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Technicolouring the Fridge: Reducing Food Waste through Uses of Colour-coding and Cameras

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ABSTRACT

Domestic food wastage is a growing problem for the environment and food security. Some causes of domestic food wastes are attributed to a consumer's behaviours during food purchasing, storage and consumption, such as: excessive food purchases and stockpiling in storage. Recent efforts in human-computer interaction research have examined ways of influencing consumer behaviour. The outcomes have led to a number of interventions that assist users with performing everyday tasks. The Internet Fridge is an example of such an intervention. However, new pioneering technologies frequently confront barriers that restrict their future impact in the market place, which has prompted investigations into the effectiveness of behaviour changing interventions used to encourage more sustainable practices. In this paper, we investigate and compare the effectiveness of two interventions that encourage behaviour change: FridgeCam and the Colour Code Project. We use FridgeCam to examine how improving a consumer's food supply knowledge can reduce food stockpiling. We use the Colour Code Project to examine how improving consumer awareness of food location can encourage consumption of forgotten foods. We explore opportunities to integrate these interventions into commercially available technologies, such as the Internet Fridge, to: (i) increase the technology's benefit and value to users, and (ii) promote reduced domestic food wastage. We conclude that interventions improving consumer food supply and location knowledge can promote behaviours that reduce domestic food waste over a longer term. The implications of this research present new opportunities for existing and future technologies to play a key role in reducing domestic food waste.

Categories and Subject Descriptors

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

General Terms

Design, Experimentation, Human Factors.

Keywords

HCI, behaviour change, user behaviour, colour code, FridgePal, food supply, food location, urban informatics, Australia

1. INTRODUCTION

An increasing amount of global food waste is contributing to environmental problems, exhaustion of landfill capacities and has implications that jeopardises global food security. Each year, Schneider [28] argues that 25% of the global edible food supply is discarded, which has a severe impact on maintaining food security. Further, the discarded food produces greenhouse gas emissions that impact the environment and tightens free land development to house landfill estates, instead of housing, industry or other developments [36]. Schneider and Obersteiner [29] suggest two-thirds of domestic food waste can be prevented, arguing that a person's behaviours are the leading drivers of domestic food waste. They suggest several indicators that can influence waste prevention behaviours, including: age, income and time spent at home. Situational conditions can also promote food waste. They include: smell, appetite, desire for food and marketing/advertising of products [21, 28].

Recently, research into human-computer interaction (HCI) sought to encourage behavioural changes, so as to achieve environmental sustainability [10]. This presents an opportunity to examine the role of HCI to either encouraging or discouraging people to change their behaviours and in turn, impact food waste. In addition, a number of recent interventions have aimed to assist users with their everyday tasks. An example of such an intervention is the Internet Fridge (also known as the Smart Fridge). The aim of numerous iterations of the Internet Fridge was to provide Internet and multimedia access to benefit users. This was facilitated through a visual display located on the front of the fridge door. The display provided a number of features that enabled users to: (i) browse the Internet, (ii) manage household appliances remotely, such as air conditioners, and (iii) manage a limited range of their food supply stocks through sensory information to automatically re-order food items and thereby reduce the shopping burden of users [7]. The Internet Fridge is example of a technology that has failed to saturate the market. There were various reasons for the downfall of the Internet Fridge. However, it is widely accepted that the technology's benefits were ambiguous to users, particularly when compared to the benefits of the common household refrigerator [16, 23]. The high costs associated with purchasing the Internet Fridge further deterred users from purchasing the technology and contributed to the perception of an unnecessary commodity. This outcome provides opportunities to investigate interventions that may help overcome the shortcomings of innovations, such as the Internet Fridge and thereby provide increased benefits to users.

A growing number of interventions co-locate themselves with a refrigerator to provide key information regarding a user's food storage activities. In this paper, we examine two such interventions: FridgeCam and the Colour Code project. We

investigate each intervention's ability to assist users with managing their food in domestic settings. Both interventions are situated within the household fridge; each providing an intimate view of the user's interactions with their food over a period of time. This examination differs from previous attempts by addressing issues such as food supply and location knowledge, and visibility. Our study provides insights for future interventions about the features that may improve user knowledge of their food supply and how these features may be used to reduce domestic food wastage.

2. LITERATURE REVIEW

Food wastes are identified by one of four states: (i) original food, (ii) partly consumed/used food, (iii) leftovers (plate waste), (iv) preparation residues (off cuts, fat from meat, egg shells, vegetable and fruit peels) [28, 29]. In many cultures, novel ways to reuse food wastes are often explored, particularly through traditional methods of cooking, livestock feeds and fertilisers [35]. There are a number of causes of food waste. However, causes of domestic food waste predominately occur during food purchasing and once food enters the home [20]. Specifically, in their study of Australian households, Farr-Wharton, Choi and Foth [11] argue a lack of food supply and location knowledge are key factors promoting domestic food waste practices during food purchasing and storage. Specifically, Farr-Wharton, Choi and Foth [11] argue a lack of food supply and location knowledge are key factors promoting domestic food waste practices during food purchasing and storage.

