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Food Talks Back: Exploring the Role of Mobile Applications in Reducing Domestic Food Wastage

Geremy Farr-Wharton **Jaz Hee-Jeong Choi** **Marcus Foth**

Urban Informatics Research Lab
Queensland University of Technology
2 George St, Brisbane QLD 4000
{ g.farrwharton | h.choi | m.foth } @qut.edu.au

ABSTRACT
Mitigating domestic food waste reduces its environmental and economic impacts. In our study, we have identified the use of mobile technology to support behaviour change as a key tool to assist the process of reducing food waste. This paper reports on three mobile applications designed to reduce domestic food waste: Fridge Pal, LeftoverSwap and EatChaFood. The paper examines how each app can influence consumer knowledge of domestic food supply, location, and literacy. We discuss our findings with respect to three considerations: (i) assisting with the user's food supply and location knowledge; (ii) improving the user's food literacy; (iii) facilitating social food sharing of excess food. We present new insights for mobile interventions that encourage changes towards more sustainable behaviours to reduce food waste.

Author Keywords
Mobile, HCI, behaviour change, user behaviour, Fridge Pal, EatChaFood, LeftoverSwap, food supply, food location, food literacy, food sharing, social engagement, urban informatics, Australia

ACM Classification Keywords
H5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Food waste poses a threat to environmental and food sustainability. According to Schneider (2008), 25% of the global edible food supply is wasted each year. Ambler-Edwards, Bailey et al. (2009) argue a significant portion of wastages occur within households. Subsequently, public and private institutions have developed policy, interventions and incentives to encourage consumers to reduce their domestic food waste. However, despite these activities, food wastage still comprises approx. 40% to 60% of a household's total annual garbage (Caswell, 2008), which Wade (2011) argues accounts for approx. 20% of landfill contents in developed nations. Two-thirds of these wastages are preventable (Schneider and Obersteiner, 2007). The problematic implication of food waste is the release of methane gas into the atmosphere caused from decomposing food, which is a known contributor of global warming. Wang, Odle III et al. (1997) argue landfills contribute approx. 8% of the global greenhouse gas emissions, annually. Therefore, reducing domestic food wastage will reduce the need for land estates to house exhausted landfill capacities and decrease associated ecological impacts.

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One solution to food wastage is food sharing, and recent technological advancements have improved the ability to share food. For example, Ganglbauer, Fitzpatrick et al. (2014) explored the use of the FoodSharing.de platform to facilitate food sharing amongst consumers, farmers, organisations and retailers in order to reduce food waste in Austria and Germany. Their findings showed that FoodSharing.de successfully facilitated the sharing of food amongst large numbers of participating people, as evidenced in 17,000 active users sharing just under 1,800 food baskets within their online community. Their research showed that online social platforms can assist or facilitate in the process of food sharing between communities. Similarly, Grimes and Harper (2008) and Wei and Nakatsu (2012) provide further support for using technology to promote the sharing of food by bringing people together for social interaction and entertainment.

This paper examines how two commercial applications (Fridge Pal and LeftoverSwap) and our own prototype (EatChaFood) can increase consumer food supply, location and literacy knowledge. Food supply and location knowledge, as well as levels of food literacy are three identified factors contributing to household food wastage behaviours (Farr-Wharton, Choi et al., 2014, in press). Further, we examine the role of each application and how they can facilitate food sharing by evaluating the barriers that limit their effectiveness. The knowledge can be used to address shortcomings to improve the effectiveness of future interventions aimed at reducing domestic food waste. Fridge Pal was chosen because of its various features that provide users with a mechanism to assist with their household food management, including food supply and location information. LeftoverSwap was chosen because it provides a mechanism for facilitating anonymous food sharing. EatChaFood was developed to serve the dual function of assisting with household food management as well as food sharing among users, in order to examine how the combination of the two might lead to a more effective application.

By examining each application in a small sample qualitative study, we seek to understand the role that mobile applications can play in reducing domestic food waste by increasing consumer knowledge and facilitating food sharing.

