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ORIGINAL ARTICLE

Understanding food consumption lifecycles using wearable cameras

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Abstract Application of design in HCI is a common approach to engendering behavioural change to address important challenges such as sustainability. Encouraging such change requires an understanding of current motivations and behaviours in the domain in question. In this paper, we describe use of wearable cameras to study motivations and behaviours around food consumption by focusing on two contrasting cultures, Malaysia and the UK. Our findings highlight the potential of wearable cameras to enhance knowledge of food consumption practices and identify where and how some digital interventions might be appropriate to change food behaviour. This includes appealing to people's motivations behind food consumption and capitalising on existing practices such as gifting of food and social meals. We propose a food consumption lifecycle as a framework to understand and design human–food interaction. The use of wearable cameras enabled us to capture a high-level overview of spatially distributed food-related practices and understand food behaviours in greater depth.

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1 Introduction

Design is commonly used in HCI to respond to a range of societal challenges, often currently with a focus on sustainability and the use of persuasive technology to engender necessary behavioural change [14]. At the micro-level, it is often the behaviour of individuals that lies at the heart of effective interventions in such domains. It is individual behaviour that drives acceptance of economic pressures and regulatory frameworks and leads to change in everyday practices and attitudes.

Recent work has considered reduction in energy consumption [8, 21], but there are numerous domains that have received less attention. One such that forms part of a broader sustainability agenda is food security: ensuring that all people at all times have both physical and economic access to the basic food that they need [15]. An increasingly pressing concern due to an increasing world population and climate change, it is exacerbated by our overreliance on just three crops (maize, wheat and rice) for our food supplies [24]. Addressing this requires responses at many levels [9], from agricultural science, to the economics of supply and demand, to governance and regulation. Understanding food consumption behaviour is an important component in these responses as it is consumption that drives demand and thus is a key incentive in how suppliers behave.

This paper is thus motivated by the desire to explore the extent to which technology could be exploited to help address this challenge. Whilst this is a research challenge being tackled within specific disciplines such as nutrition

[24] and anthropology [27], DiSalvo et al. [14] argue that there is an opportunity and necessity to add to combine these interconnecting threads across scholarly disciplines through HCI design. However, food studies within HCI research have been few and limited in scope so far [10, 11, 16]. To design for meaningful and positive interactions, we must first understand current food-related behaviours and the role that technology plays in them [11].

We present results concerning the use of wearables—specifically, wearable cameras—as a means to gain this understanding. We explore the wider context of food-related activities and the motivations driving them. Through the camera studies, it was possible to build a clearer picture of overall food consumption. As food security is an inherently global issue, we have focused our work on two contrasting cultures, Malaysia and the UK, with the aim of providing a more rounded perspective of food-related behaviours and motivations. We synthesise our findings into a design framework based on a food consumption lifecycle to assist in placing our findings in relation to previous HCI research.

The paper begins by reviewing related work to provide necessary background and describing the camera method, study participants and findings. We then propose a food consumption lifecycle, discuss design implications and reflect on the method before concluding.

2 Related work

This section reviews the literature on food research in HCI in general which show some examples of digital technologies introduced to encourage social interactions, healthy eating and sustainable consumption behaviours. It further discusses a number of research efforts and approaches currently employed to study food behaviours and consumption patterns.

2.1 HCI and food

Food and interaction design have started to receive some attention in HCI. Previous human–food interaction studies have focused on areas such as food experiences and health and well-being [11]. The process of eating can have strong social influences. Online social networks such as Foodmunity can make it easier for communities to organise food-related events as a method to bond between neighbours [20]. Telepresent family dinners, as explored by Wei et al. [40], also used food activities as a medium for remote family communication.

Technologies to promote healthy eating have begun to target users, not only at the point of eating, but at the time they shop so that they are able to make healthier choices.

For example, Healthy Shelf [2] deployed on kiosks attached to supermarket shelves allows users to change the serving size on the labels in order to view the corresponding nutritional values. In future, shoppers may be able to share photographs of potential purchases using their mobile phones in order to consult with others [28]. Digital interventions at the point of eating have also explored the use of crowdsourcing community platforms to allow users to estimate their food intake and composition by sharing photos of what they are eating [29]. Some research have looked at encouraging healthy eating in workplace cafeterias using public displays and mobile applications [7].

More recently, a number of research studies have begun to explore digital technologies to support ecological sustainability with the aim of reducing the impact of food-related practices to the environment. These have included studies of greenhouse gas emissions connected to cooking [10] and a household study to understand everyday domestic practices around food and waste to inform interventions [16]. In response to these studies, technology is now being developed that aims to promote more sustainable food behaviour, such as the "BinCam" [37] to share photos of waste disposal on social networks in a bid to change existing habits and "Foodsharing.de" to support a free food sharing community to save food from being wasted [17]. For supporting local business and regional food cultures as part of sustainable food purchasing behaviour, "LocalBuy" enables buyers to purchase fresh and healthy food directly from the local producers [26], whilst "Edible earth" [3] and "Tastebooks" [5] provide suggestions of local and seasonal recipes tailored to the user's location.