Food overproduction in industrialised nations is met with marketing ploys utilised by the food industry, which are passed on to consumers and designed to impact their purchasing decisions [8, 9, 33]. For example, consumers are encouraged to make bulk purchases, because it is often cheaper than buying the same quantity of the single product [19]. However, it is not always practical for a person to consume the bulk amount within the timeframe of purchase and expiry. A product will often be discarded and replaced with fresher produce when it reaches expiry and the impacts of discarding the product may not be considered. Marketing strategies are a key tool used by the food industry to reduce food waste. However, as a result, the wastes can then occur in domestic settings instead, particularly when consumers bulk purchase products. To assist consumers with managing bulk purchases, systematic food storage practices become crucial [11]. Farr-Wharton, Choi and Foth [11] argue systematic storage can assist consumers to locate food and reduce the impact of domestic food waste practices, such as food stockpiling. This presents opportunities to assist consumers with systematic food storage in domestic settings to reduce food waste.

Further, a combination of peoples' behaviours during food purchasing, storage and consumption, and a variety of different conditions of a person's lifestyle can lead to domestic food wastage practices. Robinson and Smith [26] indicate a person's attitudes, beliefs and subjective norms impact their food practices more than their age and gender [31, 33]. Food price, quality and brand familiarity also bear weight on a person's purchasing decisions, which are reflected in their purchasing practices [6, 37]. However, purchasing practices are also influenced by a person's food supply knowledge [11]. If consumers are informed that products are already available in storage during food purchasing, it may prevent purchases of the same product. This presents opportunities to creatively provide key information to consumer of their available foods supply during food purchasing.

The purpose of household fridges is to store and prolong the life of food through cooling. This core design and functionality has an inherent flaw; the increased storage space promotes food stockpiling practices. Food can often be pushed to the back of shelves where it is no longer visible, which can make it easier for food items to be forgotten. Products are left to expire, only to be found when the fridge is cleaned. Fridges were obviously not designed to encourage this behaviour. However, modern refrigerator design relies on fridge users to know their available food supply and location of food items. These factors can be cumbersome for people with time-poor lifestyles and the low value placed on food further reduces the incentive to do so [cf. 5, 22, 28]. Additionally, occupants in households with two or more members can be unaware of available food and its location, which may have been purchased by others. This presents an opportunity to provide household members with improved awareness of the household food supply and the food's location.

Spangenberg and Lorek [32] argue behaviours can be hard to predict and influence; and Schneider [28] contends that all preventative measures for food waste should take a long term perspective that encompasses both a comprehensive and integrated approach. This suggests that solutions supporting behaviour change would benefit from targeting causes of behaviours instead of addressing the behaviours themselves. This could provide a mechanism for sustained long-term behaviour change. To reduce domestic food waste, such an intervention could target the household fridge, because it is a tool that can impact both food purchasing and storage. Emerging studies in HCI have targeted behaviour change, enabling both the recognition of climate change [38] and methods for pursuing a more environmentally sustainable lifestyle for individuals and society [13]. Blevins [2] and Fogg [14] further position HCI as a key tool to assist a behaviour change process. Previous studies have explored the effectiveness of several motivational techniques such as rewards, emotional motivation, intrinsic motivation, gamification, and goal setting. However, maintaining changed behaviours over time has proven difficult [1]. This is often because individuals experience an initial interest and motivation to change and overtime, the interest dissipates because of lifestyle, time availability and other external factors [18]. Further, Blevins [2] argues HCI research must consider embedding interaction and engagement into technology to stimulate a behaviour change process. This consideration has been approached using four complementary mandates:

- a) Provide people with knowledge and awareness of their consumption practices as to encourage a change towards more sustainable practices [10].
- b) Target the integration of persuasive techniques and methods into technology to assist individuals to adopt sustainable practices with tasks and activities undertaken in their everyday life [17, 34].
- c) An approach that combines the preceding two perspectives in order to instigate a change towards more sustainable consumer practices.
- d) Rather than changing individual behaviours, HCI interventions could also aim to change the environments we live in through an activist approach [4, 15]. The successes and failures of HCI behaviour change studies have varied with many studies gaining initial interest and stimulated behaviour changes, but failed to maintain those behaviours over time. An example is the polar bear experiment [10]. The [virtual] polar bear motivated users to decrease energy consumption. It encouraged

reduced energy consumption through engaging user emotions by changing the bear's state depending on energy consumption. The bear would appear happy and playful when consumption was low and sad when consumption was high. Dillahunt et al. [10] documented the challenges of maintaining behaviour change. Participants' feedback stated that over time the bear would be turned off or ignored. Reasons given indicate it was repetitive and participants felt as though they could not do anything about their energy consumption, which was impacting the bear.

