Supporting Sustainable Food Shopping

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Abstract

Food is a surprisingly large portion of personal GhG emissions (estimated for the UK at 27% of total emissions). Could pervasive technologies help us to influence diet choice to reduce this? Reflecting on our experiences from several recent projects, we offer some lessons concerning the complexity of intervening in the food we buy and eat, and insights for designers of pervasive technologies addressing food and the GhG impacts of diet.

Introduction

In the UK, food production, distribution and consumption accounts for about 27% of total direct greenhouse gas (GHG) emissions. Changing diet from an 'average' to a plant-based diet could save as much as 22%-26% of this [1]. Yet, we have found creating pervasive technologies to both aid food shopping and communicate foods' GhG impact to be extremely challenging. Based on experiences over a number of studies, and having tried to automatically capture the foods consumed and purchased; and understand its significance from interviews and observational fieldwork in supermarkets - we offer several insights. Firstly, we reflect on how this incredibly mundane, everyday practice is simultaneously complex and nuanced, and identify challenges and opportunities for pervasive technology to support more sustainable food interactions. Secondly, we offer lessons arising from our experience that are particularly important for those designing technologies intended to influence diet, especially for sustainability reasons.

Food and Pervasive Technology

Supporting food shopping has been a subject of pervasive computing research for many years. Digital shopping lists (e.g. [17]), and tools that make use of purchase data for nutritional advice, navigating in store, and making informed recommendation of products were popular foci. We now find there are hundreds of digital shopping assistants, shopping list managers, recipe and diet applications.

Blevis and Coleman outline sustainable food technologies, including sensors, to aid growing, tracking food provenance, and supporting online food communities [2]. Ganglbauer et al. [14] studied a successful German food sharing community with the aim of avoiding waste. Focusing on 'sustainable choice', recent research has sought to promote sustainable food through education and feedback: GreenScanner is a smartphone application that allows shoppers to take a picture of an item's barcode and displays community-generated information about its environmental impact [25]. Similarly, the EcoFriends app presents the consumer with seasonality for scanned vegetables based on social media sites such as Twitter [22]. Lofstrom and Pettersen explored reactions to three types of eco-visualisations that highlight the symbolic qualities of food consumption, including a 'morally concerned teddy bear' that cries when 'bad' choices are made [20].

The shopping cart (or trolley) has also been instrumented to provide context-based services like in-store navigation; influence nutrition and 'nudge' shoppers towards reducing food miles [18,19]. In the kitchen, 'context-aware fridges' keep track of contents using RFID, 'Fridge Cam's' draw users' attention to the contents of the fridge to avoid opening the door for extended periods and avoiding food waste [13]. Farr-Wharton augment the fridge to increase awareness of the food in the fridge, and hence reduce waste, colour-coding compartments to encourage users to group similar food items together [12].

Social networks have also been used to explore 'social pressure' to change behaviour: Thieme et al. automatically photograph domestic waste bins when something is disposed of, and share these images on a social network [23]. Social networks have been used to provide ratings and recommendations, collaborative household shopping lists [17], and remote collaboration while shopping (e.g. asking advice by sending pictures to a friend) [21]. Moving on to cooking and eating, de Oliveira et al. [11] developed a smartphone app for efficient sustainable cooking such as the preparation of instant noodles.

Recent sustainability research has begun to argue that making sustainability about information and rational choices of the individual has major limitations due to its narrow framing of environmental sustainability [4], noting how everyday practices are defined by social and infrastructural factors. More recent work, such as that of Clear et al.'s study of impacts of student cooking [8], and Comber et al.'s study of food practices as situated action [10], have begun to recognise this broader context.

Food, technology and everyday life

Challenge 1: understanding factors influencing what's bought and eaten

To uncover why intervening in what people buy using pervasive technology is complex, we need to observe and discuss what they buy. In two recent projects we accompanied shoppers and talked about the foods they bought, and conducted phone interviews with supermarket shoppers. Shopping emerges as an unexpectedly complex activity where choices are made between similar items with varying properties, according to diverse preferences and values. Our participants would often explain what motivated their choices, in terms of children's preferences, diets, family circumstances such as visiting friends or occasional celebrations, cost and storage constraints, dietary restrictions, and so on. Whilst organic or processed foods, or constituent ingredients such as sugars, calories or fats figure, there was little reference to carbon footprint, except the odd comment about transport and whether food was 'local' or imported. Our interviews provide further insight: unsurprisingly, taste and the enjoyment involved in food preparation influence what gets bought and eaten, but these are weighed up against other important factors, particularly economy and convenience. Like Comber et al. [10], we find that "issues such as time, finances, taste, weight management, and food waste" feature most prominently.