A few studies have explored designing interactive systems to support sustainable ways of living through alternative food cultures such as wild food foraging [6] and small-scale urban food production in community farms [32]. An example of a knowledge tool for ensuring food security in response to climate change includes a prototype for an online tool to help people design and create back yard agricultural ecosystems to match their local habitat, climate and weather [30]. In a separate effort to support urban food growing, visitors to a community farm can use a watering can augmented with RFID technology to hear plants talk to them [22]. Whilst many food-related work in HCI have focused on food and sustainability issues more generally, studies to promote diverse eating has yet to be directly addressed.

2.2 Studying food behaviours

Many disciplines and fields offer perspectives about food practices and decision-making, particularly psychology, economics and philosophy. Food choice decisions are

multifaceted, complex and dynamic and lead to food behaviours where people purchase, prepare, serve, give away, store, eat and clean up [36]. Factors influencing food choice are not only based upon individual preferences, but constrained by circumstances that are social, physical and economical [34]. Food choice factors also vary according to life stages. A person's life-course transitions and trajectories (persistent thoughts, feelings, strategies and actions over the lifespan) are fundamental influences on the development of his or her personal system for making food choices [13].

Methods for studying food-related behaviour often rely on broad quantitative studies or qualitative interviews and observations. Self-reported experience sampling techniques such as diary studies can also be used, but can suffer from reliability problems, especially when people are asked to report the food they have eaten [36]. Observations can overcome these problems but may not be over the extended periods of time being studied and the unpredictability of the behaviours we wish to study. To tackle this, previous studies of food-related behaviours have used cameras situated in the kitchen to capture food-related activities. These include the "Hobcam" [10] and "FridgeCam" [16]. As such, newer strategies increasingly rely on technology, building upon work in digital ethnography [39]. For example, Paay et al. [33] studied a selection of YouTube videos to examine the spatial patterns created between cooks and kitchen spaces, whilst Hutchinson et al. [23] described the use of technology probes, the messageProbe and the videoProbe co-designing technologies with users. However, as the behaviours we are interested in span a number of locations, we have used wearable, first-person-perspective cameras that capture images of food-related activities over prolonged periods of time. These images were then used as resources for prompting reflection in interviews.

The emergence of wearable cameras has allowed researchers to explore their use as research tools. For example, SenseCam has been used to support ethnographic techniques to capture work practices and provide visual records to prompt follow-up discussions [4]. Mobile phones have also been used to help document dietary choices through being worn around people's necks and the resulting images being annotated [35]. SenseCam has been used to establish the reliability of self-reported calorie intake in food diaries. In this study, it was found that out of 34 participants only one food diary accurately matched the actual intake [31]. Thus, passive monitoring can overcome the issues with traditional self-reported measures, but the authors of this work state that it should augment rather than replace existing techniques.

3 Method

This research was carried out in both Malaysia and the UK between November 2013 and September 2014. The study arose in the context of a major collaborative programme into global food security spanning Malaysia and the UK, supported by the Malaysian Government. The locations were chosen to provide design insights across two different contexts and cultures where there are diverse influences on food eaten. We take the context of Malaysia as not only a practical concern as a developing nation, but also an interesting case study in cultural terms. Malaysians famously love food, and it plays a central role in Malaysia's historical and current context. UK food has influences from, for example, European, Indian and Chinese cuisines, alongside the indigenous food produce. This provided an opportunity to engage participants in these two countries and to study food consumption in diverse cultural settings in the UK and Malaysia to gain a rounded perspective.

We employed a camera-based method to gain an understanding of food consumption habits and motivations for buying fruits and vegetables. We investigated this using wearable, first-person-perspective camera—the Autographer [1], the world's first commercial wearable camera. These wearable cameras can be clipped to clothing or worn around the neck (see Fig. 1) and passively take still images every 10–30 s (depending on sensor values). We next describe the camera-based method that we employed.

3.1 Camera study overview

The camera method was inspired by previous studies using the SenseCam (the predecessor to Autographer) to study food-related and broader behaviours [4, 31]. As we have already discussed, traditional methods such as diaries can suffer from reliability problems and subsequently visual data collection is becoming more common in this domain. Through utilising an approach that captures images automatically, a more accurate representation of the food being consumed by the participants can be achieved. In addition

Fig. 1 Autographer camera worn around the neck (*left*) and clipped on (*right*)

to this, the images illustrate the moments before and after food consumption, allowing us to see what may have prompted food choices or the method of preparation. However, whilst providing additional context to food consumption, images alone cannot provide a full understanding of the behaviours.

In our studies, the images generated by the wearable cameras were used as prompts in interviews to generate "thick descriptions" related to the activities of interest. These thick descriptions allow behaviours and their contexts to become meaningful to the interviewer [18], and they formed the basis of the data analysis.

Our participants wore the cameras for 1 week in the home and public spaces. A week was selected for the duration of the studies in order to capture a range of meals and contexts. However, the interviews also covered more general, longer-term behaviours not captured by the cameras, such as infrequent shopping trips or other types of food being consumed.

After the study period, the participants returned the cameras to the research team. At this stage, the images were analysed informally by a researcher who viewed all the images and tagged any that required clarification or showed activities of particular interest. During the hour-long retrospective interviews, participants were shown the images in chronological order to provide context, with tagged images being viewed more closely and discussed in depth. General themes of questioning were the rationale behind food choices (particularly fruit and vegetables), any supporting tools and the motivations driving behaviours.