HCI interventions targeting behaviour change face several challenges. Firstly, Brynjarsdottir et al. [3] argues persuasive technology needs to be tailoristic in its approach and that consideration of a person's environment be examined, because behaviours are enacted within certain contexts. Secondly, managing the complexities of maintaining long-term behaviour change is challenging [1]. This provides opportunities to investigate the effectiveness of using interventions to influence the causes of behaviours, thereby encouraging a behaviour change response.

Following this line of enquiry, our study explores two pilot studies, each involving a HCI intervention and exploring how each may be used to increase the benefits to users and overcome the shortcomings of previously failed interventions, such as the Internet Fridge. Firstly, we investigate FridgeCam and its influence in raising a user's awareness of their food supply. Secondly, we examine the Colour Code Project and how food location can be improved to reduce food waste. These interventions are guided by the research question: *How can situated interventions targeting the domestic fridge provide users with improved food supply and location awareness to encourage changes towards sustainable food practices?* We chose not to investigate the third factor identified by Farr-Wharton, Choi and Foth [11] in this study, because of the complex nature associated with understanding food and challenges of improving a user's food literacy. However, we explore this factor in our future research.

3. RESEARCH DESIGN

FridgeCam was originally used as a technology probe to reveal more about everyday domestic food practices [15]. In our study, we used FridgeCam (Study 1) to improve an individual's knowledge of their domestic food supply. We used the Colour Code Project (Study 2) to improve an individual's knowledge of the location of food. For each study, we recruited participants from our social and professional networks. While recruits had a familiarity with the researchers, we ensured study candidates underwent a screening process that noted household type, income and number of household residents before being selected to participate. We excluded candidates if the number of residents within their household was less than two. We did this to

specifically examine couple, shared and family households. Further, smaller sample sizes comprising between 3 and 5 participating design evaluators are identified to be more effective than larger groups in providing useful design evaluations [24]. Therefore, we elected to limit the sample sizes based on Nielsen and Molich [24] recommended sample sizes.

Each intervention was implemented over four consecutive weeks accompanied by observations and brief interviews with a designated household representative, selected by the household. We encouraged participants to provide comments and feedback of their intervention usage during the brief interviews. We conducted a final interview on conclusion of each study and asked each participant open-ended questions regarding their intervention usage. Thematic analysis was applied to evaluate the interview data. We applied visual ethnographic techniques [25, 30] to better understand the movement of food observed in the FridgeCam photographs. We also encouraged participants to take photographs when they felt a photo might show a significant occurrence, determined by them. In both cases, interviews were thought to be the best mechanism to provide a rich understanding of the impact of each study to raise food supply or location awareness. We later cross-examined the interview responses with associated photographs to corroborate what was said.

3.1 The Interventions

3.1.1 Study 1: FridgeCam

FridgeCam is an application installed on an Android device and secured to the inside of a fridge door to take several photos of a fridge interior each time the door is opened. Photos were made available to household occupants at a specified web address (mobile accessible). On visiting the address, occupants were provided with the 15 most recent photos uploaded by FridgeCam. In Study 1, the device was installed the first week of commencement. Study 1's photographs were used to ascertain the management of refrigerated food and the time spent searching for items. The final interviews with FridgeCam participants addressed four areas: (i) the influence photos had on shopping practices, (ii) the impact to participants' food supply awareness, (iii) the participant's perceived impact on food waste, and (iv) the different locations photos were utilised and the barriers to using them. We recruited 7 households in total (equalling 10 individuals) to use FridgeCam Study 1 (see Table 1). 3 of the households (a total of 6 individuals) discontinued the study after the first week of implementation for reasons, including: technology issues and conflicts of interest. However, 4 remained until the study completed. Three of the four households involved in the FridgeCam study also participated in the Colour Code Project two months prior to the FridgeCam study commencing. However, we ensured all materials from the Colour Code Project were no longer in use by those who commenced using FridgeCam to ensure equal conditions for all participants.

Table 2. A depiction of each household involved in Study 2: The Colour Code Project

#	Household Type	Living Arrangements	Number of Occupants in Household	Occupations of Residents in household	Household Income	Shopping Practices (per week)
F1	Unit	Shared household	Two	Full-time workers (9pm-5pm)	\$80,000 per annum	One large shop
F2	House	Family household	Three (including a child)	Full-time worker (9pm-5pm) & stay-at-home parent	\$70,000 per annum	One large shop and several top-up shops
F3	House	Couple household	Two	Full-time workers (9pm-5pm)	\$90,000 per annum	Several small top-up shops
F4	Unit	Shared household	Three (a couple and a house mate)	PhD student & 2 full-time workers (9pm-5pm)	\$110,000 per annum	Several small top-up shops

Table 2. A depiction of each household involved in Study 2: The Colour Code Project