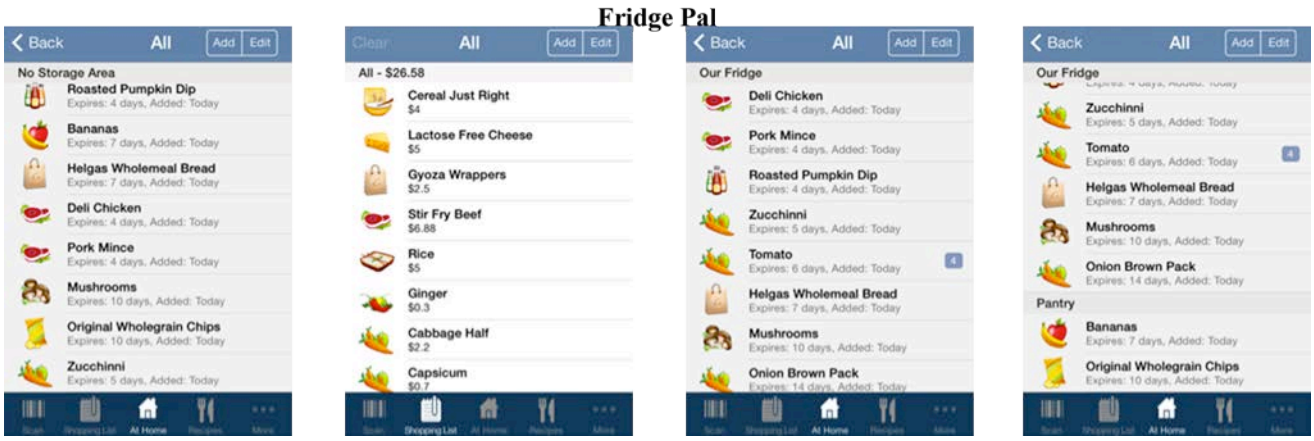

Figure 1a - d. Four Fridge Pal interfaces are presented. These are the most common interfaces users interact with.

BACKGROUND

A number of mobile applications available on the market target reduced wastage of food in various settings. Most provide features to assist individuals or businesses (e.g. restaurants) with everyday food management. The applications generally target one or a combination of the following:

- Recipe sharing and advice (e.g. Gojee[1] and Love Food Hate Waste[2]);
- Shopping list management (e.g. 222 Million Tons[3] and Green Egg Shopper[4]);
- The use of business data to inform users of cheaper foods (FoodStar[5] and Leloca[6]);
- The monitoring of business processes to reduce waste (e.g. LeanPath[7] and Wise Up On Waste[8]).

An example of an intervention targeting individual consumers includes Fridge Pal. Fridge Pal (Fig. 1a - d) provides a range of features, purposed to assist users with managing their groceries and planning their next meal. The application has several defining features that enable the user to: (i) create and manage shopping lists; (ii) add food items manually using a barcode scanner or from previous shopping lists; (iii) view and manage food items added to the inventory and divided into fridge, freezer and pantry storage categories, and; (iv) search recipes utilising food added to the inventory. Push notifications can be used to alert users of products close to expiry. We use Fridge Pal to investigate how the app's features might help improve food supply knowledge and the level of food literacy of users.

An example of an intervention promoting social food sharing is FoodSharing.de, which is a useful mechanism to reduce food waste. It operates by promoting the sharing of leftover foods that would otherwise be discarded with other individuals and communities (Ganglbauer, Fitzpatrick et al., 2014). Food sharing has been a long standing practice among existing social groups (Wei, Peiris et al., 2011). However, what remains to be explored is the likelihood of individuals sharing food with others outside of their close social circle and whether this can be facilitated by mobile applications. LeftoverSwap facilitates food sharing among known and unknown users.

LeftoverSwap (Fig. 2a and b) connects those who share food with those who take shared food. Users are provided with a local map, and shared items are presented as pins. Users take a photo of surplus food and provide a description before sharing the item at their current location. Users can also instant message the sharer of a food item. We use LeftoverSwap to examine how food sharing can reduce food waste within a known community and help to facilitate social engagement between people.

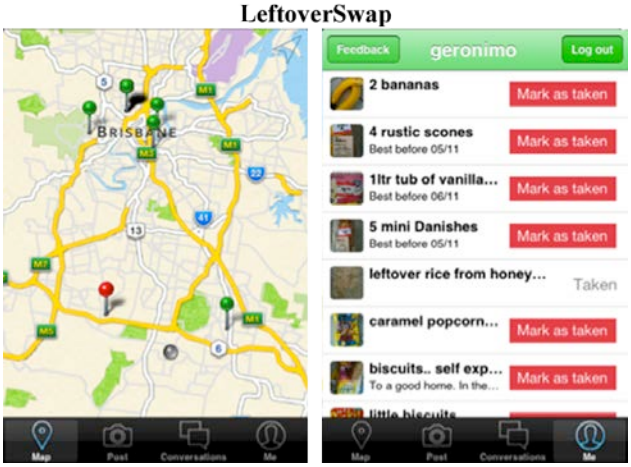

Figure 2a - b. Two LeftoverSwap interfaces are presented. These are the most common interfaces users interact with.

Using Fridge Pal in our study enables us to explore how the app influences the user's knowledge about food supply, location and literacy within their household. LeftoverSwap lets us explore food sharing within a known community. Additionally, we designed and deployed our own prototype app: EatChaFood, which

[1] https://itunes.apple.com/au/app/gojee-food-drink-recipe-app/id675249105?mt=8

[2] https://itunes.apple.com/au/app/love-food-hate-waste/id578274009?mt=8

[3] https://itunes.apple.com/au/app/222-million-tons/id528965282?mt=8

[4] https://itunes.apple.com/au/app/green-egg-shopper-shopping/id393794174?mt=8

[5] https://itunes.apple.com/au/app/food-star-capture-rate-share/id710401134?mt=8

[6] https://itunes.apple.com/au/app/leloca-instant-nearby-deals/id465271753?mt=8

[7] http://www.leanpath.com/

[8] https://play.google.com/store/apps/details?id=uk.co.torchb2b.waste

Figure 3a - d. Four EatChaFood interfaces are presented. These are the most common interfaces users interact with.

incorporates features from both apps in order to explore the effectiveness of a single application.

