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Designing for action: An evaluation of Social Recipes in reducing food waste

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ABSTRACT

Approximately, one-third to half of all food produced globally is wasted. In developed countries, roughly up to half of this food waste comes from consumers. In response to this, the UN has set goals to raise consumer awareness and reduce food waste by 50% before 2030. Our objective is to evaluate how emerging technologies could improve awareness in households. Inspired by future sensing possibilities, we envision a community-based social system that captures in-home food availability and waste patterns and uses this information to support awareness and sustainability. In this work, we describe an evaluation of a component that could be part of such a system. This component or concept, called *Social Recipes*, aims at encouraging food sharing by suggesting groups of related consumers recipes that are based on ingredients from different individuals or households. To evaluate *Social Recipes*, we conducted 3 user studies to see how it could raise awareness and reduce food waste and to suggest implications for its design. In the first two studies, we evaluated expected impacts of the concept. The third study was a home deployment, where *Social Recipes* were sent using technological probes for a more realistic experience. Here, we also evaluated it against the more common method of influence strategy in sustainability research that is restricted to feedback (i.e., eco-feedback). Our main findings showed that *Social Recipes* has raised awareness of in-home food availability and triggered food-related conversations among participants resulting in knowledge gain. However, *Social Recipes* alone was not perceived as effective in directly reducing food waste. And therefore, for the design of a community-based social system, we suggest another component to be added to the system that provides eco-feedback. This component was perceived as more effective in reducing food waste with impacts on awareness of waste generation and social surveillance. Overall, the aim of this work is to contribute to an understanding of how *Social Recipes* could impact consumers and how to design a community-based social (recipe) system that can be integrated in consumers daily activities for effective but pleasurable food waste prevention.

1. Introduction

The impact of food waste on the environment and food security has become a global concern. Previous estimates show that one-third to one-half of the world's food, approximately 1.3 billion tonnes, becomes waste (Gustavsson et al., 2011). This goes hand in hand with the overconsumption of natural resources: food waste produces 10% of rich countries' greenhouse gas emissions and is responsible for the use of 550 billion cubic meters of water globally (Food waste facts, 2015). Despite these numbers, twice as much food is produced than required by nutritional needs per living person (Fox Ceng, 2013). In fact, with less than a quarter of the food we waste, the world's nearly one billion hungry people could have been lifted out of undernourishment (Fusions, 2015). If consumers continue current consumption patterns, food production would need to increase by 70% to feed all 9 billion people in 2050. These global facts show that sustainability research, specifically in targeting food waste, should receive critical attention.

To prevent food waste, changes at various levels are required, such as in policy, technological environment, and education etc. However, as final demand of food is located at the consumer level, consumers could be considered the most important drivers of overall waste generation, resource consumption and impacts on the environment (IPCC, 2007). Research has shown that in high and medium-income countries over 40% of the total amount of food waste occurs at retail and consumer levels (Gustavsson et al., 2011; Beretta et al., 2013). Consumers generate food waste (222 million tons) that is almost as high as the total net food production (230 million tons) in Sub-Saharan Africa (Gustavsson et al., 2011). For example, studies in the United States showed that 19% of the total amount of consumers food supply gets wasted (Buzby and Hyman, 2012). In the United Kingdom, the avoidable food losses correspond to 21.3% of the purchases (Quested and Johnson, 2009). These amounts of food waste were further found

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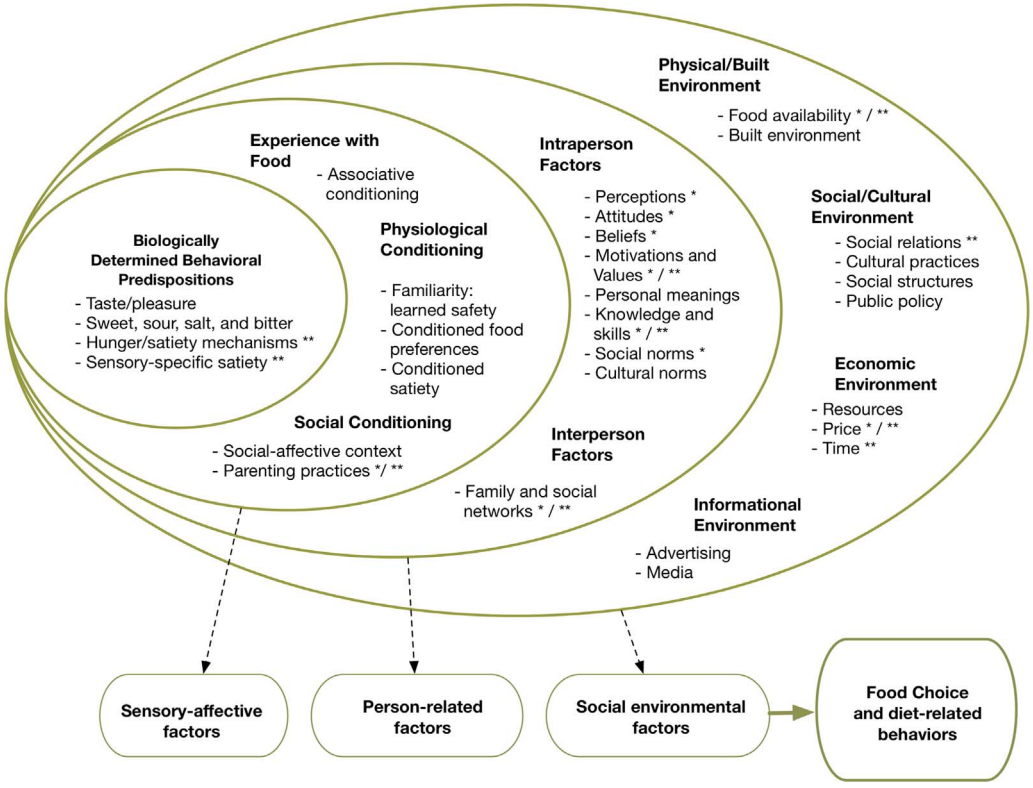

Fig. 1. Factors influencing food choices and dietary behaviors. Source: Contento (2000). Note: factors with "*" indicate determinants of sustainable behaviors and factors with "**" indicate determinants of food waste behaviors as discussed in literature.

to be dependent on the size and composition of households. Large households with unrelated adults and large households with related adults with children were found to waste the most, while single-occupancy households the least in terms of weight and costs (Wrap, 2008). Thence, if larger households are targeted, *more* food could be saved from being wasted. Moreover, large households have easier access to share or coordinate with others, which opens up design opportunities for reducing consumer food waste more effectively from a collective point of view. Overall, reducing food waste at the consumer level in Europe only is expected to impact Gross Domestic Product (GDP) increase, land use within Europe, and food security in Sub-Saharan Africa (Rutten, 2013).

Despite these findings, sustainability research has mainly put effort into areas such as sustainable energy consumption and water or resource consumption (Brynjarsdttir et al., 2012). Although ecological sustainability is an increasing concern in sustainability research, to date, food waste has received little attention. Fortunately, the United Nations have set goals to reduce food waste by 50% and reduce food chain resource inputs by 50% before 2030 (Fusions, 2015). The United Nations Environmental Program (UNEP) is aiming at raising awareness on the value and environmental impacts of food people eat by redirecting consumption patterns to less resource-intensive foods or behaviors (Moomaw et al., 2012). This has raised our interest in exploring how emergent technologies could improve awareness, resource efficiency and prevent food waste in consumers every day lives.

The central aim of this paper is to work towards the design of a domestic community-based social system for sustainable food practices. Specifically, we aim at exploring the potential of a concept called *Social Recipes* that could be integrated as a component in such a system, evaluate its impact on users and suggest implications on its design. In this concept, ingredients available from different households are combined into one or more recipes, which are suggested to a group of users. The prospective is to collectively prevent food waste by encouraging collaboration and food sharing. Apart from this altruistic aim, the concept is expected to incentivize people to share, cook, learn and enjoy food together. The concept is evaluated in 3 steps. In the first study, we identified the amounts and types of food waste as well as the reasons of wastage to see how and which food items to target. In the first and the second study, we explored the experiences expected from such a concept by presenting it verbally to study participants. In the third study, we evaluated the concept in a home deployment using technological probes (Hutchinson et al., 2003) and a Wizard of Oz approach to explore actual experiences (Dow et al., 2005). The Wizard of Oz approach is a widely used method in human-computer interaction research to explore user interfaces for pervasive, ubiquitous, or mixed-reality systems that combine sensing and intelligent control logic. With this approach, the logic behind the user interface interactions are enacted by a person rather than a system. In addition to the concept of *Social Recipes*, we prototyped the more common method of persuasion that is restricted to feedback (i.e., information of what one has wasted) for comparison purposes. With these user studies early in the design process, we can specify the behavior of the overall envisioned system and increase the likeliness of acceptance in daily lives. For our studies, we recruited students and young professionals, as they often live in large and shared households. The United Nations estimated the global population of young people has hit 1.8 billion, hence there are more young people in the world than ever before. We chose a specific target group following Wrap's claims that interventions should be developed with the specific needs of different groups in mind (Wrap, 2014); as they might require different approaches due to the complexity of waste generation.