3.2 Participants

Recruitment in the UK used online recruitment and word of mouth. In Malaysia, snowball sampling was used. Ten participants were recruited in Malaysia and eight in the UK (see Table 1).

We recruited the main household shopper (the higher proportion of females in Malaysia representing cultural differences). Our focus areas were urban and suburban, where participants could choose from a wide variety of food. In the UK, the age of the participants ranged from 20 to 40s (three males and five females). The household make-up included two participants living alone, two living in multiple occupancy households (but cooking alone), two living with a partner and two living with their spouse and children. In Malaysia, participants' ages ranged from 20 to 60s, with nine females and one male participant. Four participants were employed, whilst the other six were homemakers. One participant was single (but living with parents), one lived with a partner, six lived with young children, and two lived with older children. Household sizes ranged from two to over seven.

3.3 Analysis

The use of wearable cameras to study food behaviours allowed us to elicit rich findings from interviews. The outputs of the study included all the images taken by the camera (over 15,000 images minus those deleted by the participants) and transcripts of the interviews. The

Table 1 Demographic profile of participants. Participants from Malaysia are coded in M, whilst participants from the UK are coded in U, followed by a numerical identifier

Gender	Women		Men	
	M1, M2, M3, M5, M6, M7, M8, M9, M10		M4, U1, U2, U4	
Age	20s	30s	40s	>50s
	M3, M4, U1, U2, U3	M2, M5, M6, M7, M8, M10, U4, U5, U6	U7, U8	M1, M9
Work status	Employed	Self-employed	Student	Homemaker
	M3, M4, M5, U8	M6	U1, U2, U3, U4, U6	M1, M2 M7, M8 M9, M10, U5, U8
No. of household member	1–2	3–4	5–6	>7
	M3, U1, U2, U3, U4, U6, U8	M2, M4, M5, M6, M7, M8, M9, M10, U5, U7	–	M1
Lifecycle stage	Single	Couple	With young children	With adult children
	M4, U1, U2, U3, U8	M3, U4, U6	M2, M5 M6, M7 M8, M10, U5, U7	M1, M9
Ethnicity in the UK	White	Asian	Other	
	U1, U3, U4, U5, U6, U7, U8	U2	–	
Ethnicity in Malaysia	Malay	Chinese	Indian	Other
	M3, M4, M9	M1, M5, M6, M10	M7, M8	M2

transcripts were the main focus of the data analysis and were subjected to a qualitative thematic analysis (using open coding) to identify common themes, decision points and rationale behind food choices.

4 Food consumption activities

We now present our findings structured around five key phases involved in food consumption. These are: planning, procurement (whether shopping, gardening or foraging), preparation, eating and disposal, each of which is mediated by different tools.

4.1 Planning

Planning is a process that underpins the entire consumption lifecycle, with people planning shopping trips, cooking activities and meals. The extent of this planning differed between participants, with some planning their meals and the necessary ingredients in advance, and others choosing to leave decisions until they reached the shop, often making use of offers to save money. In the camera studies, less than half of the participants used shopping lists to plan what they needed to buy. When they were used in Malaysia, participants appeared to be closely guided by these when shopping in supermarkets: "I just create a list, so I just go in and get all I want. I actually don't care what's on sale" (M5). However, use of lists was not common in other places such as the market. One participant, M3 reported using a list only when shopping for special occasions: "I use list only when I have a dinner party or a big meal. Like yesterday, I did a breaking Ramadan's fast meal for my friends, only then I did a list".

Shopping lists were predominantly made on paper; however, one UK participant (U1) used a phone to create his list whilst standing in front of the fridge. In this instance, he wanted to ensure that he purchased foods that could be used with what he already had: "I have a look at what I've got and then I try and think of meals that I can make from it, and then what I need to make it…". In fact, the fridge was often used as a general space for planning food purchase. A UK participant (U5) routinely put their shopping list on the fridge: "… when I go shopping and I'm putting it away, I write a list of all the sell-by-dates, because I kept wasting food, and then I keep my list on my fridge".

4.2 Procurement

In the UK and Malaysia, it is common to find a number of large supermarkets, smaller "local" supermarkets and specialised shops such as "greengrocers" in towns and cities. It is also becoming more common to shop online from these stores

(though only available in Malaysia in recent years), with the ability to have shopping delivered to your front door. In the UK, respondents predominantly reported shopping in supermarkets. Contrastingly, markets are more popular in Malaysia than in the UK.

Different types of markets exist in Malaysia including wet markets (usually an indoor, fixed market), morning markets (a type of wet market with stalls along one or more public streets) and night markets (opening at night). The variety of produce and the cultural differences present in Malaysia mean that shopping is a more fragmented process. People shop at a number of locations, such as supermarkets for purchasing common produce, and markets and stalls for less common produce (see Fig. 2).