EatChaFood (Fig. 3a - d) encourages users to consume their food prior to expiration by providing features to assist consumers with managing their food, including: adding food items to an inventory, viewing all food in an inventory categorised by food types, and searching recipes containing inventory items (Farr-Wharton, Foth et al., 2013). This app extends Fridge Pal's functionality in three ways. Firstly, it provides photos of a user's fridge interior in addition to a list of available inventory items. Secondly, it provides users with a colour code scheme to improve systematic storage within their fridge. Users customise the colours representing foods on their fridge shelving, as described by Farr-Wharton, Foth et al. (2012). Thirdly, a shared space named 'Fridgescope' (Fig. 3c) provides users with the opportunity to share food with other users. EatChaFood also provides passive notifications of food expiry by categorising food: (i) green – 5 or more days left; (ii) yellow – 2-4 days left, and; (iii) red – less than 2 days left. We investigate the app's effectiveness in providing users with improved knowledge of what and where food items are available in storage. We further investigate how the recipe and food sharing features were utilised and if these had implications for food literacy.

PRIOR WORK

Remembering what household food is available and where it is located can be cumbersome. This is particularly the case with longer shelf-life foods, which may not be regularly used and is stored for long periods. Knowledge of the available household consumable food is referred to as food supply knowledge. Similarly, not only knowing what household food is available, but also knowing the location of food items can be equally challenging. This food location knowledge is particularly difficult in households with limited or no systematic food storage (Farr-Wharton, Choi et al., 2014, in press). Knowledge and understanding of how to use food to meet the needs of an individual refers to a person's food literacy (Vidgen and Gallegos, 2010). Further, experiences with food can vary for different people. However, when a person has previously had negative experiences with particular foods, they can be partial to consuming it in the future. This is because their initial experience with the food can provide an incorrect assessment of the value of the food in the future. This also, in part, refers to a person's food literacy (Farr-Wharton, Choi et al., 2014, in press).

There are countless mobile apps designed to assist consumers with their everyday food practices. Some are purposed to support the common activities a user undertakes during food purchasing, storage and cooking activities. Public and private investments have capitalised on opportunities to provide greater knowledge of food usage to users and how to manage it within domestic settings, for example, by using recipe and food diary applications (Ene, 2008; Schneider, 2008). Recent design interventions have targeted raising awareness of food waste within communities, such as the Food Waste Diary and Love Food Hate Waste apps. Changing practices around food and its waste can be difficult. Using technology is only one of many possible ways to facilitate reducing domestic food waste, but an effective one. For example, Lim, Dolech et al. (2014) explored a recipe finder embedded within an app and how it helped a community of consumers find new uses for food that would otherwise be discarded. Their approach prevents food from being wasted in two ways: (i) by providing information of food usage, increasing the level of food literacy, and; (ii) prompting food consumption before expiry. Their findings indicated that technology can simulate communal meal consumption between two or more people, presenting an opportunity to bring together otherwise separate people through technology. Further, Rouillard (2012) investigated how co-locating a mobile device with the household fridge can reduce food waste. In the study, a mobile device was fastened to the fridge for the user to interact with while exploring for food. The technology encouraged the consumption of near-expiry food to reduce waste. Their findings showed the co-location of a mobile device could be used to facilitate such a process. They propose several useful technologies that could be embedded with an intervention to assist with designing similar applications. These included: voice, keyboard, camera, barcode scanner, and image recognition to manage data. These are example interventions leveraging HCI to target food sharing and food management. However, these interventions do not directly target food supply, location and literacy

#	Sex	Age	More than 1 App	Living and Working Arrangements
Fridge Pal				
F1	M	29	No	Shared household, PhD Student (Full-Time)
F2	M	30	No	Shared household, Lecturer (Full-Time)
F3	F	19	No	Family Household (parents and siblings), University Student (Full-Time)
F4	M	38	Yes (EatChaFood)	Family Household (partner and child), Stay At Home Parent (Full-Time)
EatChaFood				
E1	M	22	Yes (LeftoverSwap)	Shared Household, Masters Student (Full-Time)
E2	M	28	Yes (LeftoverSwap)	Shared Household, PhD Student (Full-Time)
E3	M	38	Yes (Fridge Pal)	Family Household (partner and child), Stay At Home Parent (Full-Time)
E4	M	28	No	Family Household (partner and two children), Entrepreneur (Full-Time)
LeftoverSwap				
L1	M	22	Yes (EatChaFood)	Shared household, Masters Student (Full-Time)
L2	M	29	No	Shared household, PhD Student (Full-Time)
L3	M	34	No	Shared household, PhD Student (Full-Time)
L4	M	29	No	Shared household, PhD Student (Full-Time)
L5	M	28	Yes (EatChaFood)	Shared household, PhD Student (Full-Time)
L6	M	30	No	Couple Household, Lecturer (Full-Time)
L7	F	35	No	Family Household, PhD Student (Full-Time)

Table 1. Presents the relevant details of participants who used each of the three applications.

knowledge, which have been identified to be key factors leading to domestic food waste (Farr-Wharton, Choi et al., 2014, in press).

