magnet's design should act as an "enabler" by removing "barriers" preventing a person from acting ecologically (Darnton 2008) - in turn "enabling" the sustainable behaviour, another central point of (DEFRA 2011)'s model. Techniques that encapsulate all the above will be discussed in the next section.

2.3 Practices of persuasive technology

Here I will examine techniques used by current persuasive technologies which encapsulate the various behavioural models discussed prior. I will consider within the context of waste prevention and allude to how the refrigerator magnet could incorporate these techniques into its design. When examining, it is crucial to keep the findings of (Amel, Manning, and Scott 2009) in mind: "to make sustainable actions appealing to the subconscious it should be appealing for rational reasons as well as intuitive ones. Thus, techniques to reduce wasteful behaviour should require minimal time and effort".

2.3.1 Eco-Feedback

Eco-feedback is a popular technique to promote conservation and increase people's awareness of their wasteful behaviours. It is achieved by automatically sensing a person's activities and feeding appropriate information back to them through computerised means (Froehlich, Findlater, and Landay 2010). When examined within the context of (Triandis 1977)'s model of behaviour, it can be said that eco feedback attempts to promote an ecological intention within a person by fostering a positive attitude towards conservation and provoking an emotional response towards their wasteful behaviours. The use of eco feedback to influence behaviour aligns nicely with (Schwartz 1977)'s Norm Activation theory and (P. Gollwitzer and Heckhausen 1987)'s 4 stage model for self-regulated behavioural change (discussed above), as it uses data about a persons current behaviours as means to have them re evaluate the outcome of their actions and act accordingly to their personal standards. An example of eco-feedback being deployed to reduce personal food waste can be seen in (Lim et al. 2017)'s social recipes which combines traditional eco feedback techniques with social pressures as a means to prevent waste. (Festinger 1954) found social disapproval to be one of the most powerful motivators of behavioural change. Eco-feedback also leverages the practices of Engaging and Encouraging conservative action, 2 of the 4 pillars

which are central to (DEFRA 2011)'s 4E model for sustainable lifestyles.

2.3.2 Creating Visibility

Creating visibility of both wasteful behaviours and food availability seems to be an effective method to promote conservative actions. Creating visibility of what food is available to eat, when it expires and recipes to cook with it is essential in order to successfully enable the rehearsal of conservative behaviours. The repetition of such actions is sufficient in order to override existing habits according to the (Bandura 1988)'s Mastery Modelling and (P. M. Gollwitzer and Sheeran 2006)'s Implementation Intention behaviour change models. Visualising this information also encapsulates components of the Engage, Encourage and Exemplify categories in Defra's 4E's model 2.2. I will now discuss current technologies that use visualisation as a means of influencing behaviour.

- **For Reflection:** (Ganglbauer, Fitzpatrick, and Güldenpfennig 2015) developed a mobile application that acts as a food waste diary, allowing individuals to reflect on the amount of waste they produce. This diary effectively leverages social pressures as a persons reasons for their food waste is made available for other users to read for mutual reflection. The goal is to influence a person to act conservatively by having them adopt a negative intention towards food waste.
- **For Prevention:** (Lim et al. 2017)'s Social Recipes utilises visualisation for prevention, as it detects food availability as well as potential food waste and responds by suggesting Social Recipes. These are recipes that promote the use of high-risk ingredients in a social context. (ibid.) successfully uses the visualisation of fridge contents whilst leveraging the individuals interest to be socially accepted to influence their intention, thus promoting an ecological friendly behaviour.

  Another example of creating visibility for prevention can be seen in (Farr-Wharton, Choi, and Foth 2014) mobile application that tracks the contents of a refrigerator with the aid of pictures and food ID-ing. The purpose of this system is to alert users of expiring foods in an attempt to reduce food waste. RFID tags and load cells are common practices to track the contents of a refrigerator (ibid.). These methods work, but have obvious drawbacks such as requiring every item of food be fitted with an RFID tag and the fact every food item has to be in its allocated space in the fridge in order for the load cells readings to be accurate.

2.4 Design Principles

Based on the literature review, three relevant aspects emerge that should be considered when designing the refrigerator magnet. These design principles will be the at the core of every functionality the magnet deploys, and will be used to evaluate the magnets effectiveness in instigating a behavioural change and preventing food waste.

2.4.1 Create Visibility

The magnet should create visibility of 1) the expiry dates of the fridges contents and 2) the users wasteful behaviours. It should do so in order to 1) act as an "enabler" for the user to know what food's are expiring, thus removing the "barrier" of having to manually check the foods expiry dates, hopefully promoting the user to cook with foods closest to expiring first (Darnton 2008). And 2) to allow the user to reflect on their behaviours. As can be concluded from reviewing (Bandura 1988)'s Mastery Modelling and (P. M. Gollwitzer and Sheeran 2006)'s Implementation Intentions behavioural change models, if this behaviour of cooking with foods closet to expiring first is practiced for long enough, it could eventually become instinctive and

replace existing wasteful habits. The user's wasteful behaviours should be fed back to them through an effective eco feedback technique (Froehlich, Findlater, and Landay 2010). It should do so to make the user aware of the extent of their waste, in the hope of activating their personal norm and having them re-evaluate the consequences of their current actions (Schwartz 1977), (P. Gollwitzer and Heckhausen 1987). The eco feedback technique should also leverage social pressures, as I have reviewed the significance of social comparison as a means to influencing behaviour (Festinger 1954). By creating visibility, the magnet will hopefully foster a positive attitude towards conservative behaviours, thus altering the users intention and influencing them to act conservatively. Creating visibility also encapsulates components of the Engage, Encourage and Exemplify categories in Defra's 4E's model 2.2.

2.4.2 Enable and Encourage Action

Enabling and Encouraging action are 2 of 4 pillars that are at the core of (DEFRA 2011)'s 4E model for sustainable lifestyles. The refrigerator magnet's design could conform to both by providing suggestions and instructions for an action - such as recommending recipes - so that the users know how to reduce food waste rather than just being made aware of their wasteful behaviours. This would also minimise the users cognitive effort as they don't need to think of a solution themselves, which (Amel, Manning, and Scott 2009) found as essential in order to make sustainable actions appealing to the subconscious. A study conducted by (Quested. et al. 2013) to provide actionable suggestions for supermarket retailers in order to reduce waste deduced recipe recommendation as extremely effective. (Maitland, Chalmers, and Siek 2009) reiterated the findings of (DEFRA 2011)'s model in his paper that in order for persuasive technology to be successful it should encourage and enable action. The magnet could further encourage and enable the user to act conservatively through deploying various eco feedback techniques, leveraging the power of social pressures and generally increasing the users awareness of their wasteful actions. (Schwartz 1977)'s and (P. Gollwitzer and Heckhausen 1987)'s models for behavioural change found that this heightened awareness should force the user to re-consider the consequences of their actions and act according to their personal standards. The magnet could also utilise goal setting and competition as a means of encouraging and enabling action. (Tang et al. 2015)'s study of the effectiveness of persuasive mobile applications found goal-setting and competition to be efficacious in influencing behaviour.

2.4.3 Usable and Personalised

The refrigerator magnets design must be easy to use and personalised in order to promote user satisfaction and subsequently encourage use of the magnet. By having a usable and personalised interface, the magnet is conforming to the "engage" principle that is illustrated in (DEFRA 2011)'s 4E model to sustainable lifestyles. A qualitative study on how apps can engage and support users, conducted by (Tang et al. 2015) reported that participants found non-user friendly and non-tailored apps difficult to integrate into their everyday lives and also found their information to be less meaningful. This finding is in line with (Goodwin 1987) claim that a products functionality should take priority above all else. Also by being easy to use the magnet is reducing time and cognitive effort around conservative actions, which in turn makes the actions more appealing and sustainable to the subconscious according to (Amel, Manning, and Scott 2009). (Tang et al. 2015) study also found that by a design being personalised to the user, the technology becomes instantly more engaging and the information it feeds back becomes more valuable and meaningful to the user. The use of personalised eco feedback techniques and careful consideration of the overall aesthetic of the magnet's interface should be sufficient to accomplish this.

3 Analysis/Requirements

In this chapter I introduce the requirements the interactive refrigerator magnets design must satisfy in order to successfully instigate behaviour change and be a suitable tool for our final evaluation. These requirements have been realised through the background research into behavioural models and persuasive technology conducted in chapter 2, and will be used to guide the design of the prototypes which can be seen in chapter 4.

3.1 Functional Requirements

The functional requirements relate to the features the system should implement in order to accomplish the goals set out in chapter 1: to successfully influence the user to behave more conservatively. They have been prioritised using the MoSCoW method, (Ahmad et al. 2017) to indicate their level of importance to the final product, splitting them into the categories below. The “should have and “won’t have” taxonomies have been excluded here as all the functional requirements can be fully expressed through the “must have” and “could have” categories.

3.1.1 Must Have

These requirements are essential to the design of the final product if it is to successfully indicate behavioural change and reduce the user’s personal food waste. If the final product didn’t include them, then an evaluation would not be possible.

- **Visualise refrigerators contents and subsequent expiry date** - this is an essential component to allow system to accomplish its principal goal of reducing personal food waste. In doing so, the magnet is encouraging eco friendly behaviours through easing the effort around retrieving the necessary information. "Encourage" is a one of 4 main pillars in (DEFRA 2011)’s model for sustainable behaviour. Visualising the fridge’s contents and expiry dates allows the magnet to act as an "enabler" for ecological behaviour by removing the "barriers" surrounding retrieving the necessary information. (Darnton 2008).
- **Recommendation of recipes based on available ingredients** - this is necessary if the magnet is to act as an enabler, a central component of (DEFRA 2011)’s model for sustainable lifestyles. By recommending recipes the magnet is enabling ecological behaviours through removing the barriers, and effort, around economical action by showing the user how to waste less. In doing so, the magnet is also advocating the rehearsal of frugal behaviours which (Bandura 1988), (P. M. Gollwitzer and Sheeran 2006) and (Haddock and Maio 2007) found to be sufficient to override existing habits.
- **Feedback user’s wasteful behaviours** - this would be effective in increasing people’s awareness of the extent of their current wasteful behaviours, with the hope of promoting more economical intentions. This heightened awareness is key in order to activate a users personal norm and have them re-evaluate the consequences of their actions (Bandura 1988), (P. Gollwitzer and Heckhausen 1987). This is an example of eco feedback, (Froehlich, Findlater, and Landay 2010), and encourages action - a key element of (DEFRA 2011)’s model for sustainable lifestyles.

3.1.2 Could Have

These are the requirements that are desirable but not necessary for this evaluation of the system. Although they would definitely be sought after if the system was to be released commercially.

- **Connect with other IoT appliances** - with the increasing presence of IoT technology and the vision of a smart home, this seems necessary in order to enhance the user experience and enable further functionalities. Although this is not necessary for the prototype's effectiveness to be evaluated in this paper.
- **Remote access to data store** - this would increase the accessibility of the magnet's data, thus enabling user's to make calculated decisions remotely. For example when they user is shopping in the supermarket, or in a restaurant, they should be able to access the relevant information about their food at home through a mobile application. Although, again, this feature is not needed for the experimental evaluation conduced in this paper.
- **Shopping list generator** - this could further enable action as it would remove even more effort surrounding economical actions and also ensures the user doesn't "over-purchase" an item of food.