M5 stated that they shopped at the market "because it is fresh and much cheaper. Sometimes in the supermarket… the fruits and vegetables they already pack, you don't know whether it is good". They also sometimes shopped at multiple places on the same shopping trip. For example, M1 said that "normally on a Saturday, I will go to the wet market…then I come back to [the] morning market to buy vegetables. The wet one, I normally buy fish, pork, chicken and fruits because they have more variety and [are] fresh. And down here I will only buy vegetables because they are much cheaper". Another participant M5 was seen to use shopping in a supermarket more as an educational opportunity to teach her son about different kinds of vegetables: "Partly because they are very good at displaying the vegetables with information on the board". However, there was little evidence of technology being used to support the shopping process.

As well as buying food, participants in both countries made use of gardens or wild plants for food. Seven out of ten participants in Malaysia grew some of their own food either in the garden or in indoors (see Fig. 3). Participant

Fig. 2 Market sellers selling local, traditional produce

Fig. 3 Examples of lesser-known vegetables grown in participants' gardens—sword beans (*left*) and winter melon (*right*)

M10 attended a permaculture on sustainable living course and subsequently had planted many varieties of lesser-known crops in her garden such as sword beans in support of local, tropical crops. The Malay participants would often plant "*ulam*" (herb salad of Malaysia) vegetables in their own garden or in their home villages.

This way, they would not need to rely on the inconsistent availabilities of "*ulam*" varieties found in markets. There was also evidence of neighbours exchanging their home-grown produce: "my neighbour grows soursop and gives it to me…I give him veg, he gives me fruits. I gave him spring onions. He gave me papaya. It is becoming normal. I have been passing my veg to other neighbours" (M10).

In Malaysia, gardening played a more prominent role in the procurement of food, possibly reflecting climate differences.

In the UK camera studies, there was little evidence of participants growing their own produce. One family (U7) was seen foraging for blackberries and also picking apples and green beans from their neighbour's garden (with permission). Later, they used the blackberries and apples to make a dessert and also used the beans as part of their main meal. Technology use to support gardening was minimal, but M10 was seen to be text messaging a friend to seek some gardening advice and using websites as part of her research in sustainable gardening.

4.3 Preparation

The choice of food in the UK was often habitual and routine, with meals being repeated on a frequent basis and similar groceries being bought each week, often for reasons of convenience and time. The use of leftovers was prominent, with participants cooking large batches of food and re-heating these. Wastage was a key motivator behind meal planning, with meals sometimes being dependent on what had the nearest "use-by- date". Participants in Malaysia also reported having a routine to the meals they planned: "Every week I bake the minced pork…. Another day is pasta because my son loves pasta. I will cook soups twice a week because I love soups. [My partner] makes bread once a week. So on the day he makes bread, [we] will make a soup to go with the bread. So that is another day set…" (M10).

Recipe books are a key tool for supporting the cooking process, with ingredients and preparation instructions provided in them. The use of recipe books in the UK and Malaysia was infrequent, reflecting the routine nature of the meals being cooked. People often knew the recipe "off by heart" and would adapt these to the available ingredients. When recipe books were used, this was when something new was being cooked. For example, U7 looked up how to cook the green beans that they had picked in their neighbours' garden. For this, they used a recipe book that they had used when taking part in a "veggie box" scheme (where a selection of seasonal vegetables are delivered on a weekly basis): "… it's like in alphabetical order of what to do with the vegetables…. So it just tells you when it grows and how to keep …we bought it because quite often when you get the veg boxes, you end up, with vegetables … that are a bit more uncommon, that you don't know what to do with. Like loads of artichoke and spring greens, celeriac—things that you, perhaps, wouldn't normally get."

Mostly, physical recipe books were used, but occasionally, online searches were carried out using phones or other technology. For example, M4 looked up information about food that was eaten by colleagues in their office pantry that he was not familiar with. In the UK, U2 used the Internet to search for recipes for food they had purchased but weren't sure how to prepare in a certain way.

4.4 Eating

When it came to eating, the UK participants who lived alone almost exclusively chose to eat whilst consuming other media such as TV or e-books: "I like to watch something when I'm eating because otherwise it's just a boring quiet room, because my housemate's typically out" (U1). Only one Malaysia participant was observed doing this. This behaviour was also evident in the UK family households, but in general, they ate together at the table.

In Malaysia, eating with others offered opportunities to support relationships. These shared food experiences are considered "special occasions" which offer opportunities to enjoy foods that might otherwise not be eaten or be cooked in certain ways. For example, participant M1 often made Chinese hot pot (or steamboat as it is known in Malaysia) to bring the whole family together. She explained, "Steamboat needs a longer time to eat where whole family will chit chat and come back together".

There were many instances of participants (both in the UK and Malaysia) using their phones to take photos of their meals. In the UK, U2 talked about how he liked to share images of his meals on social media "I post it on Facebook, whenever I cook….if it looks good…. I've gotten good [comments],.. So I keep taking photos".

In Malaysia, the practice of eating out is an urban trend. Most participants have regular food outlets that they frequent or would try one based on recommendations by friends (see Fig. 4). In the UK it is not as common to eat out as it is in Malaysia and other countries. This could be related to cost and also habit (U2: "…It's basically economics. It's much more expensive").

Fig. 4 Examples of food outlets in Malaysia serving local, traditional food—a Malay restaurant (*left*), a street vendor selling "rojak", a local fruit salad mixed with prawn paste (*middle*), a bitter gourd noodle food stall (*right*)

4.5 Disposal

In Malaysia, a number of participants used food waste to feed plants. This sustainable food practice was often learnt from older relatives or word of mouth: "Anything that left over my mum also will do that, like yogurt and milk" (M7).