#	Household Type	Living Arrangements	Number of Occupants in Household	Occupations of Residents in household	Household Income	Shopping Practices (per week)
C1	House	Family household	Three (including a child)	Full-time worker & stay-at-home parent	\$70,000 per annum	One large shop and several top-up shops
C2	House	Family household	Four (including two children)	Full-time workers	\$150,000 per annum	One large shop
C3	Apartment	Couple household	Two	PhD student & full-time worker	\$80,000 per annum	One large shop
C4	House	Couple household	Two	PhD student & full-time worker	\$50,000 per annum	Several top-up shops
C5	Apartment	Couple household	Two	Full-time workers	\$120,000 per annum	One large shop
C6	Unit	Couple household	Two	PhD student & full-time student	\$60,000 per annum	Several small top-up shops
C7	Unit	Shared household	Three (a couple and a house mate)	PhD student & 2 full-time workers	\$110,000 per annum	Several small top-up shops

3.1.2 Study 2: The Colour Code Project

The Colour Code Project implemented a paper-based colour scheme positioned within the household fridge. Each colour represents a food group encouraging only food items of a particular group (such as produce) to be placed on the corresponding colour (e.g. green). We encouraged households to continue customising the colour scheme once it had been installed. Figure 1 shows a before and after photo of C1's fridge interior with and without their customised colour scheme implemented. A colour scheme 'map' was provided on the front of the fridge door for quick reference, which was updated if colour changes occurred and can be viewed in Figure 2. A total of 7 households (equalling 18 individuals) participated in Study 2 (see Table 2). We used the initial two weeks of commencement to observe the quantity of domestic expired waste of each household by taking note of the number of expired products and what they were. Additionally, we performed an evaluation of the most appropriate placing of colours during this period. We encouraged participants detail discarded expired products into a provided journal, which contained: (i) the product name, (ii) quantity, and (iii) a photo. We requested participants to store waste in a bin we provided to assist our observations. We disposed of the bins contents on a weekly basis. The colour code scheme was implemented at the beginning of the third week and remained until the conclusion of the study.



Figure 1. An illustration of C1's fridge interior before and after the colour scheme was applied.

We used Study 2 to examine how the scheme was used and its effectiveness in both raising awareness of food location and its influence in reducing expired food waste. During weekly visits to

participant's households, we asked a nominated household representative a number of questions that concentrated on: (i) the participants' perceived impact on food waste, (ii) participants' levels of difficulty in locating food items, (iii) the perceived impact on shopping patterns, and (iv) the challenges participant's experienced. During the visits, we captured photos of the household fridge and bin provided to observe: (i) the changes in food placement within the fridge, and (ii) what food was discarded because it reached expiration. Further, the photos presented an opportunity to understand how participants engaged and interacted with the colour code scheme; with a particular focus on the challenges participants faced both personally and socially (with other household members). We asked a series of open-ended questions at the conclusion of Study 2, which focused on five themes: (i) participants' experiences, (ii) the potential uses of the colour code scheme over a longer time, (iii) the time participants took locating desired food items, (iv) ideation of opportunities for technology integration and finally, (v) impact on participant's everyday domestic lives.

4. Findings

The interviews and photographs from each study provided insight into four characterising themes, which extend upon outcomes of a previous study [12]. The key themes include: (i) the impact on user knowledge, (ii) the social implications, and (iii) design enhancements. These themes provide a deeper insight into how technologies can be used to better promote behaviour change and reduce domestic food waste. On concluding the findings, we also present an observation regarding those participants who were involved in using both FridgeCam and the colour code scheme.

4.1 The Influence On User Awareness

Each intervention's impact on a user's food supply or location awareness was the major theme emerging from the interview analysis from Study 1 and 2. Firstly, F1 and F2 representatives from Study 1 stated that visual images provided assistance in "helping [them] remember" what items they had in the fridge. F3 suggested this was particularly useful with items such as milk, cheese, meat and leftovers, which were suggested as the most frequently used items. However, all Study 1 participants raised a limitation with FridgeCam photos. In all cases, the inadequacy of visibility regarding all available products was highlighted as a limitation for the participants. F2 further stated "I could see that I had milk and butter, but I couldn't see how much I had left inside each or if they had expired", highlighting another limitation regarding the visibility of items. F3 stated "if I had the ability to