Therefore, our study is guided by this research question: how can mobile applications help facilitate food sharing and improve consumer knowledge regarding food supply, location and literacy to promote changes towards more sustainable food practices within domestic environments?

METHODOLOGY

We addressed our study's research question by observing the use of each application over three-week periods. Our data collection also consisted of interviews conducted with participants at the conclusion of each observation period. Participants were recruited from respondents to a Facebook and email advert and were screened in consideration of their age, sex, living and working arrangements, and household type. Nielsen and Molich (1990) suggest that for design evaluations smaller sample sizes of between 3 and 5 participants are more effective in providing useful design evaluations than larger groups. The role of the participants was not specifically to evaluate the design of each application, which differs from Nielsen and Molich's (1990) definition of design evaluators. Rather, it was the role of participants to evaluate the use and interactions with the app, which included an evaluation of design. However, because of our study's similarity to Nielsen and Molich's (1990) definition of design evaluators, we thought it appropriate to apply their participant sample size restrictions. Subsequently, we chose to limit our sample sizes to their approximate recommended numbers: (i) 4 Fridge Pal; (ii) 7 LeftoverSwap, and; (iii) 4 EatChaFood participants. Three participants used more than one of these applications. Participant attrition was quite high in our study, particularly among females and hence, participants consisted predominately of males. We were unable to determine why attrition rates were higher amongst females than males. During each observation period, we gauged participants' use of the application of their choice once a week by questioning their thoughts regarding the application's useability and usefulness. On conclusion of each period, we asked participants a series of open-ended questions regarding four facets: (i) how the app influenced their daily practices around food; (ii) the impact the app had in reducing food waste, including informing food supply, location and literacy; (iii) usability and usefulness of the app; (iv) the impact the app had on participants' lifestyles. Thematical analysis was applied in order to evaluate the interview data and derive key themes. In addition, the interview data was cross-examined with the observations of use and interactions participants had with the applications to corroborate what was said. Table 1 presents our participants' key details.

Fridge Pal participants were asked to utilise the app's full functionality and we provided $10 iTunes gift cards to purchase the full version of Fridge Pal. This was a necessary step, because the full version allows for an

unlimited number of items to be entered into the inventory and access to additional functionalities whereas the free version is limited to only three food items.

We invited colleagues from our research lab to share food through LeftoverSwap. All lab members were acquainted with one another and consisted of a total of 17 colleagues, of which, 7 people actively shared or took food. We provided a 'shared shelf' within the lab's communal fridge and accessible by participants.

LeftoverSwap was used to notify others that food had been shared. We also provided an A4 sheet of paper and a pen on the front of the fridge for participants to place their name and the item they were either sharing or taking. This was because LeftoverSwap does not make clear who takes the food items offered. We used the information provided on the piece of paper to observe the sharing of food between participants. We asked participants to place shared items on the provided fridge shelf. Participants could engage in communication with the food sharer via LeftoverSwap's instant messaging feature to learn further details of the shared food item. We sent daily emails to participants, which indicated new available food items and older items still available. We moderated the shared shelf daily ensuring expired items were removed. A series of open-ended questions differing from the other observation periods were asked of those who actively participated in the LeftoverSwap exercise. Questions related to three facets: (i) Food sharing in general regarding the circumstances that participants would either share or take food; (ii) Mechanisms that supported food sharing, such as LeftoverSwap; (iii) Future mechanisms and requirements to support food sharing.

Studying EatChaFood, we instructed participants in the use of, the app including: use and maintenance of the colour code scheme, taking fridge interior photos, adding and removing food inventory items, finding recipes, and use of the shared space, Fridgescope. We provided support to participants when necessary. We asked an additional question to the standard open-ended questions regarding how participants used Fridgescope and what they thought about food sharing.

FINDINGS

Our results are structured into themes derived from a culmination of each observation period and final interviews with participants. Three main themes emerged: (i) The applications' design and features; (ii) supporting knowledge of food supply, location and literacy, and; (iii) response to food sharing.

The Applications: Their Designs and Implications

Comments about the designs and implications of each application were continually made during participant interviews. In the cases of Fridge Pal and EatChaFood, data entry was the main issue. Almost all participants suggested the current method of data entry, a three-step process outlined by Farr-Wharton, Foth et al. (2013), would limit their continued use of the application after the study's conclusion. However, some favoured certain data entry methods. F2 stated their excitement to use the barcode scanner on Fridge Pal, but reported losing enthusiasm after some products were not recognised. F1 also wanted some level of manual manipulation of data before items were entered. F1 and F2 suggested automatic food expiry was an issue and did not provide accurate information. F2 gave the example of goat's cheese and that once opened, can expire quickly. Fridge Pal does not allow manual changes to expiration dates regardless of circumstances and in that case indicated the goat's cheese would expire in over 100 days. Also, F1 stated data editing, such as removing an item from their app's inventory was not a natural action. They explained *"when I'm in the kitchen and have just removed something from my fridge, I don't naturally think to remove it from the application. Then I get automatic notifications for something I have already eaten"* (F1). All participants raised the need to improve how data is manipulated for future iterations of the applications.