Four of the Malaysia participants had compost heaps where they transformed nonedible fruits and vegetables into compost that they would then use as fertiliser. The fifth participant fed peelings to her herbs in pots sitting at the windowsill of her apartment. She had learnt this from her mother, as according to her, there was a strong culture of recycling food waste in India. In the UK, none of the camera participants had a compost heap, although one participant reflected on the fact that they had tried to build one, but it was not successful. As observed, participants tried to limit food wastage by making use of leftovers and planning meals to use up groceries close to expiration.

5 Motivating factors

As well as looking at activities, our research has also explored the underlying motivations behind food consumption. These impact on specific activities, as well as behaviours more generally. We present the key factors affecting decision-making in this section. These include knowledge and sensory appeal, health, family/cultural influences and waste.

5.1 Knowledge and sensory appeal

In Malaysia, the most cited reasons for not eating less common fruits and vegetables were a lack of knowledge (e.g. not having heard of fruits/vegetables, or not knowing how to cook them) and dislike for the texture, smell and taste. Some of these locally produced fruits and vegetables tend to have sensory features such as a bitter (e.g. bitter gourd), sour taste (e.g. soursop) or a strong smell (e.g. durian) that could cause dislike. Participant M1 reported not buying lesser-known crops from a market seller because she had previously found them to be too sour (see Fig. 2). This implies that taste and lack of knowledge about

how to eat or prepare such sour produce posed as barriers to her level of acceptance.

Another example also suggested that the lack of knowledge in food preparation had frustrated an attempt by participant M10 to try cooking a local, traditional vegetable fern, known as "*pucuk paku*" in Malaysia (see Fig. 5, left): "I bought paku from this shop. I happen to see. I don't know how to cook it well. This is my first time. But when we go to the restaurant and there is paku on the menu we will always order paku".

Other examples showed that the small number of participants who did consume certain produce (such as bitter gourd) on a weekly basis did so because of their knowledge of how to prepare it in a way that tasted nice.

"…when we go to the Indian restaurant we have the crispy bitter gourd. It's like a tempura kind of thing. I started liking it from the Indian restaurant. So I started buying it and cooking more. When you mix it with the chili and turmeric powder it tastes nice and crispy" (M2).

Many participants were seen to be blending two or more fruits, vegetables and spices so that they taste nice and give them health benefits. For example, M10 said: "We make juice a couple of times a week. We always have kedondong. We just bought it and liked it. It was available near our house. It was my aunty that first taught me to juice it".

Typically, the knowledge of how to eat or cook local fruits and vegetables often resides within a certain ethnic community such as the traditional Malay community. However, findings show that two participants M7 and M8 who came from India and had lived in Malaysia for more than 8 years managed to learn how to consume local fruits and vegetables from eating out in restaurants and from fruit vendors. M7 said that: "This one I try the soup. I try in a

Fig. 5 A local, traditional vegetable fern bought from a shop (*left*) and bitter gourd for juicing (*right*)

Chinese restaurant. I asked 'what is this cabbage' because the cabbage taste is different. They said it is Chinese cabbage [and] no need to put salt in it… Now I use it to make salad because this has more calcium, compared to normal cabbage".

From the examples above, we speculate that an increased knowledge on how to prepare or eat local fruits and vegetables will inadvertently encourage consumers to consume them more, thus increasing their demand.

5.2 Health

Some participants were seen to consume fruits and vegetables even though they may be off flavour and bitter (see Fig. 5, right), purely for health reasons: "Yes, sometimes I buy soursop. My children and I like the taste. If not nice I will also eat because people told me it is very good for health" (M8). Concerns about health as a result of sickness drove another participant (M10) to healthier food options: "We are actually health conscious… I got very sick when I was in my 20s. I felt very fatigued for a few months. And after that … I did a lot of research and I discovered alternative health. And I started from there. We grow sword bean (a lesser-known vegetable). We try to buy organic. We always go for healthier option when we can afford it". From these examples, it might be thought that raising awareness on the health benefits of lesser-known fruits and vegetables should result in an increased intake.

In the UK, health was also a key driver behind food choices, although this linked less directly to fruit and vegetables, and more to do with a balanced diet: "So, this year I've started looking at what was in my food because I was struggling with exercise last year… I tend to try and buy stuff that has low saturated fat" (U1). U3 was doing weightlifting so was keen to balance her meals and control the intake of certain things. "I try to stay low GI. So I'll eat fruit and stuff in the morning. That's why I enjoy it with porridge". Health was a strong driver for parents, with them trying to increase and diversify their children's intake of fruit and vegetables.

5.3 Family/cultural influences

Our Malaysia data showed cultural differences in eating patterns reflecting the strength of culture as an influence on food consumption. Participants cooked dishes linked to family traditions and ethnicities, with the majority of participants noting that they had learnt traditional recipes and cooking methods from female relatives: "When I was young I stayed with my aunty. So when she needed to cook, I would..see how she cooked".