3.2 Non-Functional Requirements

The non-functional requirements relate to general aspects of the refrigerator magnet, not specific functionalities, required in order for the magnet to successfully enable and encourage a reduction in the users personal food wastage. Similarly to the functional requirements, they have been privatised using the MoSCoW method (Ahmad et al. 2017). Also similar to above, all the non-functional requirements can be fully expressed through the "must have" and "could have" categories.

3.2.1 Must Have

These are the functional requirements that are integral to the systems goal of promoting behaviour change within its user's.

- **Usable & Personalised** - Proceeding the background research, specifically (Tang et al. 2015) evaluation of how apps can engage and support users, it can be confidently deduced that the system must be extremely easy to use if it is to successfully instigate behaviour change. This is due to users finding usable applications easy to integrate into their daily lives. (ibid.) also found that users perceive personalised information as more meaningful, thus they are more willing to act on it. Also by being attractive in design and easily operable the user will be encouraged to use the system, thus increasing the probability that the magnet actually assists in reducing the users personal food waste: the fundamental goal of the system.
- **Rapid Performance** - The system must perform well by having quick load and response times. It must do in order to guarantee user retention by allowing user to accomplish their desired task efficiently thus allowing for an improved user experience. (Agustin and Corrales 2018) published a research paper analysis the impact of performance on apps retention and found them to have distinct positive correlation
- **Reliability** - The data presented by the magnet must be reliable and accurate, otherwise it's main function, of enabling a user to minimise their food waste, would be jeopardised.

3.2.2 Could Have

These requirements are those not essential to the system for evaluation, since it is a high fidelity prototype that is being sued for evaluation, but would be of upmost importance if the magnet was to professionally developed and released for commercial use.

- **Scalability** – The magnet app should be able to handle more data as time progresses. Scalability is essential if the app's recipe recommendations are to become more accurate and desirable upon increased usage. Scalability is also essential if the magnet app is to be adapted to work with other smart devices, as they get developed, in order to deliver a more automated, effective user experience.
- **Available & Accessible** – If fully developed, there should be a common place where users can install the application and look for regular updates. Also the magnet's functionalists should be easily accessible by physically challenged people It could ensure this through using various output mechanisms. Also enabling the data store to be accessed remotely via a synchronous mobile app would be a great asset.
- **Security** – Lastly, if it was to be released commercially, the magnet should definitely ensure the security of the data stored. It should be protected from authorised personals and guarantee that no users can bypass the system's security to leverage it for their personal gain.

4 Design

In this chapter I will give an overview of the design of the medium fidelity prototype that was created based on the requirements established in the previous chapter. I will then document the pilot study that was conducted using the prototype. Finally I will infer design changes and implications, based on the studies' results, which will guide the design of the final high fidelity prototype.

4.1 Medium Fidelity Prototype

The medium fidelity prototype of the refrigerator magnet was created using Invision, and incorporates the functional requirements established in the previous chapter. Although the shopping list generator was a "could have" requirement, it was included here to determine whether the participants found it effective in reducing food waste, or not. The user interface medium fidelity prototype can be seen below.

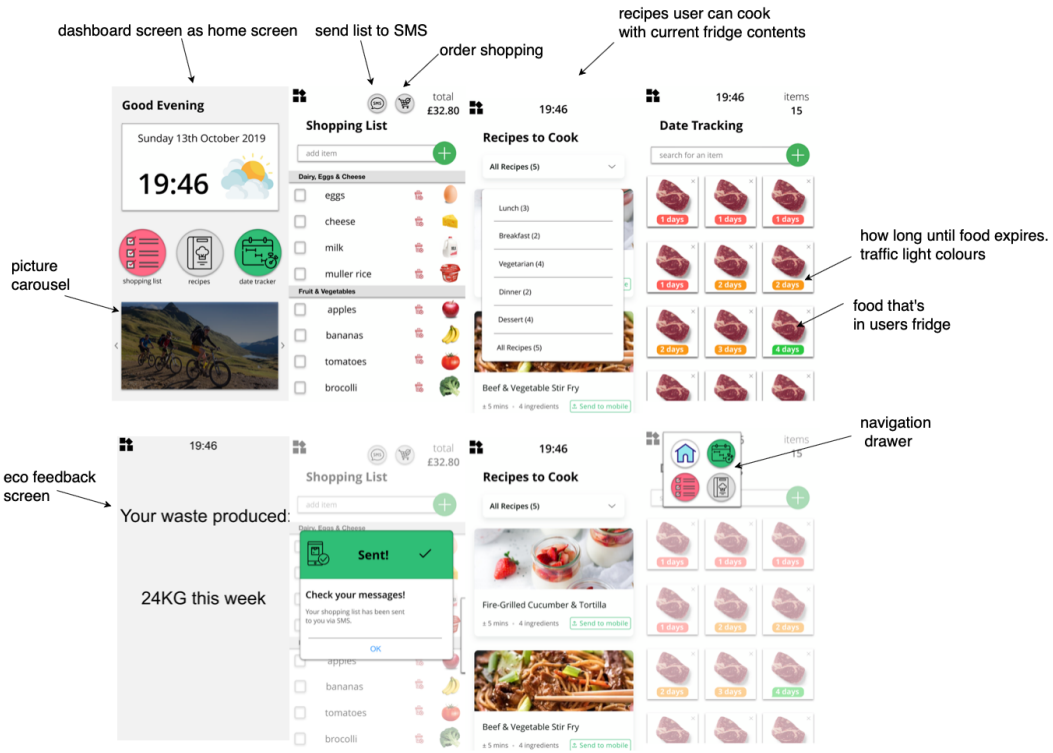

Figure 4.1: *The user interface for the medium fidelity prototype of the interactive fridge magnet. From left to right: dashboard screen, eco feedback screen, shopping list screen, recipe recommendation screen and date tracking screen. Low-level interaction implemented allowing transition between screens.*

The prototype supported low-level interaction as it allowed for transition between screens. This was so user's had a more realistic interaction with it, thus providing more insightful responses.

4.2 Pilot Study

The pilot study consisted of an online questionnaire and 6 semi-structured interviews in which the participants were exposed to the prototype of the system through completing tasks. During this task completion, the participants were asked to think aloud to better gauge their feelings towards the system. After the tasks were completed, they were then asked follow-up questions that related to comments they whilst thinking aloud. These questions are detailed in the study procedure section. The main objectives in this pilot study were (1) to explore initial attitudes towards the system (2) to establish design alterations based on the participants responses to the medium-fidelity prototype (3) determine people's current wasteful behaviours and attitudes towards these.

4.2.1 Sample

The participants for the task performances, and subsequent interviews, were selected with consideration to the following requirements: they had to be a student, they had to do their food shop themselves and they had to cook themselves at least 7 meals a week. These requirements were set as it made sense to include people that were actually responsible for their own eating habits, thus making them potential users of the system. I used 6 participants for the task performances and interviews.

The participants for questionnaire were found online as the questionnaire was created on SmartSurvey.co.uk and distributed online to students via direct messages, Twitter and Reddit communities.

4.2.2 Questionnaire

The questionnaire was left online for 2 weeks and accumulated 175 responses. The aim of the questionnaire was to determine people's current wasteful behaviour and attitudes towards these behaviours. Each question could be answered on a 5 point scale likert scale, with 1 being not often and incrementing gradually to 5, being very often. The questions were were:

1. How often does food in your fridge go out of date?
2. How often do you bin food that is out of date?
3. How often do you cook with/eat out of date food?
4. How often are you confused by the "sell by", "best before", "eat before" and "use by" instructions on food packaging?
5. How often do you forget to buy an item of food when food shopping?
6. How often do you impulse buy items when food shopping?
7. How often do you visit the supermarket in a week?
8. Would you like your shopping list to be automatically generated for you (if there was appropriate technology)?
9. "I would like to cook more diverse range of meals than I currently do?" How much do you agree?

4.2.3 Interviews

The interview sessions began with some general warm up questions about the participants experiences with shopping and cooking. Next, the participants were asked about current systems they have in place to track their foods expiry dates and how they make decisions in the kitchen.

Afterwards, the participants were exposed to the concept of the interactive refrigerator magnet through carrying out a series of simple tasks whilst being instructed to "think aloud". Once the tasks were completed, the participants were asked a series of unstructured questions which related to comments they made whilst thinking aloud.

The audio of the interviews was recorded and used in a thematic analysis to explore the participants reactions and determine attitudes towards the system. These findings were then combined with the results of the questionnaire then compared with discoveries from the literature review and the current requirements, to establish design principles and changes. These principles and changes were then used to guide the design of the final, high fidelity prototype. The results of the study are presented in the next section.

4.3 Results

4.3.1 Questionnaire

The mean answer for each question in the questionnaire, alongside its implication can be seen below in figure 2:

Question No	Mean Ans	Answer Implication
1	3.2	Food in fridges often goes out of date
2	3.51	Out of date food is often thrown in the bin
3	2.21	People don't usually eat out of date
4	2.21	People generally aren't confused with date instructions on food packaging
5	3.43	People often forget to purchase particular food items
6	3.58	People often impulse buy food items
7	2.03	People generally visit the supermarket 1-3 times a week
8 (1.yes, 2. no)	1.29	Auto generation of shopping list is desired
9	3.05	People would like to cook a more diverse range of meals than they currently do

Figure 4.2: *Table documenting the mean answer to each question in the 9 question questionnaire and its implication. Since the responses were ranked on a likert scale from 1-5, it can be deduced that if a questions mean answer is above 2.5, the participants often did or agreed with the questions contents and vice versa for below 2.5.*

4.3.2 Interviews

The interviews found that participants generally have no system in place to track the expiry dates of their fridge contents. Participants also reported that they impulsively decide what they are going to cook, usually motivated by in the moment cravings. Generally, the participants showcased a positive reaction towards the refrigerator magnet system and were optimistic about

its ability to reduce their personal food waste. Although, all 6 participants also offered constructive criticism when necessary. The positive reactions related to awareness, creativity and knowledge.

- **Awareness:** All participants were fond of the date tracking and recipe recommendation screens as it increased their awareness of what food they had in the fridge, when it expired and what they could do with it. All 6 agreed that this increased awareness would encourage them to make more conservative meal choices. The visual cueing of food images alongside the traffic light coloured expiry dates was a popular design choice as it enabled quick interpretation of the information.
- **Creativity & Knowledge:** Another aspect of the system users generally liked was creative insight that the recipe recommendation gave them. Although, they all remarked that it was difficult to discover recipes for specific foods with the current configuration as they would need to manually check each recipe's ingredients. All participants were also fond of the knowledge of their refrigerator contents that the magnet provided. They generally agreed that is was a much easier and efficient way of attaining this knowledge as apposed to opening the fridge and manually checking.

The main overall negative attitude expressed towards the system was the lack of personalisation.

- **Lack of Personalisation:** Participants found that the system lacked personalisation required to fully engage them in the product. To remedy this, the eco feedback system should offer more personaliation through deeper insights and more customized breakdowns of the user's behaviour. 6 out of 6 the participants agreed that they would be encouraged to waste less food if the magnet supplied a more in-depth, actionable insights into their wasteful behaviours.