This complexity is well captured by Warde [26], who describes four dichotomies that structure food consumption, outlining food choice as an ongoing resolution of tensions. The effect of two of these – extravagance/ economy, and convenience/ care – was particularly evident in our participants' food consumption. For example, eating at home was sometimes described as a necessary cheaper alternative to take-out and, convenience food was often reported as being consumed in place of more effortful but healthy alternatives. The tension between convenience and health was evident from remarks about the 'wrongness' of these practices: "*I snack as well, not that good for me, which might be because I don't eat regularly. Thinking about it, it's really not that good for my body, is it?*". For another shopper, seemingly unhealthy eating habits ("*I just eat really quick carbs, it's quite unhealthy*") enable a busy lifestyle of physical exercise and study practices to co-exist: "*I need food that's gonna fill me up for training but gonna be cheap and pasta's the only one that fills me up.*"

Our participants would explain their choices in terms of different family circumstances. As Charles and Kerr suggest; "*Food practices can be regarded as one of the ways in which important social relations and divisions are symbolized, reinforced and reproduced on a daily basis*" [7]. This suggests a relationship between the wider familial context and dynamics surrounding food. This is 'qualculation' (quality-based rational judgment [9]) - a complex process where decisions are made through weighing up of different interests of multiple stakeholders, even within a single family. The various routine activities associated with food shopping, cooking and consumption, have a very visible order and spatiotemporal characteristics [15]. It has a beginning: lists are written, cupboards checked, conversation about meals and diets and family activities take place. There is a middle: shops are entered and items are discussed and purchased. Then there is an end: food is prepared, cooked and served and waste is disposed of - organised within the household in relation to the broader social organization of the home.

We found food to be particularly sensitive to contextual factors like business, activity, planned events, current dietary interests, tiredness, and, of course, state of hunger. Most of our participants spoke of some structure to their food consumption, be it routine meal times or planned dishes, but even such plans were usually considered flexible. Quite often, impulses and constraints come together in the moment to, for example, displace a planned dish with a more convenient snack or to eat rather than do something else – "*I think I eat more when I'm in [at weekends], just more out of boredom*".

From this we can see that switching to more sustainable food, is more than just a question of making better fine-grained choices in the supermarket, but takes us into new territory about longer term diet and how this might fit with perceived household and availability constraints. This leads us to our first lesson:

Lesson 1: recognise the broader role of food within the context of daily life

Challenge 2: pervasive capture of what's eaten

One of the key issues facing any sort of pervasive system that provides feedback or recommendations about food, is capturing the foods consumed. We have tried various approaches from analysing shopping lists, to automated capture using loyalty card data. We reflect on the strengths and limitations of each approach below:

Shopping lists: capturing choice and decisions

Intuitively, we might think shopping lists can illuminate how people shop: they can tell us what people buy, sometimes the way a shop is organised and also give insights into the general frequency of purchases if one sees lists over multiple shops. They convey the shopper's (or household's) intentions and the planning process, presenting an interesting area for situating interventions. We spent some time collecting and studying shopping lists to see how exactly they were constructed and used, and their place in the social experience of shopping and cooking: we found considerable variation in terms of what they were constructed from, how and by whom they were assembled, and how they were used, or not used, during shopping. In Figure 1, the impact of a young child on the family shopping list can be clearly seen (though what notice was taken of this request is another matter).