We structured this paper as follows. In Section 2, we first discuss related work on how consumers make decisions around food and the factors influencing sustainable choices and food waste-related behaviors. This is followed with current solutions that aim at reducing domestic food waste. Based on these reviews, we conclude the section with opportunities for designing food waste-related technology. In Section 3, we present the overall system; a community-based social

system that tracks users domestic food availability and waste potential, and redirects behavior through social influence strategies and awareness towards more sustainable food-related practices. As part of this system, we present the concept of *Social Recipes* in more detail and our design rationale. In Sections, 4, 5 and 6, we discuss our process of evaluation. In Section 7, we provide a discussion of our findings, limitations, suggestions for future research, and other implications beyond this work. We conclude with Section 8.

2. Related work

2.1. Decision-making around food

Food-related decision-making can be a complex process and influenced by many factors. According to Contento (2010), the factors that influence our food choices can be divided into 4 main categories (see Fig. 1); biological predispositions, sensory-affective factors, person-related determinants, and social and environmental determinants. Biological predispositions includes taste and hunger which depends on our biological structure. Sensory-affective factors includes associative, physiological, and social conditioning (e.g., familiarity and parenting practices) that we have experienced throughout our lives. Person-related determinants are beliefs, norms, attitudes and skills that we have developed throughout our lives. These can be intra-personal as well as inter-personal (e.g., family and social networks). Finally, social and environmental determinants include the build, cultural, economic and informational environment we currently live in (e.g., food availability, public policy, time, price and media). These categories show how complex our decision-making around food could be. Understanding how these factors influence sustainable choices or food waste could give us better insights in how to approach wasteful behaviors and design effective interventions. Next, we will discuss factors influencing sustainable food choices and waste-related behaviors in particular. These factors are explained within Contento's framework.

2.1.1. Factors influencing sustainable choices

We commonly agree that adopting a sustainable lifestyle, i.e., where we successfully attempt to reduce the use of natural and personal resources, reduces impacts on our environment. However, this requires active efforts in altering methods of transportation, selection of ecologically responsible food, and waste prevention etc. Despite active engagements, good intentions are not always reflected in everyday practices (Vermeir and Verbeke, 2008). A number of factors influence the likelihood that we act sustainably. For example, gender is found to be a biological determinant for adopting sustainable practices. Females score higher in agreeableness and openness, which are traits associated with sustainable behaviors (Luchs and Mooradian, 2011). Social conditioning through parenting practices and our family and social networks are also important determinants. For example, we are more likely to adopt sustainable behaviors if our families share positive attitudes to sustainability (Ganglbauer et al., 2013), which further depends on our families social class (Laidley, 2011). Other important factors are intrapersonal such as perceived food availability, perceived consumer effectiveness (Vermeir and Verbeke, 2008), knowledge, our education level together with general beliefs, and being concerned about the environment (Laidley, 2011; Olofsson and Ohman, 2006; Milfont et al., 2006). Furthermore, social environmental factors that affects our decision-making are food availability and the price of food (Ganglbauer et al., 2013).

2.1.2. Factors influencing food waste behavior

Starting from our biological inclination, every time we smell food, dopamine is released to increase appetite (Abizaid et al., 2006): when we smell food while passing by food stands, we might experience difficulty to resist food. Moreover, when we observe someone who is eating a type of food we like, mirror neurons fire as if we perform the action ourselves (Cohen, 2008). This might result in a higher probability of actually performing the action ourselves. Another mechanism that could lead to waste is satiety. Hunger could lead to overbuying and leftovers that might end up in the bin (i.e., caused by inaccurate perceptions of how much you think you can eat vs. to what you can eat). Knowledge of these factors could lower food waste amounts. For example, you could do groceries when you do not feel hungry. Other types of knowledge and skill (i.e., both intra-personal factors) that has an impact on how much we waste are understanding sell-by dates, knowing when to use the fridge to store ingredients, planning meals and making lists (Wrap, 2008). Furthermore, the social and economic environments are associated with food waste behaviors. For example, parenting practices has impact on food waste: growing up in a family with a lifestyle towards sustainability makes people appreciate the food that is available (Ganglbauer et al., 2013). Additionally, the unpredictability of daily activities and social relations are associated with more waste. Everyday behaviors around food have become habitual or unconscious because of increasing demands of our time, which results in forgetting (Ganglbauer et al., 2013; Cohen, 2008). And those with less time available for food-related activities generate the most waste (Wrap, 2014). On the other hand, economic reasons could trigger attempts to reduce food waste and therefore also daily expenses (Ganglbauer et al., 2013).

2.2. Proposed and current solutions to reduce food waste

We can conclude that our decision-making process around food is a very complex one with a variety of factors. One way to reduce food waste is to improve consumers perceptions (i.e., perceived effectiveness) and knowledge (about sell-by dates, how to use the fridge, plan meals, make lists, and visibility in the costs). However, in an environment with time demands, this might not always be effective. According to Griskevicius et al. (2012), for influence strategies to be optimally effective, they must work with, rather than against, evolved tendencies. He proposed that a large portion of human-inflicted ecological damage is caused or exacerbated by five ancestral tendencies which have devastating consequences in the modern world; propensity for self-interest, motivation for relative status, proclivity to unconsciously copy others, predisposition to be shortsighted and proneness to disregard impalpable concerns. And according to Manning (2009), to empower sustainability is to make sustainable actions appealing to the unconscious and impulse associative system: a sustainable action should be appealing and grabbing for rational reasons as well as gut-feeling. Hence, strategies to tackle wasteful behavior should require minimum time and cognitive effort from consumers.

So far, the most common approach aims at raising awareness in schools or public campaigns (Thonissen, 2010) where consumers get informed about topics such as food purchasing, storage, preparation, or actual shelf life. However, the information provided is in a context irrelevant for the targeted behaviors. Consumers might gain knowledge and have good intentions, but this might not be reflected in their daily lives as discussed by Vermeir and Verbeke (2008). Moreover, it requires active effort to remember these strategies at the right time so it can be applied into practice. We believe, to support sustainable actions, consumers should be engaged in the environment that is relevant to the targeted behaviors. Researchers in the field of Pervasive Computing and Human Computer Interaction (HCI) have taken influence strategies to raise awareness closer to homes. For example, eco-feedback is a common strategy to encourage conservation and increase awareness (e.g., of water, energy and fuel) by automatically sensing peoples activities and feeding related information back through computerized means. It aims at fostering positive attitudes towards sustainability and the adoption of sustainable behaviors (Pierce et al., 2008; Froehlich et al., 2010). It replaces hidden environmental information and behavior patterns with more accessible and under-

standable information without requiring too much effort from consumers (Holmes, 2007). Applying this strategy for capturing and influencing food waste-related behaviors, however, would come with challenges as food-related behavior cannot be easily sensed and is complex to define due to its invisible nature. Although, most pervasive or persuasive sustainability research focus on other topics, developments applied to food waste behavior are getting increasingly important. The latest developments can be categorized in: (1) mobile applications, and (2) sensor based systems (RFID tagging or camera tracking) to log or track food availability or waste. In line with these developments, we will discuss examples that aimed at creating visibility of wasteful behaviors for reflection and examples that aimed at creating visibility of food availability for prevention.

2.2.1. Creating visibility of wasteful behaviors for reflection

Ganglbauer et al. (2012) developed a mobile food waste diary that allows consumers to reflect on how much food they actually waste. The diary addresses visibility in different phases of food practices for self reflection and was found to stimulate deeper insights about the relationships between food waste, experiences, habits, knowledge, occurrences and intentions to change (Ganglbauer et al., 2015). The reasons of food waste were made available to other users in order to encourage sharing and mutual reflection. Another recent example for reflection is BinCam, which is a system that replaces an existing kitchen bin (Thieme et al., 2012). The bin has an attached camera on the underside of the bin lid to automatically capture digital images. These images were then uploaded to an application on Facebook where they can be explored by all users of the system for mutual reflection. With this system, researchers aimed at motivating reflection and behavioral change in food waste as well as recycling habits of young adults. Both, BinCam and the food waste diary aimed at encouraging sharing of food waste behaviors and mutual reflection. For example, BinCam enables users to form connections with relevant others while leveraging on individual's interest to be socially accepted. The use of social influence strategies is considered to have high potential in generating positive behavior changes (Foster and Lawson, 2013), which is also an important aspect in our overall system and design rationale.

2.2.2. Creating visibility of food availability for prevention

Smart phones and cameras has also been used in a fridge to improve the visibility of in-home food availability (Ganglbauer et al., 2013). For example, Farr-wharton et al. (2013, 2014) introduced a mobile application that can track the ingredients inside a color-coded refrigerator with the help of pictures and food identification. Their main goal was to alert users before the expiration date to achieve a reduction in food waste. Similarly, advances in food sensing technology is expected to have a significant impact on food waste prevention. Smart refrigerators, for example, can record expiration dates using bar code readers and Radio Frequency Identification (RFID) technology (Rouillard, 2012), so that food that is sensitive to spoiling can be closely monitored. RFID is a technology that connects the objects over-the-air so that the objects can be tracked and the data about them can be shared by individuals and organizations. Using sensing technology, the refrigerator may alert when the food reaches a point where it must get used. Future research on smart refrigerators aim at an optimization of food identification with image and speech recognition techniques to improve the interaction process as well as to provide recipes based on recorded ingredients (Rouillard, 2012). These pervasive sensor-based approaches, which includes interactive fridges, and fully equipped smart kitchens open up a wide range of possibilities to support practices around food that could potentially help in reducing waste (Bucci et al., 2010). And *Social Recipes* could be one possibility.