4.4 Design Implications & Changes

After reviewing the results from the pilot study, a set of design implications and changes were devised. The implications detail aspects of the medium fidelity prototype's design to include in the final prototype and the design changes detail aspects to be removed. The design implications and changes can be seen in the lists below:

4.4.1 Design Implications

1. **Include recipe recommendation** based on the fridge's contents as 75% of people that filled out the questionnaire agreed that they would like to cook a more diverse range of meals. This indicates that people would find recipe recommendations useful. The participants that were interviewed were asked if they disposed of expiring food because they didn't know what to cook with it and 5 out of 6 of them agreed.
2. **Include a date tracking system** that visualises the fridge contents through images and the respective expiry dates using colours. This increases the user's awareness and knowledge of their, thus reducing the chance of the user allowing it to expire.
3. **Offer a more in-depth insight into the user's behaviours** in the eco feedback system, in order to increase the system's personalisation and information value to the user.

4.4.2 Design Changes

1. **Remove dashboard screen**, and instead make the date tracking screen the home screen. The dashboard screen was acting as a barrier between the user and their desired information, thus decreasing awareness.

2. **Offer a way to browse for recipes by ingredient.** This would allow user's to find recipes that use food's that are actually expiring, as apposed to manually checking themselves. This would increase the system's ease of use and remove effort around the actions necessary to reduce food waste.
3. **Remove shopping list screen**, although it is a desirable feature - it doesn't necessarily aid in reducing the user's food waste and definitely adds a layer of complexity to the system. It could be discerned that removing the shopping list screen would definitely increase the simplicity and subsequent ease of use of the system, a design philosophy that was highly valued by the participants.
4. **Include alerts screen** which guides the users decision making process by recommending the best next actions for the user to take with respect to minimising their food waste. The alert's screen could also be used to feedback some wastage information to the user.

4.5 Final User Interface

The prototypes final user interface can be seen below which builds on the initial medium fidelity prototype by incorporating the design implications and changes established from the pilot study.

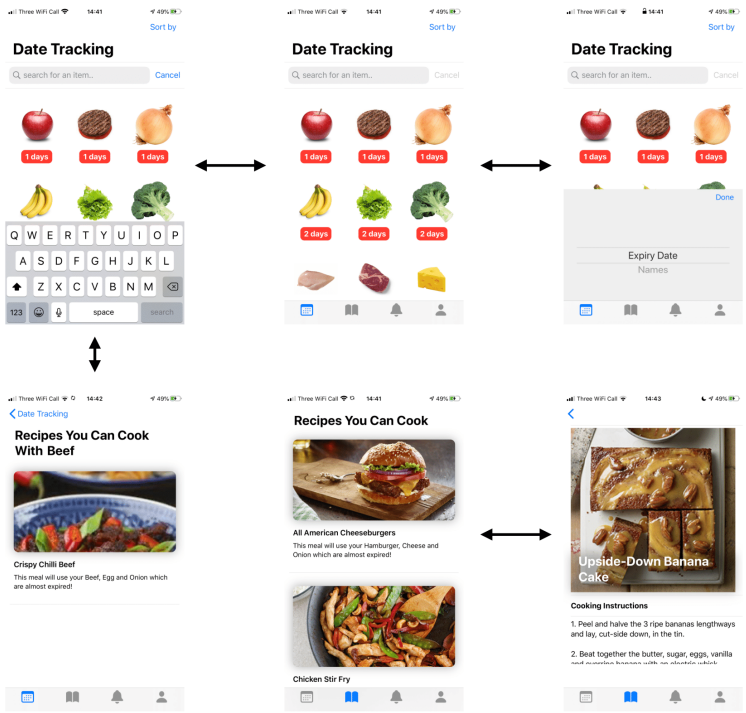

Figure 4.3: *The final UI of the date tracking and recipe recommendation systems. Screens from left to right, top to bottom: 1) Date tracking screen, showing the user searching for a food item using the search bar 2) Date tracking screen displaying the refrigerators contents alongside how many days left until it expires. Traffic light colours are used to represent how soon a food expires. The user can tap on a food and have recipes displayed that use it. 3) The recipes being sorted 4) Screen showing all recipes that use a particular ingredient 5) the recipes that the user can currently cook. 6) Cooking instructions for a recipe, alongside an image and it's title.*

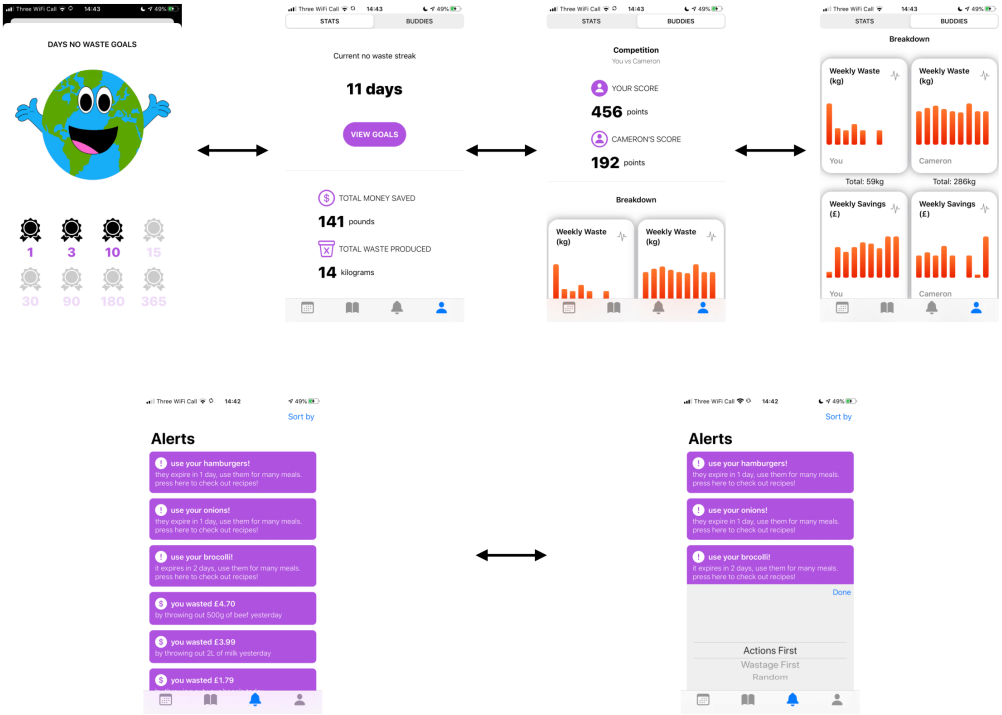

Figure 4.4: *The final UI of the alerts and eco feedback systems. Screens from left to right, top to bottom: 1) Shows which accolades the user has achieved for their days no waste streak. The number under badge represents days in a row. 2) Users personal stats screen which shows the current days no waste streak, the total money that the user has saved and the total waste they have produced. 3) Competition screen which allows user to compete with friends, with the goal to produce the least waste. This screen shows how many points the user and friend currently have. More points = less waste. 4) Bottom half of the competition screen which has a graphical comparison breaking down the user, and their friends, waste produced and money saved over the last week 5) Alert screen recommending the best next action for the user to take in order to minimise waste. 6) Shows the alerts being sorted.*

5 Implementation

In this chapter I will demonstrate how the design outlined in Chapter 4 was implemented, discussing the tools and techniques used in detail. This chapter will also explain aspects of the system that weren't necessary for this evaluation, but would be if the magnet was to be deployed, such as: retrieving the users food data and sensing their behaviour.

5.1 System Architecture

The Internet Refrigerator Magnet can be broken down into two main part: the application itself and the back-end store and services. Since the prototype was being created for use in a lab experiment, and not actually deployed in a persons home due to the time constraint of this project, back-end services and data were hard coded. Although, the back-end was conceptualized to demonstrate the magnet's feasibility and provide guidance for future work. This is all illustrated in the architecture diagram below:

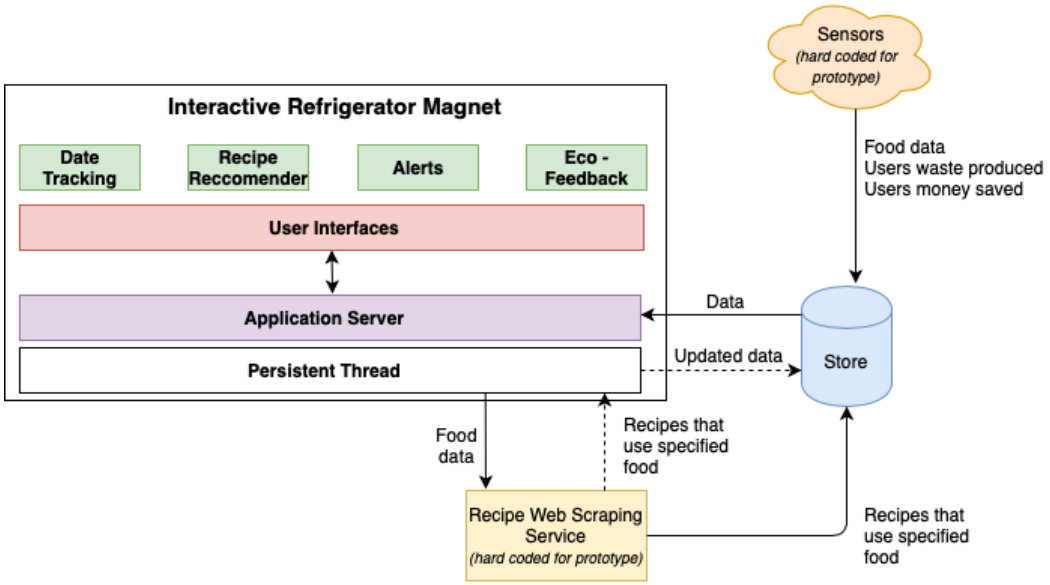

Figure 5.1: *Full system architecture diagram, describing the connections between each component of the system. It is marked where stubs were used instead of real data/services.*

The system was designed following a three-tier architecture pattern (JReport 2018), consisting of a presentation layer, an application layer, and a data layer. This was because an architecture of this sort is modular and flexible. The **presentation layer** merely contained the user interfaces of the different functionalities and was required in order to visualise the food data, recipes and users stats. It was also necessary to enable the user to interact with the system. The actions issued through the user interfaces are delegated to the application layer through commands. The

application layer contains the logic of the entire system and is necessary to enable the systems various functionalities. The systems logic generally works by mapping a command to a use case, then executing. Lastly, the data layer comprises of all the data storage for the system. For the prototype used in this paper, all of the data was hard-coded: as illustrated in diagram 5.1. This was because the application was being used in a lab experiment, and not deployed in a persons home: therefore the data **needed** to be manually input. A breakdown of how each component was or could be implemented can be seen in the following sections.

5.2 Tools Used

For ease and simplicity it was decided that the refrigerator magnet application was going to be developed as a mobile phone application, with the phone posing as the "refrigerator magnet". I decided to make an iOS applicaton as I wanted to leverage Swift's new user interface API: SwiftUI (Apple 2019).