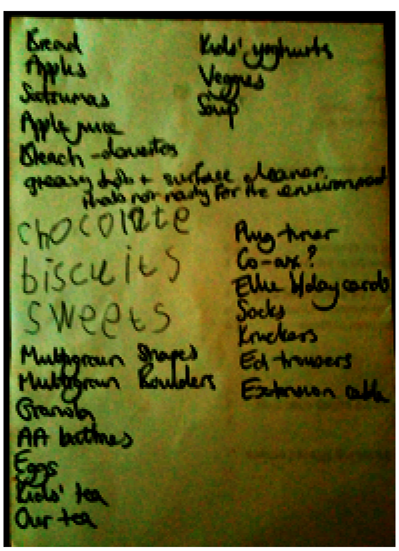

Figure 1: One of our participant's shopping lists.

Most of our lists were scribbled on scraps of paper but their construction and use varied. Some lists were drawn with reference to the cooking of specific meals whose ingredients were carefully documented (and sometimes ticked off). Other lists appeared to be constructed around the grouping of foodstuffs and in one particular case (where the wife wrote the list but the husband did the shopping) by reference to the layout of a specific supermarket. There was one instance of a shopping list constructed on a mobile phone. This also became an object of family cooperation in that the daughter who accompanied her mother shopping had the responsibility for deleting shopping items as they were located. Of course the mere existence of a list does not ensure that the list is used, that all list items are purchased, or that other items will not be seen and bought in store. In fact, research [3] suggests quite the opposite, confirmed also by one of our participants: *"Before I go shopping, I generally try and make a list of what I wish to buy – however often fail to follow this, and go round the aisles, picking up anything I choose. I then use my list at the end, to check if I have forgotten anything I particularly wanted".* Although some of our participants appeared to stick rigidly to their lists, others, like those in the Block and Morowitz study [3], bought other items and, for some, the list represented less than half of their eventual purchases. Grocery list compilation, like the shopping process itself, depends on navigating and intersecting knowledge about family, household and grocery store.

It is important for the designer of such systems to understand the ways in which the list can be understood, and in particular the way that the household and related people *understand* the list (lesson 2). In terms of expanding upon this and exploring technologies that, for example relate to the Internet of Things, one can see that combining, elements, such as shopping lists, household diaries and kitchen implements could provide a whole plethora of research opportunities.

Lesson 2: recognise the many ways everyday technologies such as the shopping list are understood

Manual capture of foods consumed

Tracking the foods that people actually consume, is similarly fraught with difficulty. Although we might tire of endless pictures of meals on social media websites, there is really an enormous gap between these pictures and the number of meals (and snacks) we actually consume. To exploit such a feed, or generalise it further by using body worn cameras, there is the question of how to turn the rich visual information into quantitative data we can use. We might ask users to enter their meals, as with 'quantified self' activity trackers, or calorie counters incorporated into diet plans, but this certainly requires a high degree of motivation from participants - and, like any food diary, offers considerable potential for omissions or creative accounting!

Automated capture of food preparation

In our 2013 paper analysing the direct and embodied GhG impacts of food in student residences [8], we used unobtrusive sensors including energy monitors and a motion triggered stills camera mounted above the cooking appliance. This was surprisingly effective for catching meals prepared on the hob, and even in the grill and oven. We captured nearly 12,000 images, and could competently identify the foods being prepared, and in what quantities. In our paper we find what is cooked, and how the impacts are repetitively constructed from a limited repertoire of meals. We were also surprised by how much more significant the GhG impact of the foods were than the direct (energy) impacts of cooking them in the majority of cases.

We should not ignore the shortcomings of our approach. Identifying the foods was certainly a manual process, and very time consuming. But further, we were not able to fully capture foods prepared in other ways (e.g. using the microwave oven), or raw foods (e.g. salads), that might have been lower impact meals. Thomaz et al. [24] investigated the feasibility of a variation of this approach for automated dietary assessment: in their approach, a wearable camera, strapped around the user's neck, was used to capture a photo log of daily activities. Food and eating related photos were then filtered out using Amazon Mechanical Turk with 90% accuracy, and these are annotated with location and meal type information. This approach captured a more holistic account of consumption compared to our method, but it is arguably more obtrusive and the granularity of the data is too coarse for quantifying GhG impacts (lack of food types and quantities). Further investigation is required to determine whether these factors could be accurately identified in photos from a body worn camera.