Several participants provided opportunities to improve the functionality of each application. F1, F4, E3 and E4 suggested a method of automatically populating the application's inventory with items scanned from a shopping receipt. Further, F1 indicated their preference to undertake the majority of interaction with the application through a device embedded within, for example, the refrigerator and use a mobile application for interaction during grocery shopping. F1 suggested this might reduce the burden of data removal from the application's inventory, because it would allow users to easily see what food is available within the fridge before opening the door. Another finding was identified that indicated a need to address how application notifications were delivered to users. F1 and F4 stated the usefulness of receiving push notifications as reminders to consume some food items, whereas F2 and F3 ignored or disabled push notifications, because they found them to be invasive.

Participants' responses also indicated a need for integration of the main features of their application and other tools they already use in their everyday lives, such as email for notifications. Additionally, F1 suggested a number of applications that provide nutritional information. They suggested if this information could be integrated with the food that is being added to the inventory, *"all of a sudden, you know what I'm buying and you know what I'm eating, therefore you may be able to give me some feedback on whether what I'm eating is actually good for me or not"* (F1). E2 further stated that they are already using a variety of mobile applications to serve different specific purposes. Adding an additional application would need to provide significant benefit to their life or it becomes a burden to use. However, they suggested that if an application can be used easily in conjunction with other applications they are already using or if the application can combine the functionalities of several others, then the single application might improve in usefulness and purpose. E1 also stated that future iterations of apps similar to EatChaFood would benefit from improved and more comprehensive notifications. They suggested notification information might include not only products that are expiring soon, but what recipes they could be used in. E1 further stated recipe

information could be categorised into: quick snacks, moderate meals, and longer preparation meals to provide the user with a choice, which best represents their current situation. Several participants also suggested LeftoverSwap might benefit from integration with other applications. L1, L3, L4 and L6 stated LeftoverSwap could incorporate technologies used in their everyday lives, such as email to notify users of food available in walking proximity. L1 and L5 stated the ability to customise notifications would be beneficial. They stated their preference for the ability to preselect preferred food items and be notified if other people shared those items.

Food Supply, Location, and Literacy Awareness

Our findings revealed a second theme suggesting participants felt their application supported and informed knowledge of their food supply and location, and improved their food literacy. In some instances, participants reported an increase of all three. Our findings suggested participants experienced this particularly when using Fridge Pal or EatChaFood. However, several participants indicated LeftoverSwap also contributed to increasing their food literacy. F1, F2, E3 and L2 all mentioned the applications they were using helped to improve food literacy. In the cases of Fridge Pal and EatChaFood, they did this by providing the number of days a product should remain edible under refrigerated conditions. F2 indicated this information helped to inform him of how long a product should last under normal circumstances. F2 suggested he had limited food expiration knowledge and would benefit from this type of feature in such apps. Similar comments were made by F4. Fridge Pal and EatChaFood also provided recipes utilising food that was available in the user's inventory, which participants indicated increased their food literacy in some instances. It did this by providing some participants with recipe options they may not have previously used in preparing food. F1 stated the use of Fridge Pal's recipe function helped to repurpose an item about to expire, which was bought for another planned meal. E3 indicated a similar scenario where EatChaFood helped to repurpose expiring food. Overall, all Fridge Pal and EatChaFood participants noticed a reduction in food wastage, which several participants indicated was because of an improved understanding of food expiration. Therefore, participants had experienced some level of increased food literacy.

Our findings also showed an impact on a users knowledge about their food supply. Several Fridge Pal participants suggested they would have knowledge of most of the items available for consumption in their food storage. However, F2, F3 and F4 stated they would occasionally dispose of forgotten items that had expired. Each participant suggested in some cases, those disposed items had been placed behind other newer items and eventually were forgotten about. F2 stated the notification feature of Fridge Pal was a helpful tool because it overcame the issue of items being pushed behind other newer items and allowed for consumption before expiration. F1 provided a unique view, stating the notification feature of Fridge Pal enabled a one way conversation to occur between the food and the user; *"All of a sudden food is saying 'eat me, I'm about to expire,' giving the food a voice that it did not have before"* (F1). In part, this occurrence provides food with a passive form of communication to improve its chance of consumption rather than being wasted. E3 suggested the one inventory per household function helped their household manage their food stocks effectively. However, E3 stated, *"between the inventory list and the photo of my fridge, I preferred the photo, because it showed me things like how much milk I had left."* While the photo may not have clearly shown all items, because of item placement and visibility, the visual information is often richer than the inventory list. E1 and E3 suggested having both an inventory list and a photo of the fridge interior assisted during shopping experiences. It did this by providing the users with the information they sought in both a visual and list form, such as the user inspecting if they had *"lettuce or sour cream"* (E3) in storage before purchase. E1 stated *"EatChaFood can reduce food wastage by preventing the purchase of food I already have, so the doubling up of items I have in storage does not occur."* E1 further suggested that supply information should incorporate all available storage locations, including: the household fridge, freezer, pantry and *"other sources as well, such as the fridge from work"* (E1).