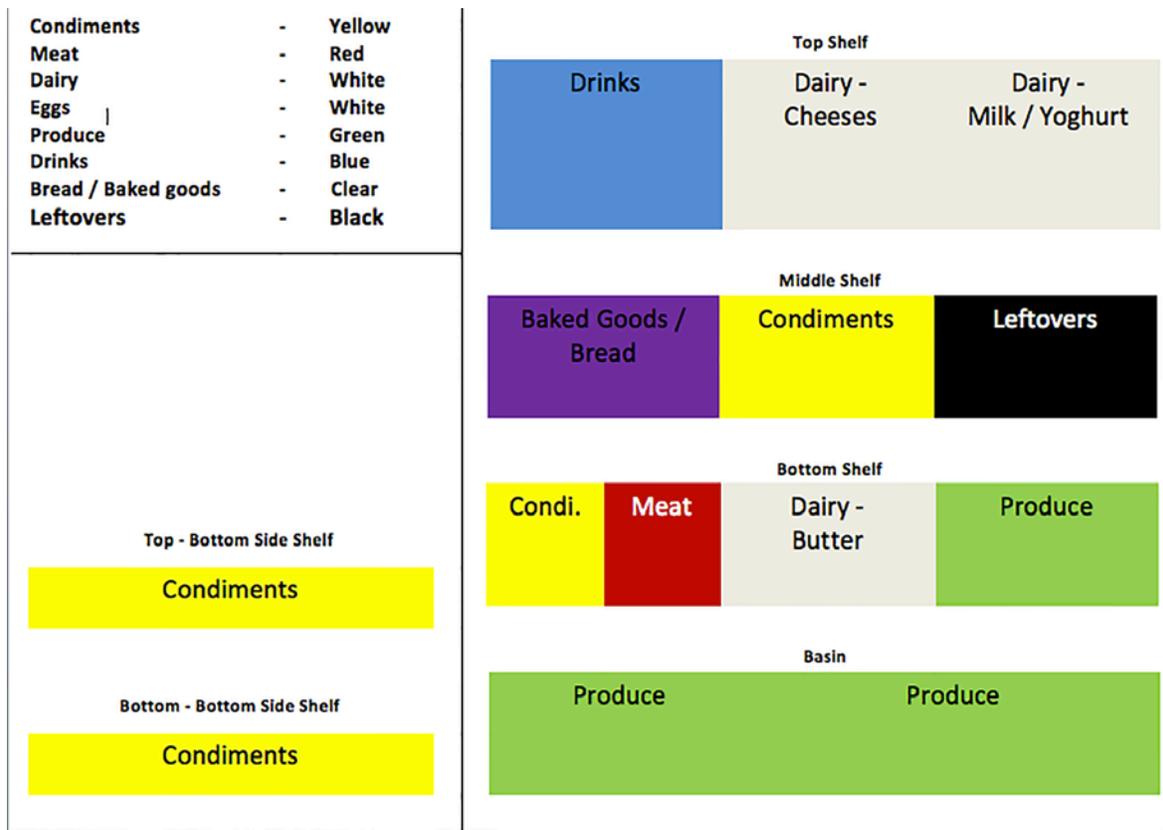


Figure 2. An illustration of C1's colour scheme 'map'.

adjust and move FridgeCam with ease, I might have gotten a better angle that showed me more items”.

Figure 3 shows examples of each household fridge regarding what can and cannot be seen with the FridgeCam and where the device is located. F3 also stated that unless there were multiple cameras, each with differing angles of view; it was unlikely that FridgeCam was able to provide them with information about all available food in their fridge. F3 further stated, “while I don’t think FridgeCam can provide this, if it was able to, I would quite happily change some of my practices” (such as opening the fridge to see what products are available before going to the supermarket to purchase groceries). Additionally, F2 stated that on several occasions “I looked at the FridgeCam photos and noticed I already had some products that I intended to buy, so I didn’t end up buying them and I would have without the photos”. F2 further stated that they perceived a reduction in their expired household food waste, which they believed FridgeCam photos influenced. An observation made by the researchers of F2’s household waste corroborated the statement given by F2. A similar outcome was identified for the F1 and F3 households. However, F4 viewed the FridgeCam photos sparingly and no change in expired household food waste was observed.

Similarly, Study 2 showed an influence on food location awareness. All participants in Study 2 stated that they experienced a perceived increase in knowing where to find food items in their fridge. Several comments in the interviews suggested that the colour scheme map placed on the front of the fridge assisted with knowing where to locate items before participants opened the fridge door. However, on further inquiry, all Study 2 households stated that they stopped using the colour scheme maps after the

first few days because they knew [roughly] the general location of items. The findings indicate that the visual colour scheme supported knowledge growth about item location. However, C2, C5 and C6 stated their preference for actual pictures of food to be printed on the coloured plastic pieces to show what items can be placed on a colour, which would make the map redundant. In future research, we suggest that pictures of meat, dairy and produce, etc. be placed on the appropriate colours for better recognisability.

Further, our Study 2 findings indicated that in comparison, food waste after each week was less for those participants using the colour code scheme, rather than those who used the FridgeCam photos. One explanation for this finding is that increasing awareness of item location is more effective in decreasing waste compared with increasing knowledge about the available food supply. However, because these are pilot studies, more testing and evaluation is required. Our findings also indicated that households could maximise their food waste reducing through the use of a system of food storage, such as the colour code scheme. Study 2’s C1 and C4 stated that the colour scheme had a significant influence on reducing expired waste in their homes. They suggested this was because of the de-cluttering process and the implementation of a system of storage undertaken when implementing the colour scheme within the fridge. Their photographs taken of their fridge interior support this hypothesis. Therefore, this positions the implementation of a system of food storage in a household as an important mechanism to assist with reducing expired household food waste. On the other hand, an observation of the photos taken of the household fridge in C3 and C7 throughout the experiment indicated that approximately 30-40 essential food items were commonly stored. For this reason, both



Figure 3. A Demonstration of example FridgeCam photos taken of each participating household's fridges.

representatives suggested that a system of storage, such as the colour code scheme, was not needed. The fridge interior of C3 can be viewed in Figure 4.