Capturing what is bought

In our recent work, we were fortunate enough to gain access to loyalty card purchase histories from a retailer for our participants. It should come as no surprise, that modern supermarket retail systems keep a record of what we've bought to a fine level of detail. This is valuable, not only for stock control, but linked with a persistent identifier, provides the grounds for loyalty programmes offering a longer lasting relationship with the shopper through targeted special offers and discounts. From the data we sampled, it was certainly possible to see all the goods purchased against the loyalty card for an extended period. From the timestamps, prices and costs, we could track the frequency and value of shops over time, but also correlate and compare the spend and GhG footprint of the products against the store norms.

The benefit of this approach is that the data is already in the digital domain and can be easily handled computationally. It could also be made available in real-time. For all its insightful detail, however, it is certainly important to recognise the limitations of this lens: we do not know how skewed a view this affords - anything not bought using the loyalty card is not visible to us. More importantly, any foods bought (or even grown) outside of the store are effectively invisible, and this includes potentially high impact foods such as fast food and food from restaurants, as well as lower impact alternatives, such as anything from organic box schemes, or the garden. Capturing the shopping receipts, as often available online, would suffer from similar limitations of view (lesson 3).

We have found that capturing the diet of individuals and the household is extremely difficult in the general case. For research and pilot scale studies then, the labour intensive methods we have trialled and described are extremely informative. We have found in our studies that there is considerable repetition in diet, so sampling the foods eaten periodically could generalise well. Supplementing observations and lists in the home with longer-term analysis of loyalty card data, may well support adaptive approaches where fine grained reflection is once again triggered when shopping patterns and diet changes are suspected. We pose the more general capture of food across our lives as a challenge to the community.

Lesson 3: recognise the limited view of pervasive sensing and commercial analytics

Challenge 3: attributing sustainability impacts to food choice

A final constraint for sustainable food applications is the degree to which we can assess the 'carbon footprint' of foods. This, unfortunately, is also complex. Carbon footprinting is a manual investigative process, necessarily requiring some approximations and simplifying assumptions. For background, the carbon footprint of a food accounts for the emission of the six Kyoto Greenhouse Gases involved in the growing and manufacturing of the food, from the source to the point of sale. This accounting includes gases emitted on the farm, as a consequence of, for example, electricity used, transport, processing, packaging and storage of the product before it is sold. Transport in turn includes the extraction, shipping, refining and distribution of fuel, and the manufacture and maintenance of vehicles. All products sold by the store, must also include the overhead of running the store, including energy used, staff travel, office consumables, and so on. The final figure for each product represents the sum of all of these elements multiplied by their global warming potential (GWP) relative to carbon dioxide over a 100 year period. Simple products with few or a single ingredient, like raw meat, fruit or vegetables, are less complex to account for than highly processed products (e.g. convenience meals) that are composed of multiple ingredients. If we truly want a footprint figure 'to our plate', then we should dutifully include the shopping trip, and preparing and cooking the ingredients too.

In terms of the local supermarket, with tens of thousands of products, footprinting each food is intractable. It also requires a high degree of openness on behalf of the company and its suppliers. We must by necessity choose a representative subset of products to stand for each product group, just to make the task tractable and affordable (lesson 4). With this, we can start to draw comparisons across product groups (e.g. chilled meats, vs. processed meats, or meats vs. vegetables). It should be clear however, that making fine distinctions between two similar products based on their impact, as we might wish if we were to build a shopping aid that offers product comparison, is not possible with this (state of the art) granularity of impact assessment. To illustrate further, consider the tomato: two brands of tomatoes might have very different impacts depending on their country of origin; whether they were grown using sunlight in the country of origin (in season) or in hot houses; and whether they were air, sea or land freighted. Or at least, two such products cannot be differentiated without finer grained GhG impact assessments based on these factors, and current information on the particular products in question. This is not easy information to gain access to due to the many suppliers involved, and there is currently no clear benefit for the supermarkets and suppliers to make this information available to developers or consumers.

Lesson 4: The resolution and tractability of carbon footprinting, poses further challenges for the design of systems recommending sustainable choices.