EatChaFood also provided users with a mechanism to support a system of storage within their household fridge. Participants were mixed in their responses about whether they thought the colour code scheme was useful and what impact it had on food wastage. E3 stated having the system on a mobile device is not as effective as it would have been in a physical form within the fridge. The application provides the opportunity for a user to place food items according to its particular food type. E3 indicated the storage system only works if all household members actively engage with the application to remind themselves of where to place or locate items. However, E3 and E4 suggested methods to improve this would include having a physical coloured system within the fridge itself to indicate the location of food. E1 also stated an application, such as EatChaFood that provides both support for food supply and location knowledge *"helped to locate some items, but would be more useful for people who have a lot of food, such as larger family households"* (E1). Nevertheless, all EatChaFood participants favoured the colour code scheme with E2 and E3 stating the system raised their awareness of some items, particularly those items with a longer shelf life that may have been in storage for a considerably longer time than high turnover foods. Such awareness about food inventory will provide the opportunity for users to consume those items before they expire, thereby further reducing food wastage.

Response to Food Sharing

Our findings indicated a final significant theme that emerged during our analysis of EatChaFood and LeftoverSwap interviews suggesting food sharing is a controversial action for our participants. None of the EatChaFood participants opted to take food shared by other participants. While the sample size was relatively small, we felt it necessary to explore why participants were hesitant. In questioning EatChaFood participants on

this matter, all provided similar responses. The issue of trust was raised. The participants stated that unless they knew the other person, or at the very least, knew the person with a level of familiarity, they were unwilling to share food. The responses indicated a level of fear and uncertainty; in that participants did not want people they did not know potentially coming to the house to take a shared item. E3 said, *"I just don't want people knowing what I eat."* E1 and E2 indicated their concern related to the awkwardness of a stranger approaching the participant's household to retrieve the shared food item. However, several items of food were placed on EatChaFood's Fridgescope for sharing with others. E2 also stated *"the benefit of receiving free food might help motivate users to overcome the amount of data entry required to used the application."* However, this was not a general consensus amongst the other participants.

When the issue of trust was raised regarding the sharing of food, we sought to explore this further with our participants who used LeftoverSwap. We asked participants to provide us with the circumstances under which they would feel comfortable both sharing food with others and taking food shared by others. Their responses provided an indication of the circumstances, which were generally similar across all LeftoverSwap participants. Participants were more comfortable to give or take food items if the items were either: (i) packaged; (ii) shared by or to a well-known and trusted person, such as a family member or close friend, or; (iii) if a well-known and trusted person recommended the person or community where food was shared by or to. Participants' comfort reduced when sharing food amongst a known community, such as amongst work colleagues or housemates. However, participants still felt comfortable enough to consider taking or sharing items within these communities and would, in most cases, *"take the risk"* (L2, L4 and L6). This also became evident with most participants' choice to take food shared in the communal fridge. L2 stated they *"would share food to build relationships, such as sharing food at a social gathering."* Generally, participants were more willing to give food than take it. However, all participants indicated they would be hesitant to share or take food items amongst an unknown community. Again, this fell back on the issue of trust, not only in the person sharing or receiving the item, but the food item itself and the conditions it underwent before it was shared.

Our findings also showed that most LeftoverSwap participants felt a sense of responsibility for food they shared with others. L2 stated, *"I feel as though the food I share with others is a token or gesture of goodwill. If no one takes the shared food and it expires, I don't want people having negative feelings towards me because the food had expired. So I would take responsibility and remove it if it expired because no one had taken it."* Further, our observations showed the majority of LeftoverSwap participants did not share food items. However, all participants took at least one item. L2 and L7 commented on the social justice of sharing food. L2 said, *"if you share food with others, it is expected that those who take the food would at some point share food back."* L7 also provided a similar comment saying *"others should share food if they are taking it."*

DISCUSSION

Impact on Food Supply and Location Knowledge

Our study shows that there are several design features of Fridge Pal and EatChaFood that improved food supply and location knowledge for users. In the majority of cases, our findings indicated the use of the app assisted with a reduction in our participants' food wastage. In particular, an up-to-date food inventory list and a visual photo of a fridge interior were the most effective design features improving food supply knowledge. However, this process requires that all food items across all storage areas, including the fridge, freezer and pantry, be incorporated into the food inventory. A potential problem is whether it is practical to manage food through a mobile device, in a different location from where the food is stored. Our findings support the outcomes identified by Rouillard (2012) suggesting a co-located device with food storage is likely to be better in providing real-time management of food storage data. An additional functionality is required that will deliver real-time 'easy to manage' information that provides a user with their full inventory of edible foods, giving them informed choice to prepare a variety of meals. This will reduce the possibility of food items being wasted. If a full list of items were available, it would also improve recipe searches and assist users during shopping experiences. In turn, this would prevent purchases of items already in storage.