GitHub, (GitHub 2020), was used for version control and xCode as the IDE since it has built in GitHub compatibility. A Trello board was used for time management and issue tracking. The project was developed in a series of sprints, with each focusing on a particular aspect of a functionality.

5.3 Retrieving and Feeding Back Food Data

This was a necessary function of the application if it was to effectively reduce waste. This section will detail how the functionality to feedback food information was implemented and how the magnet would, in theory, retrieve this information through sensors, illustrated as bubbles in diagram 5.1.

5.3.1 Cameras vs QR Code for Retrieving

Since the prototype was to be evaluated in a lab experiment, the application was pre-loaded with a food inventory and the subsequent expiry dates. Although if it was deployed on somebodies refrigerator it would need to sense this information itself. Two feasible and effective ways this could be accomplished are: scanning QR codes on food packaging or supermarket receipts; through camera's using computer vision algorithms.

The camera's are clearly the more usable and desirable option since it requires nothing from the user, and in theory could be implemented without any programming skills by using a service such as Google's Teachable Machine (Google 2020), which can be easily trained to recognize images. Although, this method would be the more expensive of the two since it would require cameras to be installed inside the refrigerator and also would require a large, detailed data set of food images which incorporates various supermarkets' packaging.

Using QR codes is clearly the less usable but more feasible option as it only requires the application to support bar codes scanning and have access to a database connecting bar codes to products. The user would do the rest. Most modern day mobile phones come with this functionality already built in. A company called Edamam have already created a food API which connects to a data set detailing over 550,000 different foods, allowing them to be searched via bar code (Edamam 2019). An API like this could easily be connected to the refrigerator magnet application and the user could easily load their food data via scanning bar codes with their mobile phone.

5.3.2 Feedback

A Swift package: QGrid (Q-Mobile 2020) was used to achieve the 3 column wide grid displaying images of the fridge's contents alongside the relevant expiry date. A visual of the grid can be seen below:

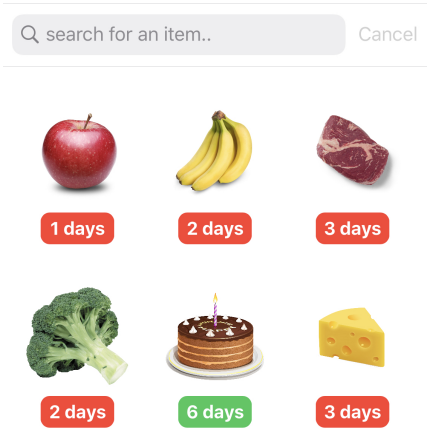

Figure 5.2: *The grid implemented using QGrid (Q-Mobile 2020) showcasing an image of the food alongside it's expiry date. By default the grid is sorted by expiry dates, but here it has been sorted by names to illustrate the traffic light colouring of expiration dates.*

Traffic light colouring was used to help communicate the expiry date, although the grid's default configuration was to be sorted by expiry dates such that the expiring food was always displayed first to encourage its use and discourage its waste. The user had the option to sort the food by names - which it has been in the graphic above - and could search the list through typing into a search bar. The search bar also supported dictation since the magnet would be on the refrigerator face: typing on a keyboard would be tedious compared to simply speaking. Aside from the it's alignment, the entire front end of the grid implemented using components from the SwiftUI API (Apple 2019).

5.4 Generating and Recommending Recipes

This feature was necessary to show the user *what* to do with the expiring food. For this experiment, the recipes were manually coded into an array and loaded through a structure named Recipe which stored a recipes name, image, description, cooking instructions and ingredients. Using this modular approach enabled implementation of crafty navigation such as allowing the user to tap on a food to find all it's recipes and incorporation of a search bar. Although, if deployed, the magnet would need to be constantly refreshing the recipes to match the constantly the changing refrigerator contents: so a hard coded array of recipes wouldn't be substantial. A better way would be to be actively scrape websites which share recipes that use food the user has available. The magnet application could allow users to thumb up recipes they enjoy so that the scraping algorithm can focus its search on similar recipes. This concept is illustrated by the "recipe web scraping service" tile in diagram 5.1.

The recipes were fed back through tiles showcasing its title, image and description detailing which foods it used that the user had were close to expiring. Upon tap, the tile expanded into cooking instructions. Again, this was all achievable using SwiftUI components (ibid.). A visual of the recipe tile can be seen below:

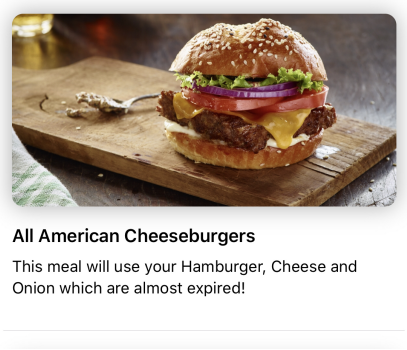

Figure 5.3: *The recipe tile detailing the recipe name, image and which of the user's ingredients it uses.*

5.5 Eco Feedback

This section details how the various aspects of the eco-feedback system were implemented. Including how the magnet could sense the user's behaviour and how the competition with a friend works.

5.5.1 Sensing Behaviour

Since the magnet's back-end data had to be pre determined for this lab experiment, the statistics representing the users behaviour shown were hard coded. But if deployed, the application would need to actually monitor the user's behaviour automatically. This is illustrated in the "sensors" cloud in the system architecture diagram 5.1. The behaviours that were fed back to the user were money saved, waste produced and and how many days in a row they hadn't wasted for. This could all be monitored by simply connecting to a smart appliance named Winnow Vision (Winnow 2019). Winnow Vision is a "smart" bin that uses a camera and scales to record which food items are being disposed of and how much of it. It's intended use is for chefs to monitor which food is being waste, but the data it collects could be easily shared with the refrigerator magnet to generate the required behaviour monitoring statistics. The "money saved" prompt could be calculated by determining a user's average waste over a month, then tracking their waste produced in the proceeding months and converting the difference into pounds sterling. This would be easily implementable using (ibid.)'s smart bin and some basic mathematics. The user interface for feeding back these statistics to the user can be seen below:

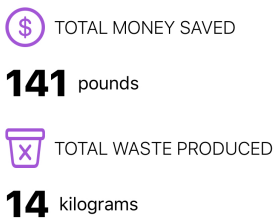

Figure 5.4: *The user interface to feed back users total money saved and total waste produced since beginning to use the refrigerator magnet*

"Goals" were created in the form of days in a row without wasting. As soon as the user wasted, the day counter was reset to 0. Rewards for these goals were presented as virtual accolades,

becoming coloured once achieved and left opaque if not. A large graphic of a "happy" earth is also included to sub-consciously remind the user of the environmental benefit from acting conservatively and not wasting food. A visual of this user interface can be seen below:

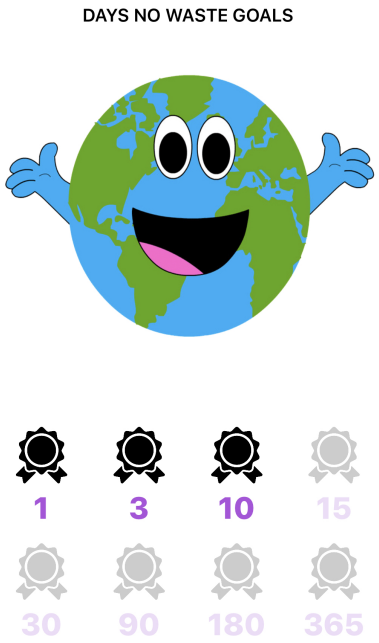

Figure 5.5: *The user interface of the goal accolades the user could achieve through day streaks of producing no waste.*

5.5.2 Competition With A Friend

In an effort to leverage social pressures to influence the user to waste less, the magnet allowed a the user to compete with a friend. Their scores were simply calculated based on their recorded waste. The premise was simple, less waste and more money saved equated to a higher score. Their scores were then displayed in a bold, readable interface that can be seen below.

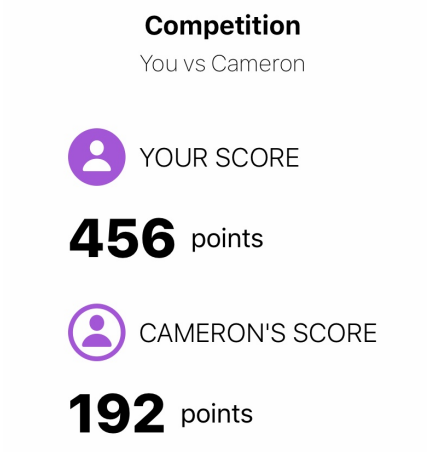

Figure 5.6: *The user interface comparing the scores of both users in competition*

On the same screen, charts comparing the user's weekly waste in kilograms and savings in pounds sterling were supplied. The user interface of the graphs was created through utilising an external API: SwiftUICharts (AppPear 2020). A complete visual of this user interface can be seen below.

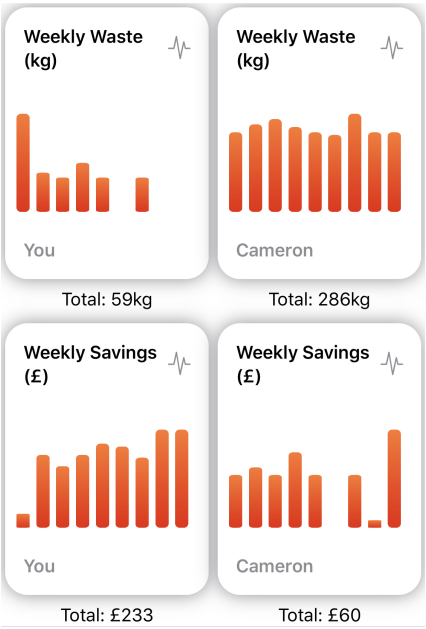

Figure 5.7: *The user interface comparing the weekly waste produced and money saved by the users in competition*

6 Evaluation

This chapter outlines the procedure used in experimentally evaluating the interactive refrigerator magnet with the aim of assessing how effective it would be in reducing food waste. The results of the evaluation are presented and then discussed within the context of the 3 design principles for persuasive technology that were established in Chapter 2.

6.1 Aims & Limitations

The fundamental question this paper scrutinises is "How can an interactive refrigerator magnet be designed to reduce personal food waste?". Given the broad nature of this question it is unlikely that a singular investigation will provide a definite answer. The most obvious, and possibly most effective, experimental evaluation would be to simply have participants deploy the refrigerator magnet in their home and measure their food waste before and after deployment, alongside a series of questions querying their experience with it. But given the time constraint of this project, it is unfeasible to conduct an evaluation in of that sort. Thus a set of design principles have been established in Chapter 2, based on the analysis of many accredited research papers, that will be used to evaluate the refrigerator magnet against. The idea being: that if the magnet can conform to all 3 of the design principles, it can be deduced that the magnet has the ability to successfully instigate behavioural change. If the magnet can successfully instigate behavioural change, with the focus being on promoting ecological behaviours, it can further be concluded that the magnet is able to effectively reduce a user's personal food waste.

6.2 Participants

12 subjects were evaluated using the same procedure. The subjects were of varying ages, all within 20 to 25 years old, with 10 being male and 2 being female. All subjects met the following requirements: they were students, did their own food shops and cooked themselves at least 7 meals a week. These requirements set to ensure that the participants were actually responsible for their own eating habits, and subsequently the food waste produced from their household.