Future directions: Meaningful choices & the importance of context

Given the nuanced complexities of food shopping and food in the home, and the challenges of tracking the interactions with food - the question remains: how might pervasive food data be effectively incorporated into new, sustainable human-food interactions? Our focus here is on consumption, but we should rightly acknowledge how consumption sits within supply chains and institutions, and encourage further research into the scope for pervasive computing interventions that address sustainability beyond the consumer, too.

In terms of sustainability, with few exceptions, we find there is little direct concern with 'sustainability' or 'carbon footprint' – instead there is a mishmash of vaguely related practical and moral concerns, choices and dichotomies such as processed / unprocessed, local / imported, healthy / unhealthy, balanced / unbalanced, practical / impractical and so on, reflecting the various ways in which the activities of shopping, cooking and disposal are interwoven with other complex social and familial responsibilities and obligations. People are obviously not entirely unaware or ignorant or uninformed about their 'carbon footprint'. This is not just a case of simply providing more information – it is just that other issues, familial, financial, temporal, spatial issues, and so on, take precedence in the mundane, everyday tasks of shopping and cooking. The context of food consumption is complex and multidimensional, often subjective, and markedly absent from the pervasive data that we have discussed (i.e. shopping lists, receipts and loyalty cards, prepared meals). However, if we hope to provide useful recommendations for more informed choices around food, they are likely to be most effective, and meaningful, if they overlap with these factors. We are reminded here of the importance of not limiting ourselves to just 'corrective technologies', but also to support everyday food [16]. From our accounts, there are various levels of granularity at which we might consider framing and food intervention:

Individual products: Regarding the utility of different types of change, it seems that substituting ingredients would involve the least amount of effort for the user, but the changes that can be made are limited without ramifications for the meals to which they belong, and, substitutions themselves might be constrained by the preferences of other household members. Given the multitude of factors people already need to take into account when deciding what to buy, and the generally low priority that sustainability takes for them, it is clear that messages about environmental impact need to be carefully integrated. Our participants mentioned quality, cost, price comparison (i.e. cost per biscuit), health ("E- numbers") and environmental impact, as well as taste, convenience, and storage. A digital shopping list might offer an ‘augmented view’ not possible with paper lists, that indexes into, and celebrates (e.g. taste, organicity, ‘naturalness’) [16], availability of what is seasonal, or low-carbon, available nearby from sustainable sources, while taking into account these other factors. Of course, some of them are not straightforward to capture, like ‘convenience’, and would perhaps require user mediation. And, incorporating all these features could easily result in a complex application that is more off-putting than engaging. Given this, and the various ways in which lists are used, or rather not used in the store, it may be more effective to exploit online food shopping portals, or adjust how the stores’ fill online orders, rather than simply target the list.

Meals: Alternatively, we might aim to change entire dishes that are consumed. If we can capture dishes, and their context (e.g. ‘economy’, ‘little preparation effort’) – perhaps making effective use of user mediation, again – there is potential to suggest more meaningful, and impactful (in terms of sustainable practice) alternatives than might be the case for individual products. We would caution, however, that substituting entire dishes requires a potentially much larger burden on the user, perhaps introducing them to new foods and cooking methods, and importantly, reducing the efficiency of the shopping and meal preparation process. And, efficiency in food practices was clearly valued many of our participants, evidenced by the construction of structured shopping lists, hurried visits to the supermarket, and appreciations for convenience foods.

An alternative approach to food practice transitions that might better fit with the participants in our studies, is to refrain from more effortful changes to practices (e.g. introducing new recipes) until time when users might be more attentive to them. In our findings, these might be times when food plans are vague, for example when ‘Kids tea’ or ‘Veggies’ appears on the shopping list (Figure 1), or when participants are actively searching for or reading recipes. Or, a perhaps more difficult one for computer recognition, when dichotomies or food choice are in the process of being shifted, for example when convenience food habits are being shifted to more healthy ones, or when saving money becomes of greater importance.

Supporting flexibility and compromise: Although we saw participants whose food practices involved little planning, many participants were quite organised and purchased foods with a mind towards the meals that they intended to eat over the following days or weeks. However, often plans did not materialise, as some other practice or event is prioritised and got in the way, e.g. being late for work, in a rush to get to lectures, or in the mood for a take-out or more convenient snack. Such alterations to pre-planned meals can occur on any time-range, from deciding ‘in the moment’ what to eat, to deciding to attend an event or do something else a few days in advance. These deviations often introduce challenges to future food plans as fresh ingredients become closer to their use-by dates, and so future plans around food need to be reshuffled too, or, perhaps more likely, ingredients get thrown away.