2.3. Design opportunities

These current developments in pervasive and mobile technology show new opportunities on how consumers can be supported in reducing domestic food waste in their immediate environments. Based on our literature review, we see three relevant aspects that we should consider in the design of our overall system:

- **Smarter technology.**

  With the future of the Internet in mind, technology could help in improving awareness of domestic food waste and provide solutions that are embedded in our daily lives and that require minimum time and cognitive effort from consumers. Smart fridges, for example, could provide suggestions for recipes or healthy tips based on its content before users enter a grocery store. Furthermore, a smart bin could help consumers in understanding what and when they are wasting, and provide clues or suggestions on how to reduce waste.

- **Designing for action.**

  Technology could help and provide suggestions for an action so that users know *how* to reduce waste rather than just their wasteful behaviors. This would also reduce cognitive effort required from consumers in the sense that they do not need to come up with a solution (e.g., opposed to the food waste diary Ganglbauer et al., 2015). Maitland et al. suggested that for persuasive technology to be successful, it should be designed to encourage action. Systems designed for action was argued to have impacts on creativity, pleasure and nostalgia, gifting, connectedness and trend-seeking behaviors (Maitland et al., 2009). In sustainability research, the nature of the expected behavioral change is often unspecified (Brynjarsdttir et al., 2012).

- **Considering the social context.** Studies have shown the importance of social environments in shaping our individual decision-making processes (Ganglbauer et al., 2013, 2012). Social influence strategies mediated through technology, could have high potential in generating positive behavior change (Foster and Lawson, 2013). Moreover, according to Midden et al., social mechanisms that humans use to influence others, such as social approval, peer pressure, norm activation or social comparison, are principles that can be applied successfully for supporting behavior change (Midden and Ham, 2013). Although, social activity was found to be a determinant of food waste (Ganglbauer et al., 2013), with our *Social Recipes* concept we aim at using social activity to discourage food waste.

3. Social Recipes: a concept to reduce food waste

We took these opportunities into consideration in designing a community-based social system to reduce food waste. The envisioned system, as shown in Fig. 2, allows users to log and track available in-home ingredients as well as their wasteful behaviors through appliances in the kitchen such as a fridge and a bin. Based on this information, the system is expected to help users to redirect behaviors, through social influence strategies, towards more sustainable food related practices in terms of food waste. The main function of the system is to detect food availability as well as potential food waste and respond by suggesting *Social Recipes*. With these particular recipes, the intention is to encourage the use of high-risk ingredients owned by different individuals in a creative and social alternative. Additionally, the system could provide information of food waste types and amounts (i.e., eco-feedback) to improve understanding of wasteful behaviors as an additional feature to encourage users to use the suggested recipes. The concept of *Social Recipes* is expected to provide moments for collaboration, creativity, connectedness, and inter-cultural encounter, which is in accordance with recent suggestions on exploring the roles of collectivism and community for food sharing practices as a way to reduce food waste (Comber et al., 2013; Silberman et al., 2014). With this concept, we aim at using social activity to discourage food waste,

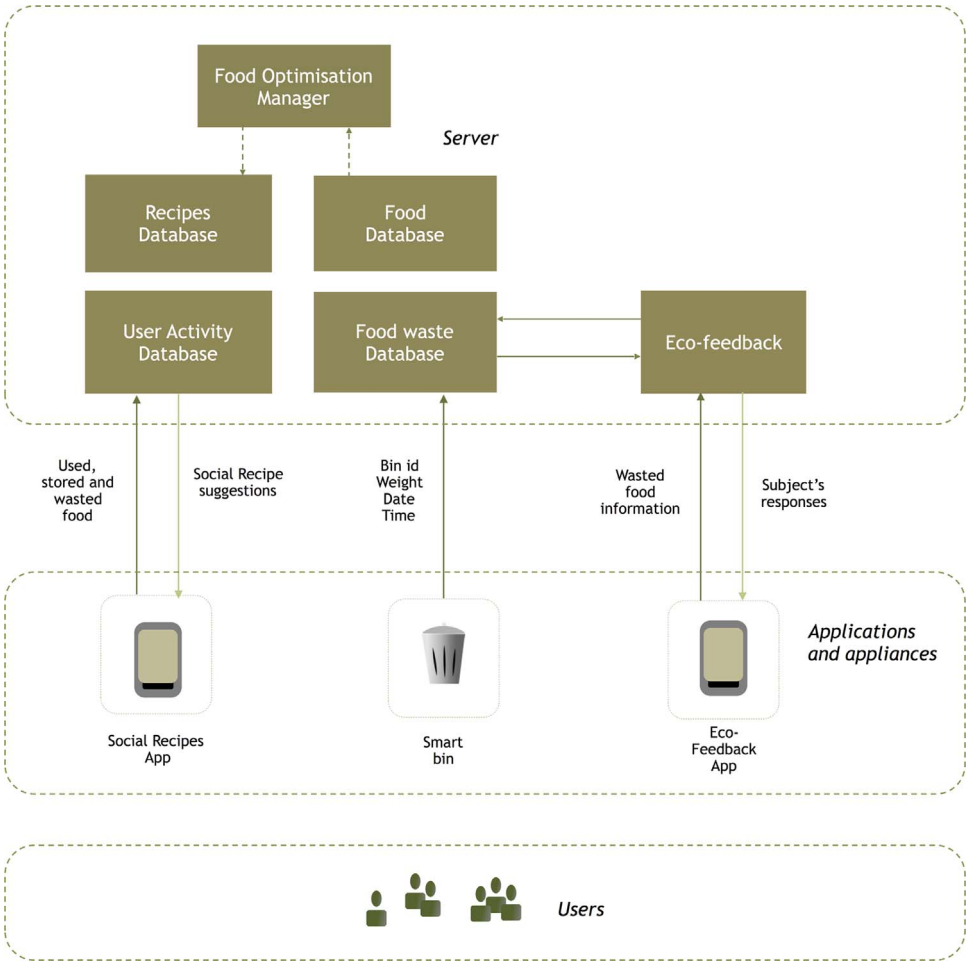

Fig. 2. Overview of the system. Available and wasted ingredients are collected from users through a Social Recipes application, which gets stored in a server. Food availability is then handled by a food optimization manager who finds and sends Social Recipes to a group of users. Wasted ingredients are also collected and weighted by an augmented bin, which is processed by an eco-feedback manager and fed back to an eco-feedback application, visible to all users.

which is in line with the celebratory technology described by Grimes and Harper (2008).

3.1. The sharing economy

The concept is inspired by the emerging sharing economy. Some well known examples of sharing concepts are Airbnb or NightSwapping for accommodation, and Uber or Blablacar for car rides. These communities can provide benefits for providers and receivers in terms of costs, personal and social experience, and for Blablacar also in terms of sustainability. Despite their successes, we believe the HCI community has insufficiently explored the potential of food sharing. Although, there has been previous work in the area of human-food interaction that celebrates the positive relationships people have with food, most do not target food sharing in particular. For example, the designers of I8DAT aimed at producing actionable knowledge through the sharing of food images for educational purposes (Choi et al., 2011). Similarly, the Hate Waste Love Food[1] application was developed for recipe sharing while 'on-the-go' but not actual food. With our concept of *Social Recipes*, we aim at producing actionable knowledge but from the perspective of what is available from a group of users to encourage collaboration. Examples of food-related applications that support a different type of sharing includes Foodmunity and Eatwell. Foodmunity (Gross et al., 2011) is a platform through which community members can share personal experiences about meals. These personal experiences may focus on a variety of topics such as culture, religious events, or family. The main aim of the platform is to share these experiences with others as a basis for exposing people to the new and the unknown. EatWell (Grimes et al., 2008) allows users to create voice memories describing how they have tried to eat healthfully in their neighborhoods (e.g., at local restaurants) and listen to the memories that others have created to facilitate a sense of community empowerment. Like Foodmunity and EatWell, *Social Recipes* aims at facilitating a sense of community. However, it also aims at encouraging users to *actually* get together, share their ingredients, and collaborate in making food together in a sustainable and social manner. Moreover, across the globe, communities for food sharing are emerging but these are not mediated by technology. For example, the food-is-free project[2] helps people gain independence from the agricultural industry. It focuses on community building and gardening where those involved learn how to connect with neighbors through front yard community gardens. There are also communities where farmers and retailers can offer, and consumers and organizations can collect free food items such as described in Ganglbauer et al. (2014). Our work builds on this idea of free food sharing but from the angle of in-home availability and smart home technologies. Although there are applications that do support food sharing such as LeftOverSwap (Farr-Wharton et al., 2014) and ShareYourMeal,[3] these do not aim at facilitating this sense of close communities. Instead they allow users to exchange or share cooked

[1] www.lovefoodhatewaste.com

[2] www.foodisfreeproject.org

[3] www.shareyorumeal.net

Table 1
Participants Demographics.

Group	N (m/f)	Profession	House type	Relation	Consumption habits
A	2 (m)	International students from China and India	Single studios on campus	Neighbors	They all mainly cook for themselves during the week and prepare their dinners for two to four days.
B	2 (m) 1 (f)	International students from Portugal and Germany	Apartment	Two are friends	The two friends always buy food and have dinners together, while the other cook for herself because of her vegetarian diet.
C	2 (m) 2 (f)	Young professionals from Turkey and Australia	Each couple in different apartments	Good friends	Each couple eat alone, except for certain occasions they get together.
D	5 (m)	International students from India	Two on campus, one in an apartment for 3, two in an apartment for 7.	Good friends	Get together almost every weekend to go to the market, cook and eat.
E	3 (m)	Students	Apartment	Good friends	They do many activities together, and share similar friends.
F	2 (m)	Young professionals	House	Regular house mates	Very busy, cook and eat at home only couple of times a week.
G	3 (f)	Students	Student residence	Sorority friends	Socially very active and have dinners in big groups at least once a week.
H	5 (f)	Students	Student residence	Friends	Socially very active, members of a sports club, cook and eat together regularly.

leftovers or meals for a small price without facilitating further interactions. Next, we discuss the studies we conducted in evaluating the potential and impact of our concept and suggest further implications for its design.