The Indian participants in our study were found to follow their cultural practice of vegetarianism, preferring to consume "Indian vegetables" such as drumstick, patola, pumpkin or other melon-based vegetables. The Chinese participants often stir-fried or boiled their vegetables, preferring imported ones. The traditional vegetables were only preferred by the Malay ethnic group, where they were consumed as "ulam". Participant M3, for instance, preferred consuming "ulam" daily because she grew up with her parents eating it every day.

In the UK, there was evidence of participants picking up a taste for certain flavours or spices from their family and also from their travels: "when I was a kid we used to have like, a chilli or a curry… So we had quite, sort of, spicy stuff….So think that contributes to my liking of it… And I'm much more adventurous than I used to be because I went to Japan a couple of years ago and before that I was, like, just stick to the kind of meats I know, but now I'm, kind of, like, try everything, it's brilliant" (U4).

5.4 Waste

One of the strongest food motivators in the UK studies was the desire to avoid waste. This would impact on what people bought in the shops and what they chose to cook on a specific day. U5 used sell-by-dates to try and avoid this: "I write a list of all the sell-by-dates, because I kept wasting food, and then I keep my list on my fridge". In the UK, U1 was exposed to an article about Kale in a fitness magazine, which prompted him to go and buy it. However, he was put off by the size of the packaging and the desire to avoid wasting it: "I did buy [kale] after reading that, because they were saying how good it is for you … I wouldn't buy it again because it didn't taste that great… and you get so much in a bag that I would have to use it, like, every other day. You could only buy it in one size that's why I wouldn't buy it again".

When probed, participants found it difficult to express exactly why this was such a strong driver. Yet there may be links with recent initiatives in the UK for reducing waste. Food waste accounts for almost half of all waste-related CO_2eq emissions [12], and with the UK government pushing for a "zero-waste economy" [38], a number of campaigns such as "Love Food Hate Waste" have been deployed. Subsequently, for example, participants often chose meals that made use of the same standard ingredients in order to use up a whole packet of food.

6 Food consumption lifecycle

We now turn to wider discussion of our findings. They suggest that much of what people choose to eat is dictated by *routine* and *sensory* appeal and that a lack of *knowledge* about how to prepare more unusual food may act as a

barrier to eating diversely. We also know that motivations behind food consumption more generally include *health* concerns, *cultural* influences and a desire to avoid *waste*. Interventions need to appeal to these motivations.

Our findings also suggest where and how some interventions might be appropriate to motivate people to try new fruits or vegetables. This may occur if the fruits or vegetables are procured in unusual or unexpected ways (e.g. as a gift, through produce exchange or foraged in the wild). We also found that people are willing to try them when they are taught about their health benefits or how to prepare/eat them (e.g. from relatives or vendors). They may be inspired by their eating out meal experiences to try to re-create a dish that they had eaten or to adapt the ingredient into their own cultural cooking (e.g. Chinese cabbage being made into an Indian style salad). Supermarket display boards may also help people learn about less common produce. Lastly, as the majority of participants in Malaysia and in the UK are concerned about food waste, a way to eliminate this is to encourage more people to grow their own food, thus allowing them to grow local plant varieties and also use food scraps as compost or fertiliser.

Our findings also show that mobile technology, such as smart phones and tablets, was a ubiquitous feature in the lives of most participants, albeit not directly mediating the activities. Tool use varied between participants, with some relying on shopping lists and recipe books.

In order to understand these findings more generally, we reflect on the idea of a food consumption lifecycle. We generalise this as a way of understanding our findings in relation to previous research and also drawing out implications. We draw inspiration from previous work from agricultural and business [25] that have talked about food supply chains and product lifecycles. Our study suggests that we can usefully think of food consumption as an overall lifecycle. Previous research in HCI has engaged with some parts of this cycle, but our study suggests that it is useful to step back and look at the bigger holistic picture in order to seek more complete or joined-up solutions. This is an important design approach because after meals have been planned, it is already too late to influence any issues related to food security. Once the food has been procured, the following phases of the lifecycle have significantly less influence over the larger problem such as food security.