6.3 Procedure

6.3.1 Tasks

Each participant was warmed up with a brief introduction to the magnet application and its functionalities. After the participants confirmed they were familiar with the application, they were instructed to perform a sequence of simple tasks and to "think out loud" whilst performing them. The tasks were grouped by the applications various configurations so that each configuration could be isolated and it's effectiveness evaluated independently. This way of grouping tasks was also beneficial when it came to comparing the various configurations. The tasks and intended configuration of the application for each set are as follows:

Application Configuration: **Default.**

1. Find the 3rd cooking instruction for cheeseburgers.
2. Find the recipes available that use onions as an ingredient.

Application Configuration: **Date Tracking screen sorted by expiry dates.**

3. Find how long it is until your eggs expire.
4. Name any food that expires in more than 6 days time
5. What would be the least wasteful ingredient/recipe for you to cook just now?

Application Configuration: **Date Tracking screen sorted by alphabetically by names.**

6. Find how long it is until your grapes expire.
7. Name any food that expires in less than 5 days time.
8. What would be the least wasteful ingredient/recipe for you to cook just now?

Application Configuration: **Repeat task for all 3 Alert Screen configurations.**

9. What is the first alert that jumps out at you?

The subject was asked to "think aloud" whilst performing the tasks and the mobile phones screen was recorded, with the microphone enabled.

6.3.2 Questionnaires

After the participants performed all 9 tasks, they were asked to fill out 2 questionnaires. A 5-point likert scale was selected for both questionnaires as it doesn't force the respondent take a stand point, as it allows for a natural "don't know" response.

The first questionnaire was constructed to determine how persuasive the subject found each different technique used in the eco-feedback screen. Namely, the Positive Reinforcement (represented through the "total money saved" prompt), Disincentives (represented through the "total waste produced" prompt), goal setting (represented through the "days no waste" accolades) and social comparison (represented through the competition with a friend screen). The questionnaire can be seen in the appendix A.2.

The second questionnaire was (Brooke 2013)'s System Usability Scale. This questionnaire was selected as there has been a great deal of research conducted that advocates its effectiveness. The questionnaire was issued to the participant after they had completed all the tasks so that they had had a good level of exposure to the application prior to gauging its usability. The questionnaire can be seen in the appendix A.1. NASA's Task Load Index questionnaire was initially considered but abandoned after Brooke's scale was deemed more effective to evaluate the usability of a product.

6.3.3 Interviews

After the participant had completed all the tasks and the 2 questionnaires, the semi-structured interview was conducted. The interview's audio was recorded to aid the analysis, and all subjects were asked the same set of questions, as follows:

1. Was the visualisation of the refrigerators contents and subsequent expiry date clear and intuitive on the date tracking screen?
2. If deployed in your home, would you see yourself adopting the practice of cooking with foods that are expiring first i.e does the magnet remove or add effort surrounding checking the expiry dates?
3. Do you feel that the eco feedback screen could encourage you to reflect about your wasteful behaviours more during your day-to-day?
4. What was your initial impression of the recipe recommendation system, what would be the requirements for you to actually cook the recipes that are recommended?
5. What method of retrieving recipes did you prefer: tapping on the food from the date tracking screen or browsing via recipe screen?

6.4 Results

6.4.1 Tasks

Alongside the task performance being recorded to gather qualitative data for analysis, the application exported a range of logging data to csv. The 2 most relevant, and interesting, records are the task times and the count of paths taken to access recipes for tasks 1 and 2. The mean task time out of the 12 participants for each task can be seen in the box and whisker chart below:

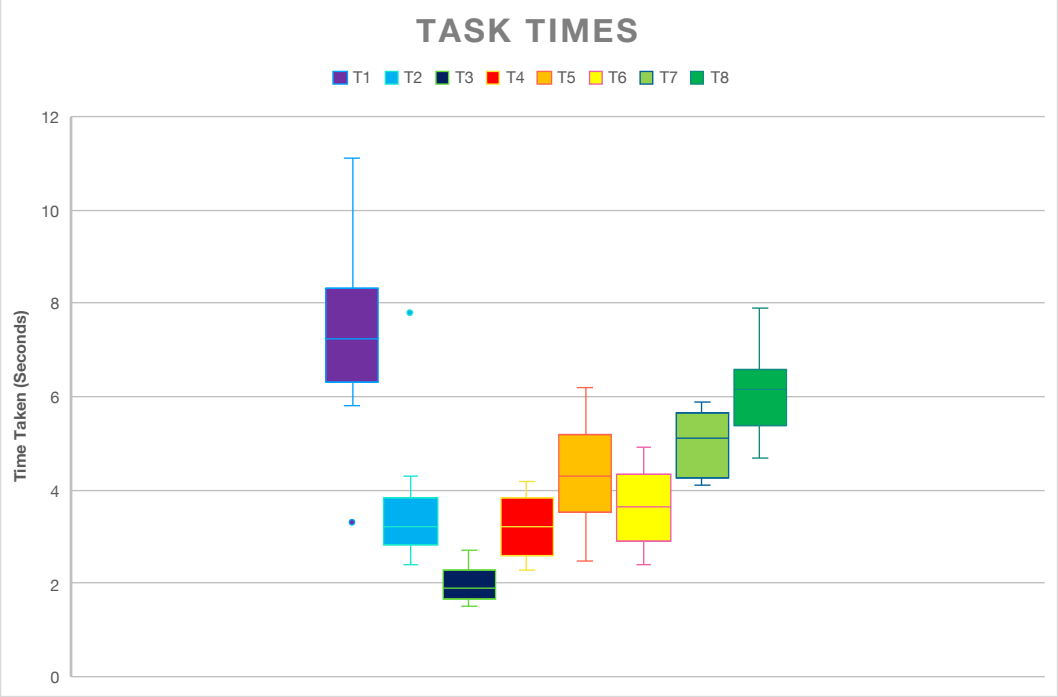

Figure 6.1: *Box and whisker chart depicting how long participants took to complete all tasks*

An interesting way to interpret this data would be to directly compare the times taken for the tasks that were repeated over the 2 configuration of the date tracking screen. This will give us an insight into which configuration, sorted by names or sorted by expiry dates, is most effective at assisting the user to retrieve the important information. The tasks have been paired as they were identical tasks, just asked twice for each configuration of the date tracking screen:

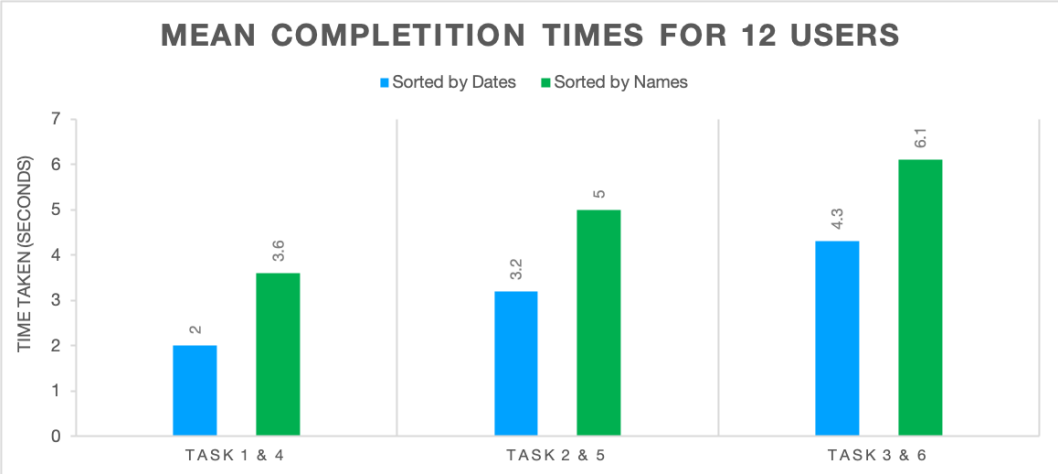

Figure 6.2: *Bar chart depicting the average time taken to complete tasks involving retrieving information from the date tracking screen. Times are compared for both configurations of the screen*

Another useful insight the CSV data gave us was which paths user took to find recipes for tasks 1 and 2. This comparison would indicate which method of retrieving recipes, tapping the food directly or browsing the recipes screen, is preferred by users.

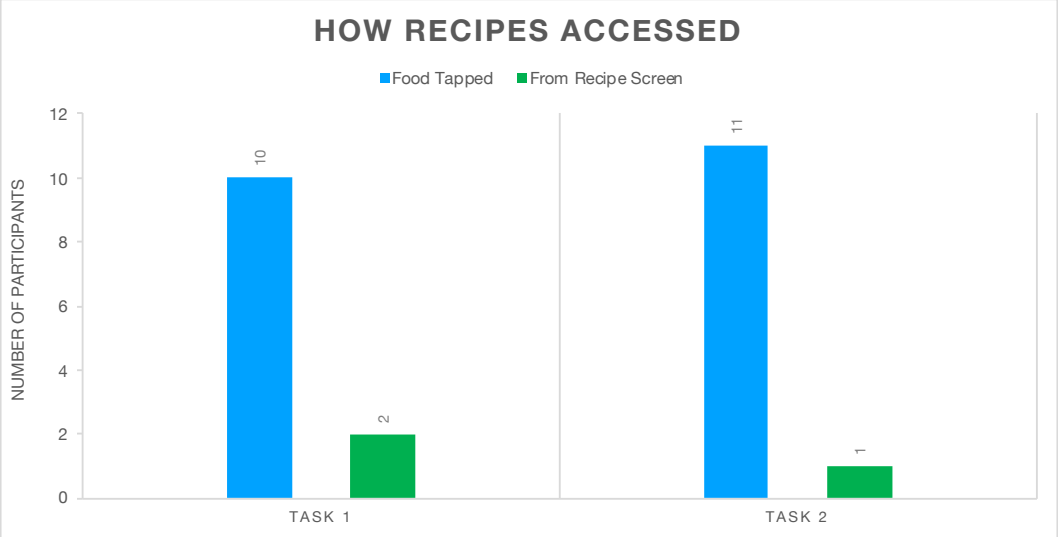

Figure 6.3: *Bar chart depicting how participants accessed recipes for tasks 1 and 2*

6.4.2 Questionnaires

The questionnaire results were collected and layered bar charts were used to visualise the responses. A usability score was calculated using the responses from the System Usability Scale questionnaire. The score was calculated following the method outlined in (Brooke 2013) paper presenting the scale. The responses, and usability score, can be seen below:

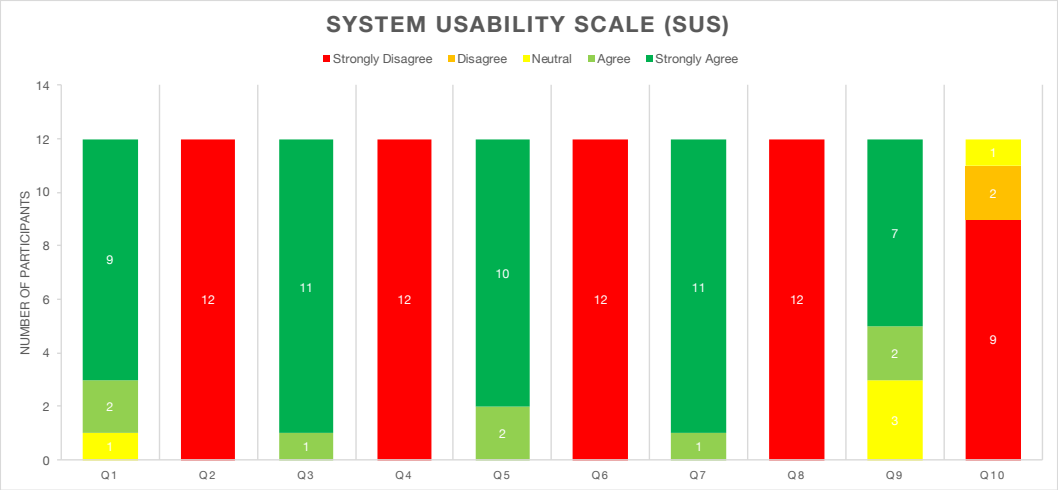

Figure 6.4: *Bar chart depicting how participants responded to the SUS questionnaire.*

The reason users generally disagreed with every even numbered questions and generally agreed with every odd numbered questions is because the even numbered questions ask negative questions, such as: "I found the system unnecessarily complex to use". Whereas the odd numbered questions ask positive questions, such as: "I thought the system easy to use". A **usability score of 94** was calculated using (Brooke 2013) method. This indicates that according to the 12 participants the magnet had excellent usability. Brooke stated, in his presentation depicting the method, a usability score above 80.3 would be regarded as grade A: "excellent usability".