4. Structured interviews (Study 1)

The first study was a structured interview study in which participants logged their food waste for a period of a month and were interviewed once per 2 weeks (i.e., with a total of 2 interviews per household). The objectives in this study were: (1) to identify the most common food waste types and reasons in this specific target group, and (2) to explore expected experiences of a community-based Social Recipe system.

4.1. Methodology

4.1.1. Participants

The study was carried out with 8 groups of friends or neighbors with a total of 27 individuals between 22 and 31 years of age (see Table 1 for participants demographics). All participants were living in urban cities in the Netherlands: 5 groups were living in the same house (B, E, F, G and H), and the remaining groups (A, C and D) were either neighbors or were very good friends of each other but not living together. We decided to include these remaining groups to see how they find the concept motivating or demotivating: differences in spatial distance was expected to provide additional insights for the design of our concept. Participants were recruited through Universities' facebook pages (i.e., the International Student Network, and Industrial Design), by means of an information/invitation letter delivered in their mailbox (i.e., for those living on campus), and through personal networks. All participants were visited at home after work hours and were compensated with vouchers.

4.1.2. Study procedures

At the beginning of the study, all participants were provided with a small box, a black marker, a small table bin, and a kitchen scale. They were asked to collect their grocery receipts during the study period and use the box to store their receipts and the black marker to cover any item that was considered private. These receipts were later used as cues for biweekly retrospective interviews on their food wastage in the last 2 weeks. Hence, all participants were interviewed twice, individually, in couples, or in the presence of other group members. The purpose of the interviews was to get familiarized with the type of food they commonly waste and their reasons for wasting. This was done by going through the items one by one and by asking participants if they have wasted anything. If they did, they were asked to give an estimation of how much it was in percentage of the total item and why it was disposed.

Participants were further instructed to use the table bin for all food-related organic waste including edible as well as inedible parts such as bones, tea bags, egg shells, and fruit peels. The inclusion of inedibles was done to prevent differences in the definition of edibility. They were asked to weigh the table bin every time before they empty it and write down the amount on a log sheet. Log sheets were provided and replaced after each interview.

In the last interview, a description of *Social Recipes* was verbally explained in a hypothetical fashion to gather their expected experiences and reactions towards the concept. *Social Recipes* was described as follow: *"Imagine a system that knows which foods you have in your house, which foods your friends have in their house, and that can suggest you to get together with your friends to make a recipe with the available ingredients without having to go to the grocery store."*

Participants were free in responding to the concept.

4.1.3. Analysis

To simplify the analysis, each food item was considered equal to a single fruit or vegetable such as a banana or cabbage, but also a basket of smaller fruits or vegetables such as cherry tomatoes, or one portion of rice or pasta suitable for one meal. Each reported food item was further categorized into different food groups: fruits, grains, dairy, vegetables, meat and fish, or other (e.g., sandwich spreads). A thematic analysis was conducted to categorize the reasons that were provided for wasting. We also conducted a thematic analysis to explore their attitudes towards the concept.

4.2. Findings

During the whole study period, a total of 231 food items were wasted excluding drinks (other than milk), desserts, cookies, and confectioneries. We categorized the reported food waste items into different food types: fruits, grains, dairy, vegetables, meat and fish, or other (e.g., sandwich spreads), and found that almost half of all the wasted items were vegetables. Most of these vegetables were disposed partly with an average of 64% of the whole item, indicating the significance of targeting vegetables.

4.2.1. Food group in relation to the reason of wasting

Next, we categorized the reasons of wastage using thematic analysis, and the following categories emerged; the way of consumption, items gone badly, doubtful items, and dealing with leftovers:

- *Ways of consumption:* includes all items that were used for flavoring and parts that were cut off because of a recipe description.
- *Items gone badly:* includes all items with visual characteristics of decay such as mold, changes in color, or growths through the skins (e.g., in potatoes). These could further be caused by forgetfulness, busy lives, big purchases, unpredictability of longevity, change of meal plans, and the weather.
- *Doubtful items:* includes visual unattractiveness such as drought or over-moisture, expiration dates, items that were left open in the kitchen for one or several days and were not trusted anymore in terms of quality, and items that were just considered old and had been in the fridge for a long time. These could also further be caused by forgetfulness, busy lives, social activities or knowledge.
- *Dealing with leftovers:* includes cooked or prepared ingredients that were left after dinner but not worthwhile saving (e.g., too little to save or not tasting good) or leftovers without plans of usage in the near future. This category also includes meals that were saved for days with the intention of usage but were eventually forgotten (cf. causes above).
- *Other reasons:* included an occasion where something was saved without foil, a food item was partly bad at the time of purchase, the taste was unexpected, it was difficult to get the rest out of a package, a non-sticky pan was used, and where the fridge was not working well.

Overall, vegetables were found to be wasted most often due to physical deterioration (N items = 38) or were expected not to be edible and thus doubtful in quality and safety (N items = 41) (see Fig. 3.) These findings shows the potential of targeting perishables with *Social Recipes* to encourage its use before it gets forgotten.

Design implication 1. The use of existing ingredients in *Social Recipes* with the intention of reducing food waste could be defined and explored as a constraint satisfaction problem. The system should find optimum recipes with ingredients that will likely be wasted (i.e., in this case vegetables). It could, for example, consider minimizing the amount of available ingredients as the most important constraint by

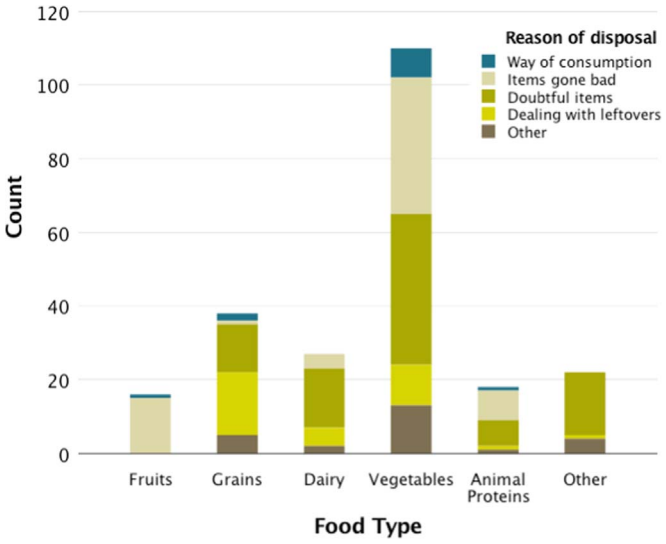

Fig. 3. The amount of reported items per food type categorized by reasons of wastage.

prioritizing ingredients. This could be done by assigning different risk levels to the ingredients based on how long the ingredient has been available in the home *or* the average longevity of the specific food item (which could be derived from a database). For example, levels of risks could be: high (the item has been available for more than 4 days), medium (the item has been available for 3–4 days) or low (the item has been available for 1–2 days) *or* high (the item is good for max. 2 days), medium (the item is good for max. 4 days) or low (the item is good for more than 4 days).

4.2.2. Expected experiences

Most participants were enthusiastic about the concept of *Social Recipes*, but also noticed disadvantages or detractors. Reasons for using such a system relating clearly to its *advantages* were for habitual purposes, awareness, creativity and surprise, and coordination:

- *Awareness*: We found that a number of participants consistently threw away the same type of vegetables because they had difficulties in predicting how long the item would be edible at the time of purchase. For this reason, they saw potential in having a system that would help remind or motivate them to use items with a constant likelihood of being wasted. For other participants, items were wasted because participant just simply forgot them due to a busy lifestyle. This was especially the case for discounted perishable food items (e.g., economy packages or sales). Therefore, participants expected a system such as *Social Recipes* to improve awareness and help remind them of what they have available. Our concept could help increase awareness of the availability of items that gets wasted most likely (i.e., vegetables) to remind or encourage its use before it gets bad (i.e., the most common reason for disposal).
- *Creativity and Surprise:* Participants did not only foresee how *Social Recipes* could help remind them of what is available but also how it could inspire them. It could trigger creativity around cooking as it could be used as inspiration for other recipe possibilities. Moreover, they expected the content as well as the timing of the suggestions to be positive surprises while encouraging spontaneous and fun meet-ups around cooking. This is in accordance to Maitland et al. (2009) expectations on designing for action.
- *Coordination:* Participants also foresaw the usefulness of *Social Recipes* in supporting coordination between the individual members of an household around shopping as well as cooking. It was expected to provide better visibility of availability within a group without the requirement of intensive communication such as calling each other. We found that participants often had similar items available that

could have been shared instead. For example, *Social Recipes* could help in preventing users from buying similar or already available items. This is also in accordance to Ganglbauer et al. (2012) suggestion to design for collaboration to organize daily practices around food and ultimately reduce food waste.