We synthesised our findings into the food consumption lifecycle framework for understanding and designing food solutions or interventions (see Fig. 6). The framework is developed through a qualitative process of analysis aimed at describing and explaining a pattern of relationships between different food activities or phases that are mediated by tools and also influenced by wider motivations. Phases include procurement (through shopping, gardening or foraging), cooking, eating and disposal, with planning as a central activity behind each of these. The lifecycle helps us to identify potential opportunities for digital interventions to augment various motivating factors, with the images in Fig. 6 illustrating existing practices that these could target.
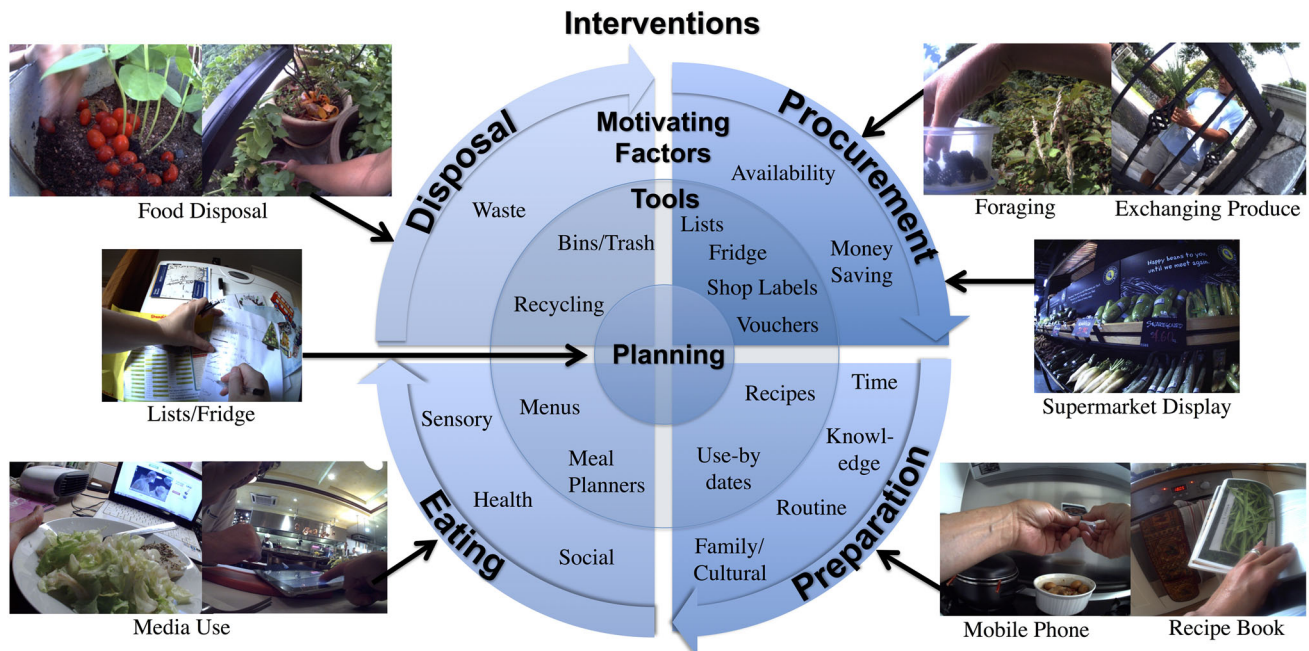

Fig. 6 Food consumption lifecycle

7 Design opportunities

In this section, we further discuss design opportunities arising from results of the camera study. In relation to food behaviour, we identified several key barriers to eating diversely to include lack of knowledge on food preparation of lesser-known produce, routine, cultural background and availability. The wider context of food consumption and the driving motivations behind it are vital when developing technology. From review of existing work, it is clear that there are many examples of salient and valuable HCI work being carried out. Yet these lack a holistic and joined-up view of the entire lifecycle of food consumption. Seeing things in terms of the proposed framework makes us realise that we need to consider all activities when designing interventions. The framework helps designers to consider effects across phases when designing food interventions, as food practices are complex and interconnected as evidenced in our data. Some strategies might include the following:

- Concerns for food wastage might encourage individuals or families to plan meals around leftovers or buy groceries to use with food close to expiration. For example, designers of food recommender or decision-support systems may want to consider connecting procurement and preparation activities with ways to reduce food waste.
- Lesser-known crops tend to have stronger sensory attributes, and a lack of knowledge about how to eat or prepare them properly may pose barriers to acceptance. As such, point-of-sale interventions may be a primary area for promoting a new food product. For example, by scanning a product with a mobile device will provide information as to how to cook or eat it.
- In circumstances where lesser-known produce is hard to find in the market place, food procurement systems can be extended to provide knowledge to help consumers grow them and utilise food waste, contributing to food diversity.
- The experience of eating a new food might encourage people to acquire recipes for preparing it. This may often take place in social settings such as restaurants or during special meal occasions. As such, designers may consider creating stronger connections between eating and preparations. For example, technologies for supporting social aspects of eating could also support recipe sharing so that people know how to recreate a dish themselves.

Planning is perhaps the one central point where we could develop more holistic approaches, since it sits at the centre of all phases. Determining what to cook, buy or eat, based on recipes we love or new recipes to try, are all part of meal planning. Here, people design meals with ingredients that satisfy nutritional requirements, personal taste and also meet objectives related to local and seasonal availability and known methods of preparation. For example, in order to encourage diverse eating, we need to provide information about alternative produce, as well as the knowledge of how to procure and prepare it and ways to avoid wasting any leftovers. As such, meal-planning tools will need to be based on comprehensive domain knowledge related to these activities.

This domain knowledge could include indigenous and traditional food knowledge systems to be preserved continuously for future generations to tap into. Many of the traditional cooking methods reside with the older generations who, in Malaysia, are mostly computer illiterate. Interventions could look at technology to encourage different generations in families or communities to work together to capture the knowledge and preserve it for future use. Our study suggests the potential of using wearable cameras and mobile devices for such purposes. The challenge is in the design of an integrated software application that allows users to organise and stitch together captured digital images or videos into recipes or food stories that also include information linked to the rest of the consumption cycle. It is then important to look at ways to share and disseminate this knowledge between generations and communities, and across cultures. In much the same way that we propose the capture and sharing of cooking information, technology could provide opportunities to capture and present gardening knowledge. This is important as gardening ensures a supply of local variety of produce, which would sometimes be hard to find. This could be through employing crowdsourcing techniques or the augmentation of seed packets and other gardening tools.