Our findings also indicated challenges in supporting food location knowledge. The findings indicate systematic storage is not a common practice amongst our participants. The virtual colour code scheme was found not to be as effective as the physical colour code scheme (Farr-Wharton, Foth et al., 2012) in reducing food waste. One explanation suggests the app requires the user to observe the colour code scheme via EatChaFood before placing food in the systematic location. We argue that this task involves an additional step that does not benefit the user. Therefore, we believe that interventions assisting food storage would benefit from being integrated with food storage. We suggest this may require a new approach to household fridge design and should be considered by fridge manufacturers in the future. We also suggest other mechanisms supporting food location knowledge – for example, radical re-thinking of the way space is utilised within food storage and using a Lazy Susan style food rotation apparatus on shelving within storage. These may improve how food storage is organised and efficiently utilise space, reducing the risk of lost or forgotten items.

The burden of manual data entry and removal was also a key issue raised by all participants involved with Fridge Pal and EatChaFood. The findings point to a need to improve how data is added and removed from the food inventory. Suggestions were made to make the process automated or partly automated. This will need to be embraced by producers and retailers in the future, because there are currently opportunities that enable the

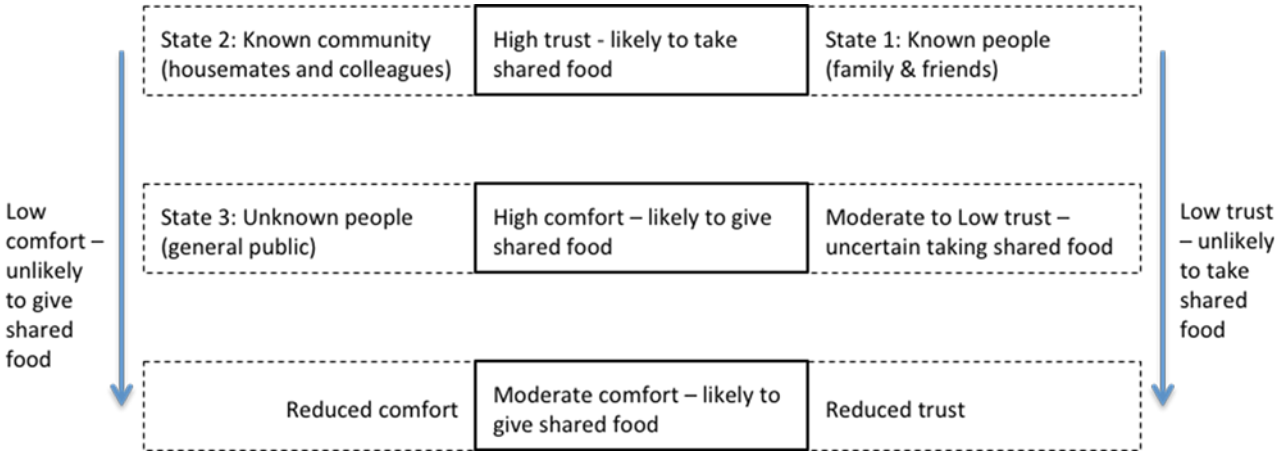

Figure 4. An illustration of our proposed food sharing acceptability scale.

capabilities to automate the process, such as scanning barcodes and including a product name and expiry. Further, other possibilities could leverage technologies, such as RFID tags that could be used to read product information as they enter or leave household storage, and then automatically update a food inventory with the product name and expiry. We recognise some limitations of these approaches. For example, Farmers Market produce might not have barcodes or RFID tags to capture details of food, such as product name and expiry. However, image recognition may play a part in the larger solution as the technology becomes more accurate and widely available amongst the general community.

Impact on Food Literacy

Each application improved a user's understanding of how to use food, thereby increasing the level of food literacy. We found that one of the more effective design features was the recipe suggestion. This feature was beneficial in informing new ways to utilise food. This was the likely contributor of a reduction in food waste, because leftover preparation residuals have an opportunity to be utilised, whereas previously, Schneider (2008) argued leftover residuals were often wasted. This process is supported by the findings of Lim, Dolech et al. (2014). However, a short-term impact is likely to be experienced in this case and we suspect previous practices will return in time, because the need for a co-located intervention has not been provided, which was indicated to be a main issue for our participants. To overcome this potential problem, engaging the user directly is necessary. However, this does not necessarily have to occur through technical interventions and instead, the intervention should aim to facilitate change in the way users view, share and source food to reduce its waste. Automatic food expiry features are also useful in informing users of food shelf life. We suggest future interventions provide automated food dating with the option to provide manual input. This would help to provide accurate information of food expiry and improve the level of food literacy for users.