Participants also expressed negative attitudes towards *Social Recipes*:

- *Preparation values:* A reason for not using *Social Recipes* might be when users cook extensively and spend time on cooking individually for others. A couple of participants valued cooking as an individual activity which they think should be done in advance before a guest shows up for dinner. This was considered to be a means to show hospitality. However, this preference was also impacted by the size of their own kitchen.
- *Travel distance:* Another reason why participants might not use *Social Recipes* is the distance they need to travel in order to get together with friends for dinner. Participants might prefer going to the grocery store that is nearby over collaborating with friends as it could be more convenient and less time consuming. This could, however, depend on someone's personality or current mood rather than the actual travel distance.

Design implication 2. The system should suggest the location for cooking based on the size of the group that is suggested with a *Social Recipe* so that the place can accommodate the number of people that are sharing. For those who prefer to cook for others individually instead of collaboratively, the system could allow users to provide their preference around the activity of cooking. With Blablacar, for example, users can indicate whether they like hearing music or chat while driving. These options should also be considered in a concept like *Social Recipes*. Furthermore, travel distance should be minimized for all individuals receiving a suggestion. If a supermarket is located closer than a friend, users might find it easier and more convenient to go to the supermarket. Therefore, the system should consider the distances between users and to supermarkets. For example, to increase the attractiveness of a *Social Recipe*, the system should consider ingredients from users who are located not much further than the closest supermarket or it should minimize the distance to be traveled by all users. Also, a constraint value could be defined so that users do not need to travel more than a predefined distance.

4.3. Summary

Findings showed that our community-based social system should target perishable ingredients as they get wasted most often. This is also in accordance to previous findings (Ganglbauer et al., 2015). Given the reasons provided for wasting these ingredients, such as forgetting and social activity, *Social Recipes* could be a potential approach for more effective waste reduction. Indeed, participants foresaw its impacts on awareness of availability, creativity around cooking, and coordination or collaboration. However, we acknowledge some limitations in this study. First, participants were aware of the purpose of the study, which could have had impacts on their comments. Hence, in the second study, we did not tell participants of the main purpose of our concept in reducing waste. Second, so far findings are self-reported and not observed so we do not know how *Social Recipes* would actually impact behaviors. Therefore, we conducted a third study with technological probes to provide participants with a more realistic experience of *Social Recipe* suggestions so we can observe natural reactions towards the concept. These two studies are discussed next.

5. Focus group (Study 2)

As a follow up of study 1, a double-blind focus group study was conducted with six PhD students and one moderator. The main objective was to see what participants think about *Social Recipes* if the concept is not introduced to reduce food waste; what advantages or disadvantages do they foresee in this particular concept? We kept the moderator in a neutral position and used a double-blind procedure to guard against experimenter bias and influences.

5.1. Methodology

5.1.1. Participants

Participants were recruited with the following requirements: they all had to live with at least another person, cook at home at least three times a week, eat or cook together with friends at least twice a week and they had to do groceries themselves. All participants were from China, but living in the Netherlands. Our choice for selecting Chinese students is because of their cooking culture as they cook regularly in social settings. And as the world largest emerging economy, China is suffering high waste amounts at the consumer level comparable to Western countries (Liu et al., 2013). All participants were compensated with lunch during the session.

5.2. Study procedures

The session started off with some general warm-up questions about food experiences. Next, participants were asked about what makes a good food-related experience to get insights in what they value most. This was followed by a question about which food items they have available at home and whether they would share these with other people. We then presented the concept of *Social Recipes* using the same description as in the first study and asked (1) how they see the system would impact them and (2) who they would prefer to use the system with. Here, we also conducted a thematic analysis to explore their attitudes towards the concept. The focus group session was attended by two researchers who made notes. The session was video recorded to support the process of analysis. A thematic analysis was used to explore reactions towards the concept.

5.3. Findings

Generally, participants agreed that the presence of other people was what makes a good food experience. What they enjoy the most is having food with friends and the activity of preparing food for others. The social company was most valued. Almost all participants in this session were enthusiastic about the concept of *Social Recipes*. Like participants from study 1, they foresaw how it could impact food waste and positive interactions but also noticed disadvantages or detractors. Reactions which clearly relate to *advantages* were on connectedness, creativity and knowledge:

- *Connectedness:* Participants liked how *Social Recipe* suggestions could create the feeling of being connected with others through the in-home available ingredients. These suggestions, which is expected to come in as surprises at random moments, could provide users with more opportunities to see friends, share private moments and grow closer to each other. The collaborative aspect in saving food together was expected to bring a sense of community.
- *Creativity and Knowledge:* Another aspect participants liked was that *Social Recipes* might help them in gaining new cooking skills. Users foresaw how they could learn from the suggestions from the system as well as from each other when they cook together. It could create an opportunity for the exchange of knowledge around cooking practices: the suggestions were expected to inspire creativity and to initiate conversations.

Participants also expressed negative attitudes towards the system. This was mainly related to trust:

- *Trust:* Specifically, we identified two types of trust. The first type of trust was in the suggestions provided by the system: some participants indicated the importance of receiving suggestions according to the foods they like with nutritional value. The second type of trust was in the way others take care of their food items before they are shared. For example, where they have placed or saved the items before it is shared.

Design implication 3. Trust could be a challenging issue for design, but critical for the acceptance of food sharing technology. We can discuss implications for both types of trust we identified above. For example, to deal with the first type of trust, the system could construct user profiles based on what users bought before and provide recipes with familiar food items that are nutritionally balanced. Adopting healthy eating patterns are expected to have great additional effects on sustainability than reducing food waste alone (Rutten, 2013). For the second type of trust, the system could allow users to find and invite their friends, or connect with potential future friends who have the same tastes or food interests. Moreover, the system could allow them to set a parameter for the number of users for receiving a recipe suggestion. We expect this could increase acceptance rates, as it might be more difficult to coordinate with more people.

5.4. Summary

In this study, findings showed potential of *Social Recipes* with impacts on creativity, knowledge and connectedness, with trust as main detractor. These are different findings from the first study. However, the study is still limited as actual impact on behavior is unclear. In the next study, participants were provided with a closer experience of Social Recipe suggestions in a home deployment study.

6. Home deployment (Study 3)

For the home deployment study, technological probes (Hutchinson et al., 2003) were developed and implemented to provide participants with the experience of Social Recipes in a daily life environment. A Wizard of Oz approach (Dow et al., 2005) was adopted, with objectives to explore (1) the impact of *Social Recipes* and (2) how eco-feedback could add in supporting food waste-related behavior. The ultimate goal was to further provide design implications for development based on triangulation of findings from all three studies.

6.1. Methodology

6.1.1. Participants

Four groups of participants were recruited with a total of 15 individuals (students and young professionals) between the age of 20 and 28. Each group consisted of 3 – 5 individuals living together with the exception of 1 group who were friends living separately (see Table 2 for the demographics). Participants were recruited in the same manner as in the previous studies. With the exception of 1 group, participants were not required to travel to share food so we could discover other design implications. All groups of participants received *Social Recipes* of which 2 groups also received eco-feedback. In this study, we used pseudonyms to protect each participant's identity.

6.1.2. Study procedures

The study took place for a month. In the first week, participants were given time to get acquainted with two probes; a mobile application for food logging, and an augmented bin to monitor organic waste. These probes are discussed in more detail in the next section. We used Whatsapp chat groups for all communication with participants such as for instructions, questions, comments, and anything else participants like to share such as pictures. We also used Whatsapp to send the *Social Recipe* suggestions according to the Wizard of Oz approach, which logic is also explained next.

Table 2
Participants Demographics. Intervention type: SR = Social Recipe suggestions, EF=Eco-feedback. We use pseudonyms as a reference to participants.

Group	Name	Age	Gender	Housing	Intervention Type
A	Andrea	23	M	same	SR & EF
	Alan	25	M	house	
	Anton	24	M		
	Adam	25	M		
	Aykan	23	M		
B	Brenda	24	F	same	SR & EF
	Beatrice	23	F	house	
	Bianca	23	F		
	Beth	21	F		
C	Chris	24	M	same	SR
	Colin	20	M	house	
	Carla	24	F		
D	Dena	24	F	separate	SR
	Daisy	28	F	houses	
	Diana	26	F		

6.1.3. Technological probes

Technological probes were developed to evaluate *Social Recipes* and the additional impact of eco-feedback. These are the two concepts of the overall envisioned community-based social system as presented in Fig. 2. The probes were developed to capture in-home availability and food waste patterns from consumers, and to deliver *Social Recipe* suggestions and eco-feedback in situ.

Probe 1: Food logging and Social Recipe suggestions. In order to create Social Recipe suggestions, in-home ingredients need to be tracked. To do this, we developed a mobile application (See the interaction between the *Social Recipes* application, server, and users in Fig. 2) for iOS and Android in a hybrid approach using PhoneGap, which participants were asked to install on their phones in the beginning of the study. The mobile application was written in JQueryMobile, HTML and CSS for the user interface and JavaScript for the user interaction. Data from the users were stored locally using a SQLite database engine and sent to a server implemented with the PLAY framework.

In the beginning of the study, participants were instructed to create a user account and use the application to log their in-home food availability on a daily basis (see Fig. 4 for the user interface). To limit data entry, they were asked to log only ingredients for dinner that were available for over 24 h. In the application, participants could search for ingredients through images, and select and add them to a stock list (in-home availability) or wish list. The wish list was only meant for ingredients they plan to buy, which were automatically moved to the stock list when the purchase was confirmed. In both lists, users can enter the amount of each item in weight, numbers or liters. If an item in the stock list was disposed, users could delete it. This moves the item to the bin folder where reasons for disposal can be further indicated.