On the other hand, whilst some people plan upfront, others like to take advantage of offers during the shopping process, with this dictating their upcoming meals. This was especially true in the UK studies. Rather than a barrier to prompting food diversity, we should see this as an opportunity for design. When products are on offer, technologies could display ways to incorporate these into meals with more diverse ingredients. Information at the point of sale about how to prepare produce may also remove knowledge barriers, although it is important that this information can be captured and retained for later use.

Special food events or meal occasions can be multi-sensory and highly memorable experiences and may provide another opportunity to encourage people to try new foods. Methods could be explored to look at ways to encourage use of lesser-known ingredients. For example, people could design and share recipes and meal experiences around these new products along with other sensory

"ingredients" such as accompanying music and drinks. These could help to enhance people's perceptions of the products based on the concept of celebratory technology [19], by promoting the positive experiences of food, whilst also supporting positive changes in behaviour. As eating out is a common occurrence in Malaysia, our study showed that some participants were exposed to new food experiences when at restaurants, learning how to prepare produce that they might otherwise not considered. Interventions could explore ways to encourage this learning experience, such as augmented menus, takeaway gift packs with ingredients and recipes for recreating the meal experience at home. Our study suggests that existing food practices such as gifting of food may also be possible areas of interventions enabling new food ingredients to be introduced.

8 Reflection on wearable cameras

Our use of wearable cameras to study food consumption enabled us to collect food-related data at greater scale and understand behaviours in greater depth than was previously feasible. A wearable camera is portable and can therefore capture behaviours that are distributed across space. This was an ideal method for capturing a high-level overview of spatially distributed food-related practices. For example, in Malaysia, people shop at many different locations, such as supermarkets for purchasing common produce and markets for less common produce. They also often eat out. As such, wearable cameras were able to easily capture a range of food contexts to include additional context that the study was not necessarily setting out to capture (e.g. food gifts from neighbours, using food waste for gardening). This was vital to explore the bigger picture of food consumption. The wearable camera images were also useful for prompting reflection about the rationale behind behaviour. This method allowed a rich data set of images as well as transcripts of interviews to be captured providing insights into food-related behaviours, attitudes and motivations.

Overall participants who did take part in the study were comfortable wearing the camera and enjoyed looking back on their images. With the wearable cameras, participants are relied upon to switch the camera on and keep it on over an extended period of time. Experiences from the camera studies showed that this was not always the case, with some people forgetting to turn it on for long periods of time. Most of the participants who did not manage to wear the camera for a week instead volunteered to extend the study to cover the days where they had not worn it. Some of them made suggestions that in future studies, reminder text messages could be sent. In addition, whilst some participants wore the camera whenever they were at home, others

only felt compelled to wear the camera when cooking and eating. However, the research team were also interested in the wider context of cooking and eating practices, such as exposure to information about food, the use of shopping lists and recipes or unexpected uses of food waste. Thus, some data sets yielded more insights than others. Therefore, whilst participant control over where and when the wearable cameras could be switched on ensured participant autonomy, it introduced considerable variability in the quantity and quality of data captured.

Despite the perceived lack of awareness of the cameras, several participants appeared to take a degree of responsibility for maintaining data capture. For example, they were keen to ensure that the certain healthy products that they consumed were captured, so positioned them directly in front of the camera. Although most participants said that they did not alter their behaviour whilst wearing the camera, some of them reported slightly changing their behaviours to be more organised when they were preparing food in the kitchen (whilst maintaining all other food behaviours, e.g. shopping and eating).

In this study, the wearable cameras were a good solution for capturing a variety of behaviours in different contexts and long periods of times. However, if researchers need to study behaviour at fine grain and objectively, then this technique would be less applicable as small details will get lost (due to time lapse between captured images). Participant recruitment for food studies using wearable cameras will not be easy as not everyone will be happy to have the cameras in their home or workplace.

Future work could explore new means of studying behaviour using wearable cameras whilst preserving the privacy of participants. Other than that, future studies could seek to explore food consumption in a wider range of cultures, across a broader selection of participants. In addition to this, whilst this work captured images for 1 week and discussed behaviours more generally, longitudinal data collection methods could be used to study broader and longer-term food consumption lifecycles.

9 Conclusions

This work was undertaken using wearable cameras within the application domain of understanding food consumption practices, motivated by factors such as food security (e.g. to encourage local food consumption and reduce world dependence on a limited set of crops). The use of wearable cameras was an ideal method for capturing a high-level overview of spatially distributed food-related practices, despite some ethical and privacy concerns which we will address in future work. Our findings highlight the potential of wearable cameras to enhance knowledge of the overall

food consumption and identify where and how digital interventions might be appropriate. This includes appealing to people's motivations behind food consumption and capitalising on existing practices (e.g. gifting of food and social meals). We have summarised our findings as a food consumption lifecycle framework enabling the HCI community to understand the gaps that need to be addressed in the area of human–food interaction. Our study allows us to look at the design space in a holistic manner in order to seek solutions that fit within and take account of the entire consumption lifecycle. This provides the basis for technological design interventions that would have a real effect upon people's lives.

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