The second questionnaire looks at how persuasive participants found each separate method in the eco-feedback screen. Their responses have been depicted in the layered bar chart below:

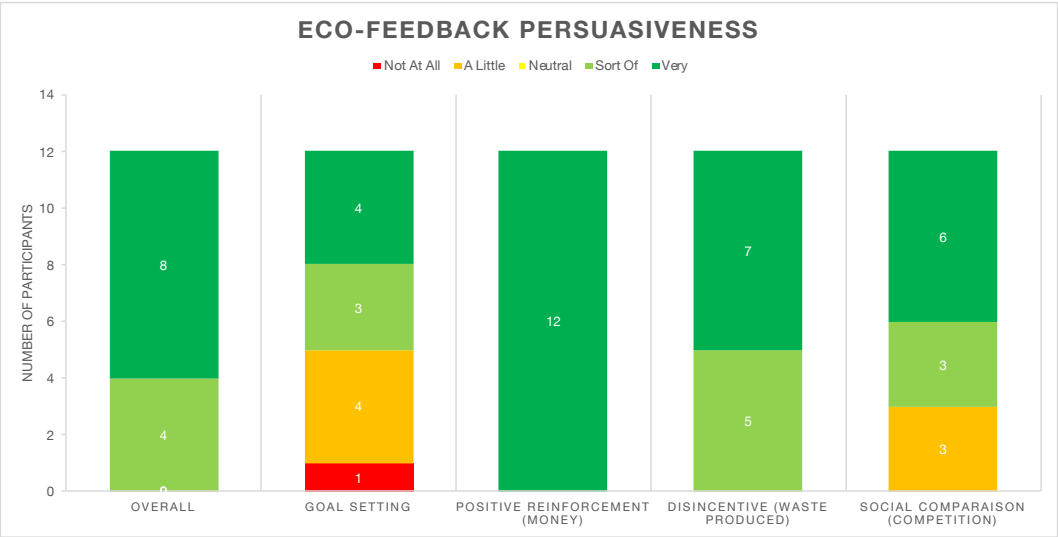

Figure 6.5: *Bar chart depicting how participants responded to the questionnaire enquiring how persuasive they determined the each item in the eco-feedback system to be.*

As can be seen, the money saved prompt was the clear favourite and goal setting least-liked. A thorough evaluation of all the above quantitive data, combined with the proceeding qualitative

data can be seen in Chapter 6.4

6.4.3 Interviews

Qualitative data was obtained through the subjects responses to the interview questions. The interviews were transcribed, transcriptions can be viewed in the appendix of this report. The general sentiments of the responses has been collated and can be seen below.

1. Was the visualisation of the refrigerators contents and subsequent expiry date clear and intuitive on the date tracking screen?

All participants thought the visualisation was clear and they mentioned that they liked the visual cueing of foods through the images and the use of colours to indicate how soon the food expired. A couple of users commented that the use of visuals made it quick and easy to process the information and also enabled them to read it from a distance. One user mentioned that he would have liked an orange colour for those foods expiring in a few days. 3 users mentioned that they share refrigerators with their flatmates so would have saw use for a "grouping" mechanism where you could browse foods by person.

2. If deployed in your home, would you see yourself adopting the practice of cooking with foods that are expiring first i.e does the magnet remove or add effort surrounding checking the expiry dates?

All users agreed that they could see themselves adopting the practice as the magnet makes the process very simple and removes the effort of manually checking expiry dates. 2 user's commented that seeing the food's expiry dates on their fridge face every time they were near the fridge would make it harder to ignore the expiring food, thus making them feel guilty for wasting it thus encouraging them to eat it. 1 user said they would be even more inclined to not wasting their food if they could receive a notification on their phone when a food is about to expire.

3. Do you feel that the eco feedback screen could encourage you to reflect about your wasteful behaviours more during your day-to-day?

All users agreed that the seeing the money they've saved/wasted would definitely motivate them to consider their wasteful behaviours more carefully when shopping or in the kitchen etc. They all agreed that if their statistics shocked them the would be especially motivated to consider their behaviours more carefully. 8 users really liked the competition feature and said that winning the competition would really motivate them to waste less. Whereas 4 users said they didn't care for the competition. 2 users said they would see use to having a group competition - amongst multiple friends - and have your results displayed on a leaderboard. 5 users really liked the "days no waste goals" whereas 7 users said they didn't care for achieving the goals unless there was a physical reward.All user's agreed that since their wasteful behaviours would always be prominently visible, since it would be on their refrigerators face and they use their fridges many times day, they would have no choice but to think more about acting conservatively. One user commented that he would really like if the stats screen reported his behaviours back in more detail. For example highlighting trends and making recommendations: i.e "you waste more on the weekends, this Monday try buying food only to last you until Friday"

4. What was your initial impression of the recipe recommendation system, what would be the requirements for you to actually cook the recipes that are recommended?

All user's agreed that the recipes would need to be quick and easy to make and actually taste good. One user commented that he would like if the recipes were ordered by "most popular". Another user mentioned that she would like to be able to multi-select foods from the date tracking screen to view meals she could make that include multiple foods. 10 user's said that they would be more inclined to browsing the recipe screen if it had more detailed filtering options. Such as: browsing by type of meal (breakfast, lunch, dinner, snack etc) or browsing by type of cuisine (Italian,

Indian etc). 2 users commented that they might not cook the exact meal, but would definitely use the recipes for inspiration. 5 users commented that they like the idea of finding recipes they haven't tried through the system.

5. What method of retrieving recipes did you prefer: tapping on the food from the date tracking screen or browsing via recipe screen?

All user's said they would use both methods. The general consensus was that they would tap on the food to find recipes if they were trying to use up particular ingredients but would browse the recipes via recipe screen if they weren't trying to use anything in particular and just wanted a tasty meal. The same 10 users, as stated in the previous question, reinforced that browsing the recipes via recipe screen would be more desirable if there were more detailed filtering options.

6.5 Analysis and Discussion

Through combining the results from the tasks performances, questionnaires and interviews a range of conclusions can be inferred regarding the refrigerators magnet's ability to instigate behaviour change. The chosen approach is to investigate whether or not the refrigerator magnet satisfies the design principles established in background research done in Chapter 2.

Since these principles have been generated through reviewing a range of accredited behavioural change models and persuasive technology, it can be confidently concluded that if the refrigerator magnet satisfies all 3, the magnets design has the ability to influence behaviour – thus it is an effective solution to reducing household food waste. The analysis is presented with each design principle as a subheading.

6.5.1 Create Visibility

It was deduced in Chapter 2 that if the magnet was able to visualise the fridge contents and the user's wasteful behaviours, it would successfully act as an "enabler" by reducing the effort around acting ecologically, a concept introduced by (Darnton 2008). Moreover,removing barriers and enabling action is core to the central aim of 'Enable' in (DEFRA 2011)'s 4E model for sustainable lifestyles – seen in Figure 2.2. It was also deduced that by visualising the user's wasteful behaviours, the magnet application would increase the user's awareness of the consequences of their current actions, in the hope of activating their personal norm and in turn fostering a positive attitude towards wasting less, thus altering their intention and influencing them to waste less. This is a concept that is highlighted in (P. Gollwitzer and Heckhausen 1987)'s model for self regulated change and (Schwartz 1977)'s Norm Activation Theory. This hypothesis is supported by Triandis model of interpersonal behaviour, figure 2.1, where a persons behaviour is said to be directly influenced by their intentions, habits and facilitating conditions.

The responses from the interview question 1, asking users how effective they found they found the visualisation, reveals that user's definitely found the visualisation of fridge contents and expiry dates effective, readable and intuitive. They were particularly fond of the use of images to show the type of food and traffic light colours to indicate the expiry date. All participants agreed that the visualisation effectively aided them to retrieve useful and actionable information about their refrigerators contents and this can be reflected through the low completion times for all task – seen in Figure 6.1. The tasks mimicked real life uses of the magnet, such as finding the most eco-friendly recipe to cook, and since the mean completion time for all tasks was lower than 7 seconds it can be concluded that the magnet's visualisation does assist it in enabling ecological action and removes the surrounding effort – one of the four pillars that are central to (DEFRA 2011)'s model for sustainable lifestyle. Figure 6.2 shows us that having the date tracking screen sorted by dates is out rightly it's most effective configuration as the users were able to consistently retrieve important information at least 1.5 seconds faster compared to when the foods were

sorted alphabetically by names. (Bandura 1988)'s Mastery Modelling and (P. M. Gollwitzer and Sheeran 2006)'s Implementation Intentions models for behavioural change dictate that if these ecological actions were practiced for long enough, they could replace old wasteful habits within individuals. Thus it can be deduced that the magnet's design does have the potential to influence users wasteful habitual behaviours to be more ecological.

The responses from interview question 2, asking if the participant could foresee the magnet's presence altering their current practices, reveal that magnet's visualisation of available food and its expiry date influences the user's intention towards wasteful behaviours as 2 users commented that seeing the expiry dates every time they opened the fridge would make it harder to ignore the expiring food by instilling a feeling of guilt, thus encouraging them to eat it. This response is in line with findings from (P. Gollwitzer and Heckhausen 1987)'s 4 stage model for self-regulated behavioural change which reports than an increased awareness is usually enough for the individual to re-evaluate the outcome of their behaviour and act according to their personal standards.