The data entered in the application by the different individuals within each group were used to form *Social Recipe* suggestions. We created and sent suggestions to participants manually with Whatsapp and according to the Wizard of Oz approach; a widely used method in

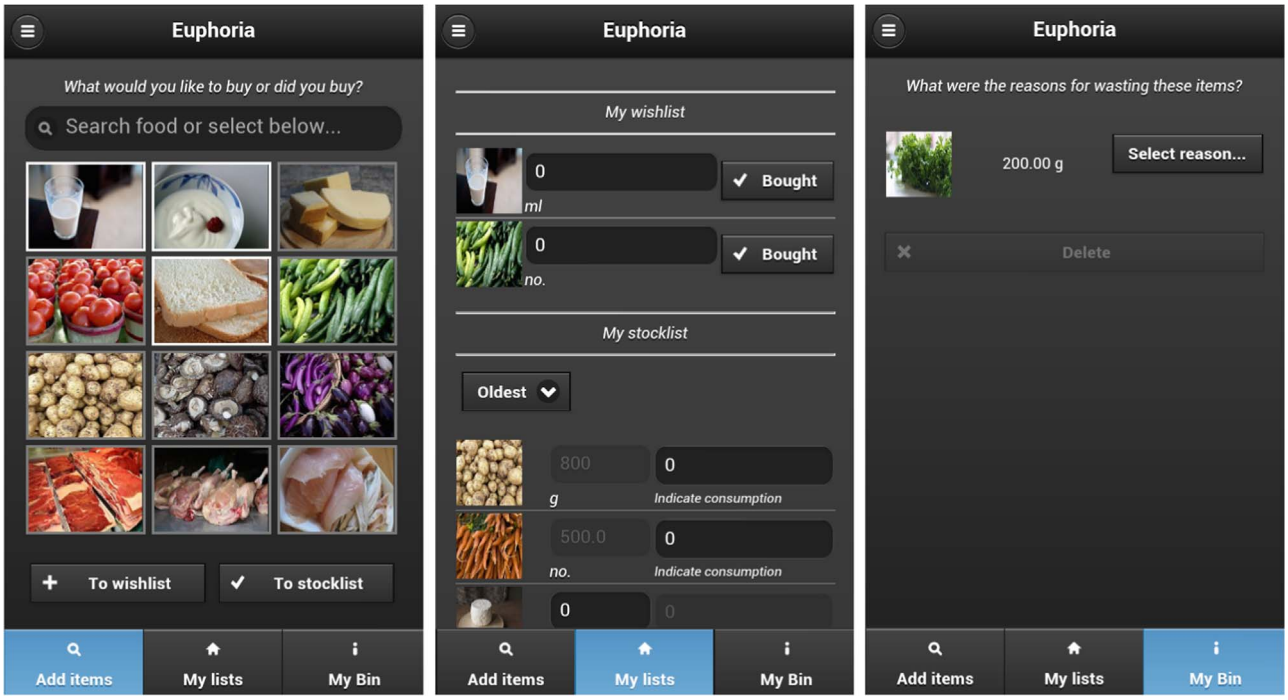

Fig. 4. The mobile application user interface for ingredients logging. Presented from left to right: the search list, wish and stock lists, and the waste list, respectively.

Fig. 5. These are two screenshots with examples of how a *Social Recipe* suggestion was delivered. Each suggestion included a picture of the recipe, the available ingredients that can be used and from which owner, and additional items to be added.

human-computer interaction research to explore user interfaces for pervasive, ubiquitous, or mixed-reality systems that combine sensing and intelligent control logic (Dow et al., 2005). We took the following steps to generate suggestions: (1) take items with a sufficient amount (more than 100 g), (2) use a database for recipes,[4] (3) initially, consider all available items, then (4) exclude items that are newest based on starting date until at least 3 recipes are found, (5) select a recipe with the least extra items to add, and (6) provide multiple suggestions if possible. Each suggestion included a picture of the recipe, the available ingredients to use and from which owner, and additional items to add as shown in Fig. 5. A suggestion was send to groups of users once a week through Whatsapp.

Probe 2: Monitoring of food waste amounts and eco-feedback. We developed an augmented bin for the measurement of food waste weights for each group of participants (see Fig. 6) and to evaluate the additional impact of eco-feedback (See the interaction between the augmented bin, server, eco-feedback application and users in Fig. 2). The bin consisted of a Dymo M5 USB postal scale, a 5 liter trash bin and a Raspberry Pi with a Wi-Fi module protected with a laser-cut wooden enclosure. The Raspberry Pi requested a weight measurement from the scale until a stable weight was found via USB, which was sent to a remote server. Participants were instructed to use the bin for all organic waste that was still edible or once edible and were provided with a list of items they were *not* allowed to throw in. Furthermore, they were instructed to reset the bin every time it gets emptied.

The data collected with the bin was fed back to 2 groups through an application installed on a tablet computer (see Fig. 7), which was placed with a tablet holder in a visible location in the kitchen. The application displayed the amount of food waste in the number of servings: every 200 g of waste was calculated as 1 potential serving. The use of metaphors are common in eco-feedback research to enhance understanding (Froehlich et al., 2012). Another common practice in eco-feedback research is the use of social comparison as an influence strategy. People compare themselves to others when objective measures for self-evaluation are unavailable (Festinger, 1954). For this reason, in the last 2 weeks, the display showed what *others* have wasted in addition to participants' own food waste amounts. This amount (i.e., *others*) was generated by taking a random percentage between 40% and 110% of participants' own food waste amounts, so that most of the time participants were receiving negative feedback. This was done to make sure that both groups were receiving similar feedback. However, participants were informed that social comparison information was coming directly from another group of participants to trigger competition.

[4] http://www.ingredienten.nl/recepten

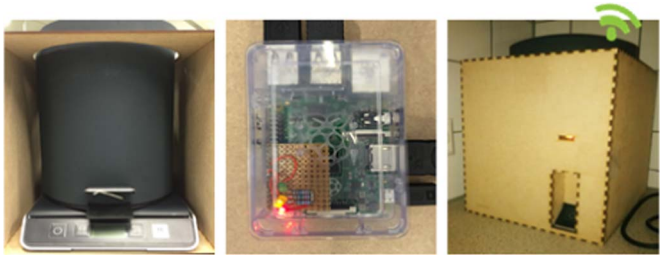

Fig. 6. The augmented bin with USB postal scale and a Raspberry Pi to receive and send data to a server.

6.1.4. Measures and analysis

After the deployment, participants were asked to fill out a post questionnaire with Likert scale questions and open-ended questions (see Table 3) to evaluate the impact of *Social Recipes* and eco-feedback on food-related behaviors, awareness, reflection, coordination and communication (i.e., social interactions). Additional questions aimed at gathering their level of motivation to change behavior and to see whether they find the concepts effective in reducing domestic food waste. Answer options ranged from very much to not at all, with items score contribution from 7 to 1, respectively. During the deployment we used Whatsapp chat groups to send *Social Recipe* suggestions and for free text messaging to gain insights in their spontaneous reactions towards the suggestions. The reactions or comments in the Whatsapp chat and questionnaire were analyzed and categorized into themes and triangulated with findings from the first and second study. Based on these results, we suggest further design implications for the proposed community-based social system. To test the viability of our interpretation of the findings and suggested implications, we conducted a respondent validation (i.e., member check).

6.1.5. Usage descriptives

This section describes the usage of the probes discussed earlier. For the mobile application, 622 actions were counted with 5 action types: opening the application, the users' list (wish and stock lists), the waste list, the users' profile, and sorting items in the users' list. 251 items were entered in the users' list of which 78 items were wasted (dairy: ci. 3705 g/liters, vegetables and fruits: ci. 3227 g and 24 pieces, grains and starches: ci. 7060 g, meat and fish: ci. 950 g). An average of 332 g of food waste went into the bin per person per week (excluding 2 participants who were only using the mobile application).

6.2. Findings on the impact of Social Recipe suggestions

In this section, we present our findings from the questionnaire scores (perceived impact) and the free-text messaging (observed impact). We should note that we only consider the questionnaire items when at least 50% of the participants have given a score of a 5 or higher on the Likert scale or when scores were unexpectedly low (see Table 3). The findings are discussed around the broader themes of what participants from the previous two studies expected to experience.

6.2.1. Awareness

Initial reactions towards the suggestions showed interest and curiosity in the Whatsapp chat; *"I think it is a good plan." - Andrea*, *"Great idea! Look delicious! Could you send the recipe? " - Dena* and *"I will indeed keep the broccoli for a tortilla, that is a good one! I think I will make that, I still have coconut left! " - Diana*. We received a total of 10 positive reactions towards *Social Recipe* suggestions (out of 36 if each person would respond to each single suggestion). This indicates a positive attitude towards the suggestions by a number of participants. However, the suggestions were not utilized. For example, in the post questionnaire, several participants reported being more aware when they received *Social Recipes*, but in the sense that it helped them remember their own current food availability. This self awareness turned into actions related to how they were dealing with their leftovers. For example, Brenda felt more motivated to keep the leftovers for an extra day and ate it at lunch. And Chris searched for other recipes online. Hence, instead of collaborating with other users in the group, participants took actions individually.