We also found small improvements in food literacy because of food sharing. Not all of our participants experienced this. However, several participants indicated the use of their senses to determine if shared food was edible. This included the participant using and trusting their touch, sight and smell to determine if the food could be consumed. We argue that the communication between LeftoverSwap participants also contributed to informing a user's knowledge of food and if it can still be consumed. Our findings showed that while participants used their own senses to determine if food was edible, they also placed a level of trust in other participants they were sharing food with. This supported the participants to trust the edibility of food that was shared by other participants. We argue future interventions targeting increased food literacy amongst users would benefit from features that enable food sharing. We propose features that provide users with the capacity to communicate with other users about their experiences with food and food expiry.

Food Sharing Roles for Mobile Technology

We found the act of food sharing to be somewhat controversial for our participants. This was not the case when sharing food between family members or close friends. However, EatChaFood and LeftoverSwap participants reported hesitation and reluctance when sharing food with people outside of their immediate family and social networks. This also provides context to Lim, Dolech et al. (2014) in that sharing meals, even in virtual circumstances, may not be effective outside of one's close social circle.

We found the participants' hesitation and reluctance to share food stemmed from a concern of trust and comfort. Our findings provide insight into a food sharing acceptability scale, which depicts three states of food sharing between our participants (Fig. 4). The sharing acceptability scale is determined by a person's trust and comfort to either give or take shared food. The act of taking food is dependant on *trust*, and the act of giving food is dependant on *comfort*. We propose the first sharing state occurs with optimal trust and comfort and occurs between family and close friends. The second sharing state occurs amongst a known community, such as housemates or acquaintances and has reduced trust and comfort with either giving or taking shared food. We found our participants were more willing to give food in this sharing state, than take

it. However, some participants were willing to take shared food in this state as well. The third sharing state we propose occurs between a person and an unknown community. We found the level of trust is significantly reduced during this state and our participants were reluctant to take shared food. Similarly, we found the level of comfort was reduced in this state and our participants were uncomfortable giving food to an unknown community or person. We found this was counteracted if a trusted person became a guarantor of that community or person. Effectively, if a trusted person promotes the sharing of food amongst an unknown community, a person will be more willing to share food. We propose future interventions facilitating food sharing could integrate the lessons we have learnt in our study to strengthen their resolve. However, we learnt from Ganglbauer, Fitzpatrick et al. (2014) that food sharing can be effectively facilitated through a technological intervention. The question remains, why was food sharing effective in an unknown community with FoodSharing.de and not as successful through LeftoverSwap and EatChaFood. We postulate that the addition of a social media channel, that is, a Facebook-facilitated community page stimulated discussion around food sharing, developing a community of 'trusted' strangers (Hearn, Collie et al., 2014). LeftoverSwap does not provide a similar forum and instead, provides a food sharing approach similar to the process of 'cold calling.' We argue our work is the initial steps in understanding how food sharing may be facilitated through the use of mobile apps. Further, we confirm that technology can play a key role in food sharing facilitation in the future, particularly if these barriers can be overcome.

We also found several participants were in favour of a rating-style system that enabled users to place appeal on other users who give or take shared food items. A rating system would assist users in deciding to give or take shared food. A rating system may also serve to alleviate mistrust in taking food and provide comfort when giving food. This system can be integrated into apps, such as LeftoverSwap, which would improve food sharing facilitation. We found several participants were interested in further information about shared food, both before it was given and after it was taken. This could be facilitated by using technology and we suggest there is an opportunity to provide contextual information, such as: (i) what the conditions were that led to shared food being given, and; (ii) what happened once the shared food had been taken. We argue this information may provide further support to improve the level of food literacy among users.

Limitations

We acknowledge several limiting features associated with the mobile applications used in our study. These limitations may have influenced the choice of potential participants not to be involved in our study. For example, EatChaFood was a prototype and thus had limited features, some technical flaws, which may have caused confusion, deterring participants from using it more actively. This may have also contributed to participant attrition rates. We further acknowledge the small sample sizes of our study. We recognise the findings of Nielsen and Molich (1990), recommending smaller sample sizes for design evaluation are more effective than larger sample sizes. However, we also note that smaller sample sizes could influence the findings. We make a final note that our study examined the use of each application by predominately males, which may have influenced the findings and that the female gender is identified to be significant regarding sustainable food behaviours (Ganglbauer, Fitzpatrick et al., 2013). We do recommend this be considered when reflecting on this article's outcomes.

CONCLUSION

Our study investigated Fridge Pal, LeftoverSwap and EatChaFood and the role each play in reducing domestic food wastage. We examined each app to determine their impact on consumer knowledge of domestic food supply, location and level of food literacy and how food sharing might be facilitated through mobile technology. Our findings showed that each application has a positive impact on raising consumer awareness of their food supply, location and literacy. We also identified several challenges faced by mobile technology that facilitates food sharing amongst a community. Our findings indicated three states under which food may be shared or taken by others: (i) sharing food with known people (for example, family and friends); (ii) sharing food with a known community (for example, housemates and colleagues), and; (iii) sharing food with unknown people (for example, general public). Further, we have developed a scale to identify the level of trust and comfort a person may experience when giving or taking food. Our findings and recommendations can be applied to future design of mobile interventions targeting reduced domestic food waste.

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