By combining the responses from interview question 3, querying the participants thoughts on the eco-feedback system, and the results from the eco-feedback questionnaire, figure 6.5, it can be concluded that the visualisation of behaviour used in the eco-feedback system was effective in influencing the participants intention. The results indicate that the most effective method of doing so was the positive reinforcement, displaying total money saved, and the social comparison which was implemented through competing with a friend for the least waste. These findings are in line with those of the background research in Chapter 2 as (Festinger 1954) found that social comparison is a very effective means of altering a persons intention and also that people tend to be more vigilant about their waste when its regarding their money - as apposed to the environments health. This relationship is also illustrated in Trianids model of interpersonal behaviour, figure 2.1. The goal setting mechanism was the least popular with participants commenting that they would find the goals more desirable if you actually received something from achieving them: not just a virtual accolade. Although, users that already had ecological intentions - prior to using the magnet - found the virtual accolades appealing. Two user's suggested a way to improve the competition feature would be to allow for group competition, using a leaderboard to present standings. In turn, this would make the competition feature more engaging: a central pillar to (DEFRA 2011)'s 4E model for sustainable lifestyles. Another user suggested that a more detailed breakdown of their behaviours alongside highlighting any concerning/actionable behaviour patterns would be desirable and further increase the level of awareness supplied by the eco-feedback screen. An example of this would be: "you tend to let your food expire over the weekend, this Monday try buying food to only last you until Friday". Doing this would force the magnet's design to further satisfy the Encourage and Exemplify pillars of (ibid.)'s model.

Overall, the magnets visualisations of expiry dates in the date tracking screen and the users behaviour in the eco-feedback screen is indeed sufficient to reduce household food waste. It effectively influences a users intention towards food waste mainly through increasing their awareness of the consequences of their current behaviour. In turn, fostering a concerned attitude through activating the users personal norm and forcing them to re-evaluate their current behaviours in accordance with this norm (Schwartz 1977), (P. Gollwitzer and Heckhausen 1987). The users found that the magnet also successfully leverages social pressures, (Festinger 1954), through the competition. Although the money saved prompt and the competition were the favourite methods of the eco-feedback screen, the results indicate that it would still be optimal to include the other methods, goal setting and the waste produced prompt, as participants had varying levels of preference for each. This distribution of preferences would be more apparent if a bigger sample study was taken.

6.5.2 Enable & Encourage Action

In order to initiate behaviour change and effectively reduce household food waste, the magnet must enable and encourage action. Enable and Encourage comprise half of the pillars in DEFRA's (the GOV Deparment for Environment, Food & Rural Affairs) published framework of how to influence behaviour, seen in Figure 2.2. The main way the magnet enabled action was through the recipe recommendation system. The aim of this was to promote the rehearsal of ecological responses to expiring food. (P. M. Gollwitzer and Sheeran 2006) and (Bandura 1988) tell us that if these responses are rehearsed for long enough, they could replace existing habits. The main way the magnet encouraged action was through visualising the users behaviours in the hope of having them re-evaluate the consequences of their wasteful actions and altering them accordingly: a concept highlighted in (Schwartz 1977)'s Norm Activation Theory and (P. Gollwitzer and Heckhausen 1987)'s 4 stage model for self regulated behaviour.

The users responses from interview question 4 indicate that users found the recipe recommendation useful and agreed that it decreased the chances of them wasting food as it showed them how to not waste, as apposed to just encouraging. The effectiveness of enabling action can be reflected by the task times: user's were always able to find the requested recipe relatively quickly (on average under 7 seconds). The ability to tap on a food and find its recipes was sought after as it made the process simpler and also ensured that recipes could be found that include the foods closest to expiring. This is confirmed by figure 6.3 where we see that recipes were found via tapping a food 10/12 times for task 1 and 11/12 times for task 2. Also the interview responses confirm that the participants felt that showing them recipes they could cook with expiring foods, didn't only act as an enabler but also encouraged them to actually take action and do something with the perishing food.

The preference for diverse filtering mechanisms is seen in the responses to interview question 4, where 10 user's said that they would be more inclined to browsing the recipe screen if it had more detailed filtering options. Types of filtering could be type of meal (breakfast, lunch, dinner etc) or cuisine (Indian, Italian etc). By including more diverse filtering of recipes the likelihood of the reducing food waste would be increased as 1) the user would have a higher chance of finding a recipe they actually wanted to cook 2) the user would be more encouraged to actually use the recipe recommendation system as it would be more attractive and effective - a concept supported by (DEFRA 2011)'s model for sustainable lifestyles - and 3) The time taken to find a recipe would be dramatically decreased, thus leading to a more pleasurable user experience which would in turn increase the likelihood of the user using the system to make decisions.

Moreover, through recommending recipes, and making the system attractive to the by incorporating more diverse filtering, the magnet's is enabling the rehearsal of ecological behaviours. Many studies have shown that in cognitive terms, rehearsal of new behaviours is sufficient to override existing habits (Bandura 1988). Including (P. M. Gollwitzer and Sheeran 2006)'s Implementation Intentions which dictates a conditioning process involving a rehearsal of scenarios. This implication is supported by the user's responses to interview question 2 where all users agreed that if the magnet was deployed in their home, they could see themselves adopting the practice of cooking with foods that are expiring first as it enables the process through simplifying it and removing the surrounding effort of manually checking dates and creating recipes that use the expiring food.

The experiment results also indicate that participants found that the alert's screen also encouraged them to take action through reporting instances they had wasted money and enabled action through recommending their best next action. Considering the responses from the users thinking aloud during task performance, it can be interpreted that the users always noticed the alerts at the top of screen first. This implies that the alerts should be organised in a way that places the most influential alerts first. What type alert is deemed most influential would vary per user as some would be more influenced by saving money, whereas others would prefer a more actionable alert:

such as what next meal to cook. This is reflected by the varying levels of perceived persuasion seen in the responses to the eco-feedback questionnaire - Figure 6.5. By positioning the alert deemed most influential for the user in a place they are likely to notice it, the likelihood of the user acting upon an urgent alert would be increased thus decreasing the the likelihood of the user wasting. The users regarded the overall eco-feedback system as very persuasive: this is directly stated in the results to Q1 of the eco-feedback questionnaire, depicted in figure 6.5

6.5.3 Usable & Personalised

The third design principle established through the background research in Chapter 2 was ensuring the design was easy to use and personalised. This was in order to promote user satisfaction with the aim of increased use and making the information provided more meaningful (Tang et al. 2015). By having a usable and personalised interface, the magnet is conforming to the "engage" principle that is illustrated in (DEFRA 2011)'s 4E model to sustainable lifestyles.

The magnet's usability was mainly evaluated through the responses from (Brooke 2013) System Usability Scale (SUS) questionnaire. A usability score of 94 was calculated from the results, figure 6.4, using the method outlined in (ibid.)'s paper presenting the scale. The method dictates that a usability score above 80.3 would be regarded as grade A: "excellent usability", which places the magnet app in this bracket. This "excellent usability" of the magnet's interface can also be supported by the low task times from participants across all the tasks: Figure 6.1. If the application had poor usability the participants would have been less likely to correctly interpret each controls function and this would have been reflected through slow task times. Responses from interview questions 1 indicate that participants found the effectual use of images and colours to greatly increase the systems usability by enabling the relevant information to be be quickly interpreted. Other responses from the same question found that the date tracking screen's usability and practicality would be greatly increased if it incorporated a "grouping" mechanism to allow users to view only their food when using a shared refrigerator.

Personalisation was achieved through the eco-feedback screen where the user could find their personal statistics about their money saved, total waste produced number of days without wasting. This personalisation clearly engaged the users as results from the eco-feedback questionnaire tell us that 8 users found the overall eco-feedback system "very" persuasive and 4 found it "sort of" persuasive. These results can be seen in Figure 6.5.

Overall the participants determined the system to have a high level of usability and personalisation. As such, it can be concluded that the design of the magnet application can effectively engage the user thus promoting its use thus being an effective design for a technological solution to reduce household food waste.

7 Conclusion

This chapter details a summary of the entire paper. Improvements for future work that were realised through the pilot study, implementation and evaluation, are also presented.

7.1 Summary

With household waste responsible for 2/3's of the global food waste, and global waste amounting to 1.3B tonnes of food - roughly £510B - a technological solution to reduce the household's contribution to this impending catastrophe appears obligatory. Some technological solutions do exist such as smart refrigerators and mobile apps but they all suffer from drawbacks such as lack of automation, high price point and lack of portability (for the refrigerators in particular). This knowledge led us to the central question that this paper scrutinises: "How can an interactive refrigerator magnet be designed to reduce household food waste?"

As such, I created a interactive refrigerator magnet to attempt to answer the question. After conducting the necessary background research, establishing design principles for persuasive tech and conducting a pilot study with user's, the magnets most effective design to reduce food waste was realised and then implemented. It featured a date tracking screen that visualises the refrigerators food contents and expiry dates, recommended recipes to users that used their nearly expiring food, an alerts screen that alerted users of their shortcomings alongside optimal next actions in order to minimise food waste and deployed various eco-feedback techniques such (Schwartz 1977)'s Norm Activation Theory by feeding back the user's wasteful behaviour to them; goal setting; social comparison through a competition with a friend.

The refrigerator magnet prototype was then used to address the paper's main question: "How can an interactive refrigerator magnet be designed to reduce household food waste?." The question was tackled by establishing design principles in Chapter 2 through detailed background research of accredited behavioural models then running a pilot study with users using a medium-fidelity prototype to explore current wasteful behaviours and attitudes towards the system, and also to get feedback to guide the design of the final prototype. Finally, a larger-scale experimental evaluation was conducted with users using the high fidelity prototype and the results were discussed in the context of the design principles to determine whether the magnet's design was effective in reducing waste and to elicit design improvements.

The experiment had 3 stages: participants were recorded completing a series of tasks and asked to "think aloud", they then had to fill in 2 questionnaires regarding the systems usability and the persuasiveness of the individual components in the eco-feedback system and finally they had to answer 4 questions in a semi-structured interview in order to gain a deeper insight of their attitudes towards the system.

From the results it became clear that the refrigerator magnet's design did indeed have the capacity to reduce household food waste as it user's found that conformed to the established design principles. The evaluation also found that the system effectively implemented all the "must have" functional and non-functional requirements detailed in chapter 3.

It was found that the magnet's visualisation of relevant food information and the users behaviours and was an effective in "enabling" and "encouraging" ecological action - 2 central aims to (DEFRA 2011)'s 4E model for sustainable lifestyles. The effective use of images and colours enabled the the easy identification and processing of the information, whilst contributing to the usability of the system. The evaluation results indicate that users found the magnet to encouraged ecological action via the date tracking screen and eco-feedback screen - with the goal setting mechanism being the least effective and alerting users of their total money saved being the most effective. The results indicate that the system enabled action through the recommendation of recipes and by promoting the rehearsal of ecological behaviours, which many studies have found to be a sufficient way to override existing habits (Bandura 1988), (P. M. Gollwitzer and Sheeran 2006). They also deduce that the magnet does increase the users awareness of the consequences of their actions, thus activating their personal-norm and forcing them to re-consider their behaviours. A model that is detailed in (Schwartz 1977)'s Norm Activation Theory and (P. Gollwitzer and Heckhausen 1987)'s 4 stage model for self-regulated change. The response to J Brooke's System Usability Scale, 6.4, documented that users found the system very usable as it achieved a usability score of 94.