Design implication 4. Food sharing technology should be designed in a way that suggestions for sharing can be seen as an option for users to deal with their in-home ingredients. For example, when participants prefer to cook and eat by themselves, which could further depend on several factors such as personality, the occasion, mood, or relationship with the others in their group, they should be able to find recipes based only on their own ingredients. In this case, users could just receive a simple reminder that their ingredients are sufficient for certain recipes that are available in the database. They

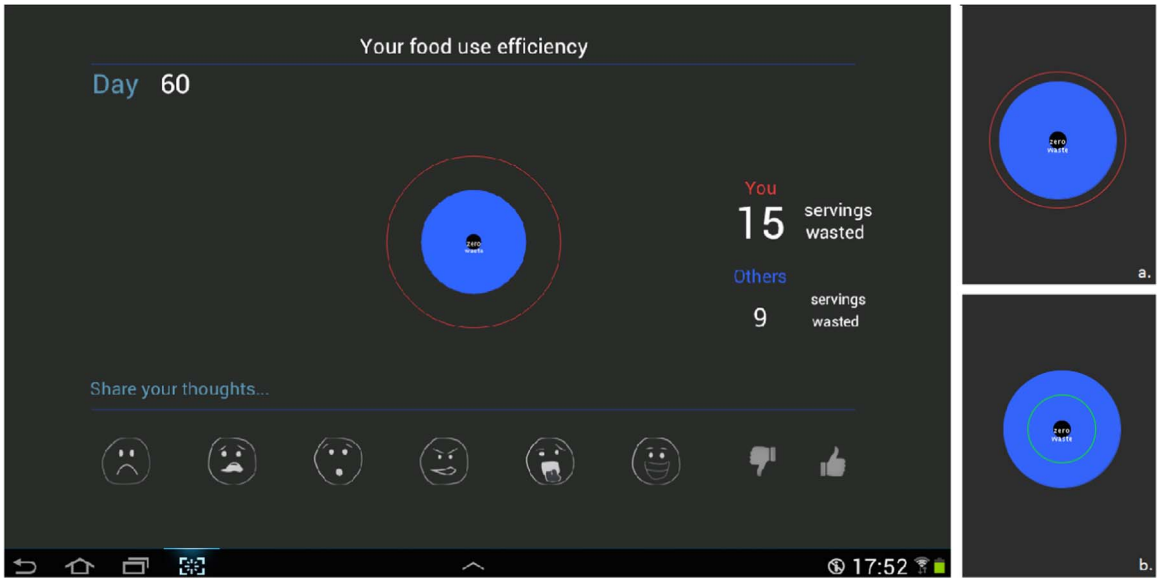

Fig. 7. The eco-feedback visualization showing negative feedback (a) and positive feedback (b) relatively to *others*.

Table 3
Summary of frequency distribution for survey 3.

Question	7	6	5	4	3	2	1	Median
1a. Do Social Recipe suggestions influence your individual behavior regarding food planning?	0	1	2	0	1	5	1	2.0
1b. Do Social Recipe suggestions influence your individual behavior regarding food purchasing?	0	1	1	2	2	4	0	3.0
1c. Do Social Recipe suggestions influence your individual behavior regarding food preparation?	0	1	1	2	1	5	0	2.5
1d. Do Social Recipe suggestions influence your individual behavior regarding dealing with leftovers?*	1	2	2	3	1	1	0	4.5
2a. Do Social Recipe suggestions influence the group behavior regarding food planning?	0	1	1	3	1	3	1	3.5
2b. Do Social Recipe suggestions influence the group behavior regarding food purchasing?	0	0	2	3	1	4	0	3.5
2c. Do Social Recipe suggestions influence the group behavior regarding food preparation?	0	0	1	2	1	6	0	2.0
2d. Do Social Recipe suggestions influence the group behavior regarding dealing with leftovers?*	1	1	3	2	0	3	0	4.5
3. Do Social Recipe suggestions affect awareness on overall food practices?*	1	0	5	3	0	1	0	5.0
4. Do Social Recipe suggestions affect coordination within your group regarding overall food practices?	0	0	1	2	2	3	2	2.5
5. Do Social Recipe suggestions affect communication within your group around the topic of food?*	0	2	3	1	2	2	0	4.5
6. How much is your level of motivation to change your behavior around food practices at this point?*	1	3	3	1	2	0	0	5.0
7. Do Social Recipe suggestions support reflection?	0	1	3	3	2	1	0	4.0
8. Are Social Recipe suggestions efficient in reducing overall food waste?	0	0	1	4	2	1	2	3.5
9. Do you consider Social Recipe suggestions to be effective to reduce overall food waste?	0	1	3	2	2	2	0	4.0
10. Does Eco-feedback provide an additional impact on your individual behavior?	0	1	2	1	1	0	2	4.0
11. Does Eco-feedback provide an additional impact on the group behavior?*	0	3	1	0	1	0	2	5.0
12. Does Eco-feedback provide an additional impact on awareness?*	1	0	3	1	0	0	2	5.0
13. Does Eco-feedback provide an additional impact on coordination?	0	0	0	0	2	2	3	2.0
14. Does Eco-feedback provide an additional impact on communication?	0	2	1	2	0	1	1	4.0
15. Does Eco-feedback provide an additional impact on reflection?	0	3	0	1	1	0	2	4.0
16. Does Eco-feedback provide an additional impact on efficiency?*	0	1	3	0	2	0	1	5.0
17. Does Eco-feedback provide an additional impact on effectiveness?*	0	2	2	0	1	1	1	5.0
18. Indicate how much impact the display without social comparison had on you.	0	0	1	3	1	1	1	4.0
19. Indicate how much impact the display with social comparison had on you.*	1	2	1	1	1	1	0	5.0

"*" indicates questions where at least 50% of the participants have given a score of 5 or higher on the level of perceived influence.

could then, for example, take another step by looking at a variety of suggested recipes and include options for new ways to cook (e.g., such as by selecting *Social Recipes*). A similar concept on innovative cooking is being developed by IBM, Chef Watson.[5] Their concept allows users to select their ingredients, but also the type of kitchen and the level of surprise or creativity using a database with more than 9000 recipes. *Social Recipes* or any type of food sharing concept, could be such an additional option. When we asked participants if *Social Recipes* should provide multiple options based on personal preferences, almost all participants (70%) agreed.

6.2.2. Knowledge

Another main finding was that *Social Recipe* suggestions triggered the exchange of knowledge between the participants in a group. For example, they reported to have more off line conversations about what to cook, what has been cooked and ways to avoid food waste. This was also visible in the Whatsapp chat of group D, who were not living in the same house. A specific instance was a conversation on how to store coriander. When we suggested a *Social Recipe* including coriander for a second time (i.e., as it was suggested in a previous recipe the week before), Diana was surprised and asked why Dena still had coriander available. She responded with an explanation on how she usually stores it, so that she can extend its use. She shared a picture with the herb in the freezer and explained to Diana that she would only cut off a small amount each time she needs some. This was a very useful tip for Diana and a *Social Recipe* suggestion resulted in a gain in knowledge on how to store food. Other topics of conversations we found online were also on how to cook with specific ingredients. These triggered conversations should be seen as another means for raising awareness (i.e., person to person), which could have an influence on behavior indirectly: in general, people are easily affected by the social environment, approval and norms (Beretta et al., 2013; Buzby and Hyman, 2012; Milfont et al., 2006).

Design implication 5. When technology aims at supporting the practice of food sharing, it should also aim at supporting the exchange of information between users. The social environment could be of valuable input for food-related decision-making. People can easily adopt, imitate or learn from others close to them and technology can take a mediating role in this. Hence, *Social Recipe* suggestions could trigger or initiate a topic for conversation. When we asked participants if *Social Recipes* should support communication among those who are suggested with a recipe, 60% of the participants agreed. A reason for not agreeing with this implication was that the ability to see each others' ingredients is already valuable and does not require much further communication.

6.2.3. Coordination

Based on the evaluation from studies 1 and 2, we expected some instances of coordination. Although, conversations around food were reported and observed, these did not result into any instance of coordination or cooperation within the groups. Despite that participants had visibility in how they could cooperate in making a recipe together, this had no impact on actually using the ingredients together. Most participants reported no influence on coordination or cooperation, for example because of plans they already made. This could further mean that the suggestions might be coming in too late or at a wrong time. Other than timing, the recipes were either unpractical or participants just did not feel like making it. Consequently, *Social Recipes* were only perceived as efficient or effective for food waste prevention by five participants.

Design implication 6. To deal with the impracticality or dislikes of the suggestions, we suggest to let users choose when to receive suggestions (e.g., for a certain day or period), set preferences for the type of recipes, and perhaps also set who they like to share food with. As participants do not change plans, food sharing technology could for example allow the user to request a *Social Recipe* suggestion at any instance when there is no plan. Moreover, timing of suggestions could also be linked to an individual's schedule. However, when we asked participants whether users should be able to set when they like to receive *Social Recipe* suggestions, answers were neutral.

[5] www.ibmchefwatson.com

6.3. The role of eco-feedback

The eco-feedback probe had an impact on participants' awareness especially when it showed social comparison information. Almost all participants who experienced the eco-feedback display indicated social comparison to be an important motivating factor. Unlike *Social Recipes*, eco-feedback was perceived as more effective in preventing food waste.