4.2 The Social Implications

Privacy and security concerns continually surfaced in FridgeCam Interviews and concentrated on a theme regarding social implications. The concern was not centred on what others may think of the household fridge's appearance, but what the FridgeCam photos might reveal about household members to a wider audience. F1 and F2 representatives expressed their concern that the wide-angle lens of FridgeCam can capture a person while they are retrieving items. That photo is then uploaded onto the web at a 'read-only' address, preventing the deletion of any photos (a limitation of FridgeCam). Participants felt 'out of control' because of this and were concerned photos might reveal private and potentially embarrassing images. F1 and F2 representatives both concluded that if FridgeCam provided the ability to have "control" over the photos that were uploaded; the scope of the image would have been reduced.

Additionally, a theme regarding social impacts surfaced during the Colour Code Project interviews, noting that on occasion, household members (generally family members) would express anger and frustration towards fellow household members. The

interviews showed that the majority of households experienced [minor] conflict as a result of members placing food items in "wrong" storage locations. If a household member recognises that another member has clearly placed an item in a wrong location (purposefully or not), frustration and anger towards the other member was experienced. Household representatives suggested the item would then usually be relocated to the correct colour. This became particularly evident with responses from C1, C2, C4 and C6 representatives, each stating the household liked the control and ordered nature the colour scheme provided. C1 and C6 representatives further stated their willingness to continue a similar order and categorisation of food types in their fridge once the study had concluded. The majority of households expressed a like for the colour code scheme because it enabled a level of fridge storage control over other household members and an ability to ensure particular items are always found in a known location.

Both studies contextualises the challenges inherent to implementing HCI interventions within domestic settings. With each intervention, a social dilemma was experienced. The photos FridgeCam took concerned participants. Not having control over exactly what content was included in FridgeCam photos and then not being able to delete or edit photos taken gave participants a fear of embarrassment, being unsure if photos could be publicly



Figure 4. A display of the fridge interior of C3 before and after the colour code scheme was implemented.

viewed. The Colour Code Project experienced another kind of social dilemma with participants who chose to opt-out of using the colour scheme being publically shamed inside the household by other members. This too may have been met with embarrassment for the person who chose to opt-out. However, other household members experienced frustration and anger because there was someone in the household who was actively choosing not to comply with a 'new' household 'culture' provided by the colour scheme. Moreover, a further theme surfaced during FridgeCam interviews regarding social impacts. All households stated their interest in showing friends and family the FridgeCam photos, as well as, the FridgeCam device itself. On further inquiry, participants were asked if they felt concern about being judged with others having the ability to view the participants' fridge (because privacy is an issue commonly spoken about in the literature). Again, privacy arose as an issue. However, participants felt that sharing information between friends was not as intrusive as they first thought on reflection and suggested that it could have further uses. However, participants were unable to specify how this might take place. These social phenomena provide a foundation to be explored in later studies.

4.3 Design Enhancements

FridgeCam participant interviews provided a final theme regarding design enhancements. Specially, the imbedding of gamification elements into FridgeCam was noted, such as task and goal setting or an awards scheme. In particular, the F1 representative stated that they personally would benefit greatly from an awards scheme style of motivation. They further suggested that having goals or tasks that encouraged them to interact more with the FridgeCam photos would have increased their desire to use FridgeCam and greatly improve its usefulness. The F2 representative further stated that reminders notifying the participant to use FridgeCam at particular moments would have helped in enabling a continued pattern of usage. The F2 representative suggested that in their household, if reminders were given for two weeks, a maintained pattern of usage would occur after that period of time. However, it would only be successful if a perceived usefulness of the technology was realised during and after that time as well.

Similarly, Colour Code Project participant interviews highlighted a theme regarding design enhancements, with participants pondering how elements of the project might be integrated with technology. Many liked the idea of having a greater control about where items were stored and the ability to find those products with ease at a later date. However, they questioned the usefulness of having the Colour Code Project available through a mobile device or on the computer. Their comments suggested that this related more to whether the participants would need that information away from their fridges and questioned whether such a technology solution should be made available through the fridge itself. Nevertheless, several participants expressed their interest for their fridge interior to be made available to them away from their fridges. This presents an opportunity to integrate other functionalities that might be required in the food purchasing phase and not just the storage phase.

Participants from both studies showed an interest to extend the functionality of each intervention, which they thought would increase its usefulness and usability. The suggestions given for each intervention may assist the shortcomings of each and may overcome the barriers to longer-term use of similar interventions in domestic settings. Further investigation might provide insight into the role that technology and the imbedding of gamification

elements into interventions can have in encouraging behaviour change and subsequently, decreasing domestic food waste.