Aside from conforming the magnets effectiveness in reducing households food waste, the evaluation results also enabled us to identify areas where the magnet's design could be improved in order to maximise its likelihood of reducing food waste. These findings are detailed in the proceeding future work section.

7.2 Future work

From the pilot study, implementation and evaluation I have identified a number of features for future development of the refrigerator magnet.

Detailed Recipe Filtering

Currently recipes can be accessed via tapping on a food from the date tracking screen and retrieving all the recipes you can cook with the chosen food, or browsing directly via the recipe screen. 10/12 user's said that they would be more inclined to browsing the recipe screen if it had more detailed filtering options. Types of filtering could be type of meal (breakfast, lunch, dinner etc) or cuisine (Indian, Italian etc). By including more diverse filtering of recipes the likelihood of the reducing food waste would be increased as 1) the user would have a higher chance of finding a recipe they actually wanted to cook 2) the user would be more encouraged to actually use the recipe recommendation system as it would be more attractive and effective 3) The time taken to find a recipe would be dramatically decreased, thus leading to a more pleasurable user experience which would in turn increase the likelihood of the user using the system to make decisions.

Detailed Analysis of Behaviour Patterns

Currently the user's behaviour is monitored by 3 main indicators, money saved, waste produced and days without wasting. The user can browse the total of each indicator alongside a semi-detailed breakdown. User's found that a more detailed analysis of their behaviour would be optimal in increasing their level of awareness about their current behaviours. They also found that in doing so, the eco-feedback screen would become more attractive and thus the data received more meaningful. An example of a more detailed behavioural analysis with the aim of minimising food waste would be a simple, accurate prompt such as: "you waste more on the weekends, this Monday try buying food only to last you until Friday".

Grouping Food In Visualisation During the interviews, 3 users mentioned that they share refrigerators with their flatmates so would have saw use for a "grouping" mechanism where you could browse foods by person. This grouping mechanism would enable the date tracking

visualisation to be more meaningful, more accurate and thus more useful to the user in terms of encouraging and enabling them to reduce food waste. It would not only be useful for university students sharing a flat, but could be utilised in any household where users store their own personal food in the shared refrigerator.

Support Group Competitions

Two user's suggested a way to improve the competition feature , through making it more engaging, would be to allow for group competition, using a leaderboard to present standings. This insight was supported as the 4 users that didn't care for the competition feature confirmed that they would be more inclined to benefit from it if it supported group competitions. This could be due to the increased social pressure it'd put upon the user as now they were subject to ridicule by many of their friends, not just one.

Remote Access to Data Store

This was detailed as a "could have" functional requirement in chapter 3 and vouched for by user's during the evaluation. Allowing remote access to the data store would increase the accessibility of the magnet's data and allow user's to make calculated decisions when outside the kitchen. For example in a supermarket or in a restaurant. This remote access could be granted through a simple mobile app which visualises all the key data stored within the magnet.

Location Based Push Notifications

This requires that the magnet application is connected to the user's smartphone. A way it could work could be that the user receiving a push notification when the GPS in their mobile phone senses their in a place of interest: a supermarket or a restaurant. The notification could alert the user that they have food at home to eat, in attempt to prevent the user buying excessive food. Thus, reducing food waste as it ensures the user makes use of the food the currently have, rather than letting it go off.

Connect With Other IoT Appliances

This was also detailed as a "could have" functional requirement in chapter 3 and would be necessary order to enhance the user experience and enable further functionalities.

These future amendments should be implemented into an improved prototype and their effectiveness validated through an experimental evaluation, similar to the one featured in this paper.

A Questionnaires

This appendix provides the two questionnaires that participants answered as part of the final evaluation.

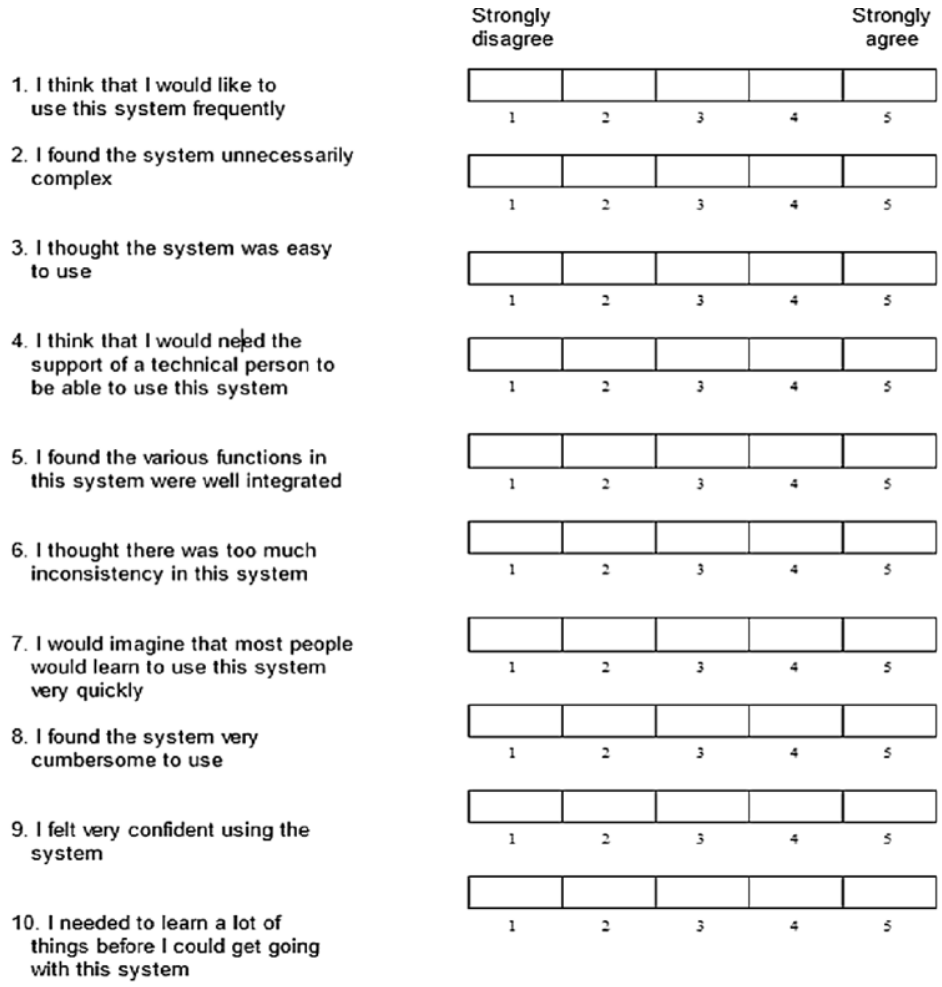

Figure A.1: *(Brooke 2013)'s System Usability Scale*

Eco-Feedback Screen Persuasiveness

Item	**Question**	**1**	**2**	**3**	**4**	**5**
Overall	Indicate how effective you think the overall stats screen would be in influencing you to waste less food?					
Goal Setting	Indicate how motivated you'd likely be to achieve the "days no waste" goals ?					
Positive Reinforcement	Indicate how effective you find the "total money saved" prompt as a motivator to waste less food?					
Disincentive	Indicate how effective you find the "total waste produced" prompt as a motivator to waste less food?					
Social Comparison	Indicate how effective you think the competition with a buddy would be in influencing you to waste less food?					

Figure A.2: *Questionnaire I created to assess how persuasiveness participants perceived each component of the eco-feedback system*

B Ethics Checklist

This appendix provides the signed user evaluation ethics checklist, required before user evaluation took place.

School of Computing Science
University of Glasgow

Ethics checklist form for assessed exercises (at all levels)

This form is only applicable for assessed exercises that use other people ('participants') for the collection of information, typically in getting comments about a system or a system design, or getting information about how a system could be used, or evaluating a working system.

If no other people have been involved in the collection of information, then you do not need to complete this form.

If your evaluation does not comply with any one or more of the points below, please contact the Department Ethics Committee for advice.

If your evaluation does comply with all the points below, please sign this form and submit it with your assessed work.

---

1. Participants were not exposed to any risks greater than those encountered in their normal working life.
   Investigators have a responsibility to protect participants from physical and mental harm during the investigation. The risk of harm must be no greater than in ordinary life. Areas of potential risk that require ethical approval include, but are not limited to, investigations that occur outside usual laboratory areas, or that require participant mobility (e.g. walking, running, use of public transport), unusual or repetitive activity or movement, that use sensory deprivation (e.g. ear plugs or blindfolds), bright or flashing lights, loud or disorienting noises, smell, taste, vibration, or force feedback

2. The experimental materials were paper-based, or comprised software running on standard hardware.
   Participants should not be exposed to any risks associated with the use of non-standard equipment: anything other than pen-and-paper, standard PCs, mobile phones, and PDAs is considered non-standard.

3. All participants explicitly stated that they agreed to take part, and that their data could be used in the project.
   If the results of the evaluation are likely to be used beyond the term of the project (for example, the software is to be deployed, or the data is to be published), then signed consent is necessary. A separate consent form should be signed by each participant.

   Otherwise, verbal consent is sufficient, and should be explicitly requested in the introductory script.

4. No incentives were offered to the participants.
   The payment of participants must not be used to induce them to risk harm beyond that which they risk without payment in their normal lifestyle.

Figure B.1: *Signed ethics checklist form part 1*

5. No information about the evaluation or materials was intentionally withheld from the participants.
   Withholding information or misleading participants is unacceptable if participants are likely to object or show unease when debriefed.

6. No participant was under the age of 16.
   Parental consent is required for participants under the age of 16.

7. No participant has an impairment that may limit their understanding or communication.
   Additional consent is required for participants with impairments.

8. Neither I nor my supervisor is in a position of authority or influence over any of the participants.
   A position of authority or influence over any participant must not be allowed to pressurise participants to take part in, or remain in, any experiment.

9. All participants were informed that they could withdraw at any time.
   All participants have the right to withdraw at any time during the investigation. They should be told this in the introductory script.

10. All participants have been informed of my contact details.
    All participants must be able to contact the investigator after the investigation. They should be given the details of both student and module co-ordinator or supervisor as part of the debriefing.

11. The evaluation was discussed with all the participants at the end of the session, and all participants had the opportunity to ask questions.
    The student must provide the participants with sufficient information in the debriefing to enable them to understand the nature of the investigation.

12. *All the data collected from the participants is stored in an anonymous form.*
    All participant data (hard-copy and soft-copy) should be stored securely, and in anonymous form.

Module and Assessment Name Interactive Refrigerator Magnet

Student's Name Joe Kadi

Student's Registration Number 2261087K

Student's Signature 

Date 12/02/2020

Figure B.2: *Signed ethics checklist form part 2*

C | Running Instructions

This appendix provides the equivalent of a `readme.md` for the Interactive Refrigerator Magnet application.

Requirements

- Xcode 11.4 or later

Running The Application

- Xcode 11.4 or later.

Package Dependencies

- Open MagnetApp.xcodeproj with Xcode.
- Run the project by selecting Product > Run within Xcode.
- Project can be run on a simulator within Xcode or on an iPhone that has been connected to Mac via USB.

D Interview Transcripts

A folder named "Interview Transcripts" containing transcriptions of all 12 interviews can be found in the zip file submitted through Moodle.

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