6.3.1. Awareness and social inclusion of technology

The two groups of participants with eco-feedback were found to value the competitive aspect of the probe. For example, group B checked up on each other when wasted amounts suddenly raised: *"It was funny to notice that we asked each other whether somebody recently threw away a lot of food when the eco-feedback increased a lot within one day." - Brenda*. Also group A showed monitoring behavior in the Whatsapp chat group, but towards the accuracy of the visualization. The group started questioning how it was calculating the total amount of wasted servings when some noise (perhaps someone was accidentally leaning on it) added 2000+ grams to the weight. Due to the sudden high amounts that was visualized, participants requested a data check for noise twice. This alertness was likely due to the social comparison information and the competitiveness that it triggered. For example, an indication of competition as a motivator for monitoring waste was the following comment:*"We want to win." - Alan*. Accordingly, they were interested in being able to track back the food waste amounts so they could check what happened at what day and reflect on it. Another aspect that might have had an impact on their alertness, is the fact that they personified the bin as a living entity. Group A named their bin 'Freddie' using a sticky note right after installation. This name was repeatedly used by all participants to refer to the bin: *"Freddie enjoyed the dinner tonight." - Alan*. One of the participants also mentioned that at the end of the study they felt like Freddie was getting too much food and that they wanted to stop feeding him. We believe, this personification might have helped in the presence of the eco-feedback system in participants daily environment, and hence awareness.

Design implication 7. A community-based social system should include feed back information with social comparison as an additional motivator to engage users to reduce food waste. Although, we expected participants to be in favor of suggestions such as *Social Recipes*, eco-feedback was perceived as more effective. Hence, we suggest to combine both techniques as they target wasteful behaviors in different, yet relevant ways. We saw, for example, that actionable suggestions could be inspiring and trigger food-related conversations whereas eco-feedback with social comparison motivated users to monitor their waste more carefully. When we asked participants whether food sharing technology should include both actionable suggestions and feedback of past behaviors almost all participants (80%) agreed.

6.4. Summary

Based on these findings, food sharing technology should be designed in a way that the suggestion for sharing could be seen as an option for users to deal with their in-home ingredients and allow for the setup of personal preferences. For example, so that users could first get familiar with the system for individual purposes. Second, it should aim at supporting the exchange of information between users to trigger conversations rather than on coordination. Food sharing technology could target the knowledge building in particular to motivate consumers. Finally, it should also include feed back information with social comparison as an additional motivator to engage users in reducing food waste.

7. Discussion

In this work, we were interested in how emerging technologies could raise consumers' awareness about food waste and how it could motivate them in taking actions in domestic environments. Inspired from insights gained in various research areas such as behavioral science on food-related decision-making, sustainability research, human-computer interaction, the sharing economy, and current developments in sensing technology, we proposed and evaluated a potential community-based *Social Recipe* system. The aim in this work was to contribute to an understanding how to design this system and how to integrate it in consumers daily activities for effective but pleasurable food waste prevention. Specifically, we explored how *Social Recipes* (with the addition of eco-feedback) could impact consumers.

We conducted three user studies and presented a number of design implications based on our findings. These implications mainly indicate that for our system to be successful, users should be given options and flexibility in the nature of information they receive. This might be required to reach a broader spectrum of users and situations where food sharing could be desirable. We have also seen that the method of influence should be a combination of information about past behaviors (i.e., eco-feedback) and information that is more directive (i.e., actionable suggestions such as Social Recipes). With both approaches impacting awareness differently, they should rather be seen as complementary. Hence, both competition and collaboration could be used as motivators to reduce food waste within a community, but the level to which it is effective might be different and depend on the user or situation. For example, competition seemed to be more motivating for reducing waste (supported by Midden and Ham (2013)), while suggestions for collaborations (supported by Ganglbauer et al. (2012), and Maitland et al. (2009)) ended up in conversations that was not perceived as effective even if it might have had impacts on food-related behaviors indirectly.

7.1. Limitations and future work

We started our evaluation of the system with determining the main contributors, the most common food waste types, and the most common reasons of wastage. This provided information on *who* to target, *what* to target and *how* food waste could be targeted more effectively. As a specific target group (*who*) was chosen in this work, findings should not be generalized directly to other types of consumers. Although this could be considered a limitation, it is also an advantage; consumers relations with foods are complex, which should not be generalized. By narrowing down the target group, a deeper understanding could be gained in the specific needs of the group, which was suggested by Wrap (2014). Moreover, the participants recruited in this work were not necessarily sustainable, were considered to have busy lifestyles and were not specifically interested in sustainable technology. Hence, participants in this work might not be using sustainable food-related technology on a voluntary basis for the purpose of sustainability. Therefore, in targeting this audience, implementation might need to be enforced or incentives such as costs or social activity should be more emphasized rather than sustainability alone. Furthermore, this work focuses on specific food types (i.e., perishables) and thence the proposed solution (*how*) should not be generalized to other food types.

Second, behavior change was not explored nor claimed in the deployment study. Instead, findings mainly provide insights into how the prototypes have impacted awareness and behaviors in response to interventions: the interventions might or might not have lead to long term impacts on behavior. In order to study behavior change, longer studies are required with a more extensive sample size and diversity. For example, different types of households, such as families with or without children, and community houses should be recruited. Research could also explore larger social network of different types. Rather than independent households, research could target a number of households

that are related to each other (e.g., friends, families or neighbors). This could extend to a whole town or city.

Hence, the length of the study was too short to evaluate actual changes in behaviors or attitudes. This is why in this study, the perceived impact on awareness and the type of reactions towards suggestions and probes were evaluated rather than actual changes. Although a longer study is desirable to explore the impact on behavior change, this should be done with an improved data entry method as this was considered an obstacle. More advanced prototypes should be developed with easier data entry before the proposed concepts can be evaluated in longer user studies. An advanced prototype or even a final system should be deployed with an interface that is easy to use to stimulate natural interactions. In this work, the systems was simulated and a mobile applications was used to test out interactions, while in the future, fully connected home appliances could co-interact (build-in applications such as in the fridge or the bin) and support sustainable lifestyles. Instead, we used the mobile application to replace future build-in applications. But the manual entry of availability seemed to be a significant stumbling block for participants which was also indicated in a previous study, where almost all participants would limit their continued use of the application after the study because of the manual method (Farr-Wharton et al., 2014). When we asked participants about their preference for the level of automation, almost all participants (i.e. 80%) preferred partial automatic food tracking to make data entry easier, but that still requires active involvements and responsibility. Consequently, the prototypes used in this work might not have captured all wasted foods or availability. Although, this work mainly focuses on the impacts of the concepts to find implications for further design, the effectiveness or desirability of the concepts might highly depend on what it can capture. And this was a major methodological and technological challenge. For example, suggestions might not have been based on all available ingredients and feedback might not have been based on all wasted foods. Consumers might need incentives to enter food availability or to use the bin properly. At the same time they might also need to enter food availability or use the smart bin properly to receive these incentives. Easy and accurate food (waste) logging/tracking is not only relevant for better suggestions, visualizations, and evaluation of the concepts, it is also necessary to better understand reasons of food waste so that influence strategies could target more specific behaviors.

7.2. Other implications

Beyond this work, some other implications should be discussed. First, there is a need to stress the role of society in trusting and accepting domestic food-related technology for sustainability. A community-based system with the aim at supporting (collective) awareness and food sharing touches a very personal side of our lives. Any attempt to changing them is a challenging task. For this reason, technology should require low effort from users, while highlighting actions that are socially and economically appealing and acceptable. For example, if consumers could be motivated in reducing their food purchases (as a way to prevent food waste), money could be spend on other things, which would increase welfare (Rutten, 2013). But this is only hypothetical. Without reliable and solid data, policy makers have insufficient basis for introducing policy changes. Hence, the question remain on how societies could be motivated to participate in longitudinal studies that allows researchers to evaluate how sustainable food-related technology could have an impact, for example, on the economy. Another implication is how to balance health benefit vs. the goal of reducing food waste. Sustainable choices might not always entail healthy alternatives. On the other hand, according to Rutten (2013), a healthy choice is equal to a sustainable choice. She claims that it is better to accompany domestic food waste reductions with behavior changes towards a healthy diet as it costs less in terms of GDP and it requires less land. In the case of *Social Recipes*, for example, this would mean that suggestions should take into consideration a variety of food intake. Moreover, it could systematically reduce dairy and meat suggestions. These design implications should be considered equally important as the prevention of food waste. Furthermore, privacy should be taken into account. Privacy is an aspect that might deter consumers from using a system as proposed in this work. Technology that tracks in-home food availability and waste pervasively, and turn visualizes this to other users, could expose private matters. The information could also be a target for taxes, insurances, health inspections, child welfare etc. Therefore, an optimum balance should be found in supporting sustainable food practices and consumers' privacy. To understand how consumers are driven by these aspects, interdisciplinary research is necessary. The complexity of these implications shows a need for integrated collaboration between behavioral scientists, engineers, designers, economists, and nutritionists in developing food-related technologies for sustainability, as well as media to get the word spread out. In general, researchers should make better use of knowledge from outside their fields that has major relevance for food-related sustainability research. The main long term challenge within the scope of this work would be to explore the effects of application mediated interventions on consumers perceptions, values, behaviors, our economy as well as our environment.

8. Conclusion

Current developments in technology is working towards a seamless integration with our daily lives; appliances might be able to, for example, co-interact and support our food practices at home with low demands of our cognitive efforts. The work presented here could be of great value for the design of future home technology in creating awareness and engagement at both household and community levels. However, more research is required as this work contains limitations and further considerations that are not yet covered. Nevertheless, by providing the experience of design interventions in situ within a relevant context allowed us to better understand the constrains of the proposed concepts. It also helped in providing an understanding how technology can be leveraged to support collaborative behavior against food waste in a domestic environment through sharing.

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