A final observation made several months after the Colour Code Project had concluded showed several participating households have either kept to the original colour scheme (with the coloured plastic sheets remaining in the fridge) or have instigated a similar re-customised arrangement of the colour code scheme. This was evident in households C1, C3 and C4, of which are still using a system of storage in the same capacity as what the Colour Code Project instigated in their households. Each of these households suggests a maintained behaviour change and a decreased waste production, continued. This shows the capacity for the Colour Code Project to instigate a maintained change of behaviour. Of those households who also participated in the FridgeCam study, the Colour Code Project was suggested to have done more to change behaviours that resulted in a greater reduction of expired household food waste than what the FridgeCam provided.

5. DISCUSSION

5.1 Raising Food Supply and Location Awareness

With several households involved in both studies, observations can be made for comparisons between each. While we did limit the sample sizes in accordance with the practices outlined by Nielsen and Molich [24], our findings showed both studies achieved their intended purpose. That is, FridgeCam provided an improvement to food supply knowledge of users and the Colour Code Project improved food location awareness. However, the comparison of themes identified in our findings suggests a larger percentage of households experienced a reduction in food wastage during their time using the colour code scheme, rather than participant's experiences using FridgeCam photos. Consequently, the findings suggest that improving food location knowledge may have a greater influence on reducing domestic food waste, than improving supply knowledge. We suggest that food location knowledge provides people with the ability to easily recall where items are most likely located, because of the colour code scheme and the person can consume an item without having to search for it. This outcome may result because of a loss of motivation to locate an item if it cannot be quickly found. Instead, another item might be chosen for consumption as a replacement, because it is easier to locate or more readily available without the need for search. On the other hand, increasing a person's knowledge of their food supply, does not necessarily translate into knowing where a food item is located. Therefore, we surmise the ability for a person to approach food storage and know where to locate foods from a particular food type, influences food waste more than knowing what food is available in the person's food inventory. However, our findings indicated that a multi-facet approach to domestic food waste reduction is needed. We surmise that a combination of improving consumer food supply and location awareness through a number of means will provide the best outcome and assist with influences practices that currently lead to food waste.

In future research we propose that consideration be given to the contextual use of each application. Firstly, the colour code scheme was present during food storage, thereby reminding participant's where to correctly store or retrieve items. However, participants have to remember to use FridgeCam photos for the visual information they provide to be useful. Therefore, future research needs to separate the impact of one intervention from the other, so that the impact of each intervention is clearer. For example, our

findings indicated that FridgeCam photos provided the opportunity for participants to view the products already in storage and thereby prevented unnecessary purchases that would lead to stockpiling practices. Farr-Wharton, Choi and Foth [11] identify interventions targeting improved food supply awareness during food purchasing as a key factor to prevent practices that lead to food waste. However, participants had to remember to view the photos prior to or during their shopping experience. If the participant did not do this, they may have continued their practices, which existed before the study.

The social aspects of life, while possibly not considered directly related to how we use technology, cannot be ignored when designing technology. Particularly with HCI and interaction design, the social dynamic is a critical component. The findings from our study reflected this. Specifically, there was an apparent display of encouragement from other participants in a household to ensure all members of the household adhered to the colour code scheme and specifically, the location items were stored in the fridge. This process likely facilitated a general shift in behaviour towards more sustainable practices. Further, we argue the process led to intrinsic motivation for users to utilise a system of storage within their household. However, we concede that the social dynamics that may have been the motivation, which encouraged participants to use the colour code scheme and not the motivation to reduce food wastage. We suggest this outcome because participants understood that if they did not comply with the scheme, it would negatively impact other household members. Therefore, the motivation for reducing food waste may not have been present and instead, a positive secondary outcome – a comparative finding that was demonstrated by Ross & Tomlinson [27]. We make the recommendation that food supply and location knowledge are key factors that can lead to a reduction in domestic food wastage. We suggest that food supply knowledge may better inform users to assist them with their purchasing decisions during shopping experiences. We further surmise that food location knowledge is best provided to a user when they are storing or retrieving an item from storage. We make the recommendation that a technology, such as the Internet Fridge, may benefit from including storage information on a digital display co-located with storage appliances.

5.2 Implications for Behaviour Change Maintenance

Our findings indicated that participants had initial expectations about the use of each intervention, which in the majority of cases did not reflect the actual use observed during the studies. Participant's experiences using the interventions indicated that in some cases, the intervention failed to meet the user's expectations. We argue this outcome caused our participants to lose their perceived value in using the intervention and subsequently, the intervention was either no longer used or was utilised in a limited fashion. The findings indicated that at this point, our participants' behaviours returned to their original practice and unsustainable practices continued. Our findings showed that this was particularly the case with the FridgeCam intervention. This also supports Bishop [1] argument that maintaining a behaviour change overtime is challenging. Conversely, participants using the colour code scheme did not initially perceive the colour to be useful. However, our findings indicated that through social pressures or general curiosity, participants found the colour code scheme to be beneficial and changed their practices to place items in their correct locations. We further saw participants stating their

preference to continue using the colour code scheme, with some changes, after the study concluded.