We might support this tendency to improvise around planned food consumption to avoid waste: a ‘smart fridge’ (e.g. [5]) might be integrated with a user’s calendar to draw attention to changes in meal plans as soon as possible, perhaps suggesting a different set of meals for the coming days that ensure perishable ingredients get used earlier, or giving advice on cooking in advance and methods of cold storage. A further interesting direction might be to provide a means of sharing unwanted produce that is close to expiry with an online community (or even with house sharers), or make it available to food poverty organisations like food banks. A cross-cutting challenge to any of these applications is that meal units be automatically identified from individual foods that a user or household possesses. Building on the work on the recognition of shopping list items, accurate recognition might be achieved over time using purchase and use data (e.g. items removed from the smart fridge).

Given that we see in our studies compromises between multitudes of factors, we might also consider that transitioning to more sustainable food consumption would entail a series of compromises, of trying and evaluating, of varying the extent to which ‘sustainability’ is optimised. We should therefore consider designing recommender systems that are flexible enough on a number of dimensions to increase the likelihood that some of them will be meaningful, but also to allow that ‘sustainability’ will not always be comfortably optimised. And so, a digital shopping assistant might well present the user with a spectrum of more and less sustainable choices to support compromises with other factors that are important to them.

Broader concerns for changing food practice: When Casey [6] writes that *‘new technologies will succeed or fail based on our ability to minimise the incompatibilities between the characteristics of people and the characteristics of the things we create and use’* we naturally agree, and suggest that there are some important challenges associated with engaging users in the environmental agenda, challenges that the mere provision of information may not meet. Household dynamics, and the overall organisation of everyday life, often serves to limit the possibilities for how food ultimately plays out in practice. A crosscutting concern in many of our participants’ accounts of shopping and meal preparation is that household members are fed in an economical way. Often, this simply involved compromises to fit some form of food into a busy or stressful day, and this was highly influenced by the availability of convenience foods in the supermarket.

Our focus on food practices misses out on the broader influences related to lifestyle that indirectly impact on the sustainability of food consumption in this way. To some extent, by seeking richer accounts of these contextual properties of meals, we are bringing into question ‘what food is for’ – highlighting pivotal factors and appreciations like convenience, sociality, and spontaneity. But, might interventions be more effective by acknowledging that the overall configurations of our daily lives affects the foods that we eat in more or less sustainable ways. An interesting avenue going forward, is to consider how digital interventions might draw attention to the ways that busy lives, stress, boredom, etc. are linked to potentially unsustainable (over)consumption, and encourage deeper reflection on the significance of our particular diets and meals in the context of our everyday lives.

Conclusion

We have used a series of our recent studies to provide insight into the many factors and influences that shape decisions around food shopping. We have also illustrated from our experience, the challenges in capturing what is bought and consumed automatically. We found that, beyond individual product qualities like price and convenience, people's food practices are heavily influenced by a multitude of other factors and constraints – like storage and transport, and less predictable, but perhaps more influential, factors like social dynamics and state of fatigue or hunger – that pose important challenges for the design of systems to encourage more sustainable food practice.

We offer some lessons from our studies to designers of pervasive systems that influence food choice, particularly in sustainability terms:

1. *Lesson 1: recognise the broader role of food within the context of daily life*
2. *Lesson 2: recognise the many ways everyday technologies such as the shopping list are understood*
3. *Lesson 3: recognise the limited view of pervasive sensing and commercial analytics*
4. *Lesson 4: The resolution and tractability of carbon footprinting, poses further challenges for the design of systems recommending sustainable choices.*

But, more holistically: the design of digital technologies focused on guiding users towards more sustainable shopping practices requires addressing challenges both technical and social in nature, and it is critical that we think about this broader design context. One of the key themes that emerged relates to the constraining force of family dynamics on what gets purchased and prepared, suggesting that effective interventions might be those that bring out and leverage the collaborative nature of household rather than individual food practices.

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