Our findings also showed further comments surfaced regarding the use of both interventions. However, the focus was on each intervention's customisability. Specifically, the findings showed participants wanted better ways to customise the interventions, with some participants suggesting it might improve how the intervention they were using would be utilised in the future. This supports the recommendation by Brynjarsdottir et al. (2012) for HCI design to be tailoristic and incorporate the individual needs of a person. Further, when observing this trend through a critiquing lens, customisation appears to enhance the functions and usability of an intervention through personalising it. The impact of customisation as an enabler of technology adoption, particularly with those seeking to instigate behaviour change needs further exploration. Suggestions provided during the FridgeCam study raised the integration of gamification elements into technology. HCI design incorporating gamification elements may improve the use of interventions targeting raised awareness of food supply and location knowledge. The integration of gamification into technology to serve a targeted purpose has been adamantly explored in the literature. Recently, a number of studies have explored the use of gamification in encouraging changes in energy usage, suggesting that gamification may assist a behaviour change process. Conversely, there are also very critical views of it as well. If gamification elements were integrated into one of the interventions, such as the suggestion provided by our participants to incorporate a rewards feature, the question remains, "would users continue using the intervention after the rewards are gone?"

5.3 Opportunity to Overcome Limitations of Previously Failed Technologies

It would be difficult to state particular design elements that should be integrated into technologies seeking to impact behaviour or reduce expired household food wastage. This is because the sample sizes of each study are limited and therefore, generalizability is limited. What our findings suggest is that design features that worked in one situation, did not necessarily in the other. In light of this, we argue a key assertion; a holistic approach that considers and incorporates a user's location, technologies they use, household type, household fridge size and number of housemates. A comparison between the findings from both studies indicates that if an intervention is to be implemented to encourage behaviour change; the intervention may be more successful if it is located in the same place as the change is to take place. For example, the colour code scheme was implemented within the fridge to assist users with their food location awareness at the location where food storage occurs. Therefore, we argue interventions targeting behaviour change would benefit from being co-located with the instrument where behaviours are enacted.

Further, our FridgeCam findings showed that participants often experienced a situation where they wanted key information about a product in their fridge, such as how much butter is still available for consumption. However, we saw that in our case, the technology failed to provide the necessary knowledge, because of the inherent limitations that were communicated to participants before undertaking the study, such as the placement of FridgeCam within the fridge can be prone to reduced visibility displayed in photos. To overcome some of this limitation, our findings showed participants raising suggestions such gamification or alert features, which could be integrated into FridgeCam. These

suggestions may provide added benefit to users encouraging the use of the intervention and thereby, having an impact in raising the awareness of a user's food supply. Further, integrating the intervention, such as FridgeCam, into an already existing social paradigm, such as a shared household, may also provide higher levels of adoption because of social pressures. While we saw this occur with the Colour Code Project, we recommend further investigation of this occurrence to gauge its effectiveness.

Our findings also identified that the Colour Code Project provided a new storage pattern, which was moderated socially by other household members. For example, our findings saw household members frowning upon others if they did not follow the organised storage pattern. This points to a social paradigm previously explored by [12] and provides support for interventions to consider social contexts in the design process, particularly regarding support for sustainable practices. We further postulate that, from our findings, the type of household and the lifestyles of a user plays a significant role in whether an intervention can and will be used, as well as where it will be used. We also suggest the size of the household fridge should be a consideration. This is because the size of storage can limit the quantity of products that can be purchased, or at least stored in refrigeration to prolong shelf life. These are design considerations that we recommend be considered when designing interventions that target improved user awareness of food supply and location to reduce domestic food wastage. We argue these design considerations have potential to overcome many of the limitations that have been experienced with previously failed technologies, such as the Internet Fridge. We reiterate the limitations of our own study and express the need for future research in this area to include larger sample sizes to examine the generalizability of the results. However, we suggest that our study has provided a foundation, from which future research can use to produce more effective interventions targeting support for sustainable food practices.

6. CONCLUSION

Our study investigated the use of two interventions, which target the reduction of domestic food waste by providing consumers with raised food supply and location awareness. We found that FridgeCam and the Colour Code Project can be used to reduce domestic food waste and also have the potential to overcome the limitations of previously failed technologies, such as the Internet Fridge. In our discussion of our findings, we made several recommendations to further extend upon the outcomes of this study, including implementing the interventions with larger sample sizes to better understand the generalizability of outcomes. We identify a number of recommendations for HCI practitioners to consider when designing interventions targeting improved food supply and location knowledge. We suggest the findings of this paper provide early foundations to explore how improved knowledge of food supply and location can be used to encourage more sustainable food practices and maintain behaviour change over time. Our research design can be applied to future interventions targeting similar outcomes.

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