



# Human-Food Interaction

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# Abstract

Food is not only fundamental to our existence, its consumption, handling or even a mere sight also bring immense joy to us. Over the years, technology has played a crucial part in supporting and enriching food-related practices, starting from how we grow to how we cook to how we eat and to how we dispose off food. All these practices have a significant impact not only on individuals but also on the surrounding ecologies and infrastructures, often discussed under the umbrella term of *Human-Food Interaction* (HFI).

This article aims to offer the reader an overview of the existing research in this space and to guide further exploration of this space. We illustrate how HFI builds upon the recent trends within HCI across four phases of HFI, namely, *Growing, Cooking, Eating and Disposal*. We categorize and disseminate the existing works across each of these phases to unfold a rich design space and to highlight the underexplored areas that the interaction designers might find intriguing to investigate.

Using the design space, we also articulate a set of opportunities for HFI that emphasize on the particular features the technology especially hardware has yet to offer to drive the human-food interaction field forward. We also highlight the design space for designing novel interactions with technologies by taking motivation from our traditional food practices related to cooking and eating food.

# 1

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## Introduction

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*“One of the very nicest things about life is the way we must regularly stop whatever it is we are doing and devote our attention to eating.”*

— Luciano Pavarotti

Food is undeniably an essential facet of our life. From birth until the moment we die, we spend a countless number of hours procuring, preparing, eating and digesting food (Rozin et al., 2003). Food engages our senses and connects us with other people. Food also has a rich cultural and social history. Its preparation, consumption and even a mere sight also bring immense joy to us (Cabanac, 2010; Lupton, 1996). As French gastronome Brillat-Savarin (Brillat-Savarin and Buford, 2011) notes, pleasures associated with eating and drinking constitute some of life’s most enjoyable experiences. It is thus no surprise that most of the millennials identify themselves as Foodies (Sarasohn-Kahn, 2016).

Today, food is the world’s biggest industry (Murray, 2007). The rapid evolution and uptake of digital technologies have blurred "*the lines between the physical, digital, and biological spheres*" (Schwab, 2016) and played a crucial role in supporting our food-related practices starting from how we grow, shop,

cook, present, eat and dispose of food with the use of digital technology (Khot et al., 2017b). These efforts are studied in HCI under the umbrella term of *Human-Food Interaction* (HFI) (Comber et al., 2014).

Although there exists no one agreed upon definition of Human-Food Interaction, Choi and colleagues (Choi et al., 2014) define it as "*the interconnection between the self and food*" (p.4). This interconnection is of importance because, "*food fundamentally influences the self and, at the same time, a person's actions also significantly influence – beyond individual food choices – the real food and related systems*" (ibid, p. 4). Food practices are here defined as any human activity in which food is involved, ranging from agriculture, food preparation, eating, gifting food, sharing meals and cleaning up. Symons (Symons, 1994) refer to these practices as "*the human food cycle*".

This article offers a first of its kind overview of the research presented in this fascinating interdisciplinary field. We motivate our work by illustrating how HFI builds upon recent trends within HCI across all phases of human food cycle. Agricultural robots<sup>1</sup> and drones<sup>2</sup> are examples of technologies that are designed to support efficient farming practices while smart kitchens (Mizrahi et al., 2016) and appliances (Sun et al., 2015) are also paving their way in consumer market offering efficient food preparation processes. Food is also becoming a favorite theme amongst digital games with games like *Cooking Mama*<sup>3</sup>, *Fruit Ninja*<sup>4</sup>, and *Cooking Dash*<sup>5</sup> that simulate cooking, selling food or eating activities in virtual environments. Equally, if not more interestingly, technologies are transforming, in diverse and significant ways, socio-cultural aspects of food. For example, societies are increasingly eating alone (Lahad and May, 2017), and they rely on digital media for a dining companionship (Parrett, 2016). Practices of personalized nutrition (e.g., Soylent) (Dolejšová and Kera, 2017), DIY food sciences (Kuznetsov et al., 2016b), and open genomics (Shaer et al., 2017) are also gaining currency among the millennials.

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<sup>1</sup> Farm Bot: <https://farm.bot/>

<sup>2</sup> Sensefly: <https://www.sensefly.com/solution/ag-360/>

<sup>3</sup> Cooking Mama: <http://www.cookingmama.com/>

<sup>4</sup> Fruit Ninja: <https://fruitninja.com/>

<sup>5</sup> Cooking Dash: <https://www.glu.com/games/cooking-dash/>

Building on the recent trends, the experts in the fields of gastrophysics (Spence, 2017) and molecular gastronomy (Adria et al., 2006) outline various innovative ways in which restaurants and food industry could innovate in food design. HFI researchers are also experimenting with new and emerging technologies like food printing (Khot et al., 2017a; Sun et al., 2015), virtual reality (Arnold et al. 2018), robotics (Mehta et al. 2018) and haptic interfaces (Vi et al., 2017) to illustrate new ways of interacting with food and give us a glimpse of a possible ubiquitous future where food and technology could submerge with each other, leading to new possibilities of interacting with food.

The field of HFI has been actively studied through various workshops (Choi et al., 2012; Clear et al., 2013; Comber et al., 2012; Dolejšová et al., 2018; Kuznetsov et al., 2016b; Raturi et al., 2017) and symposia<sup>6</sup> dedicated to various sub-topics of HFI. There are also active communities working in this field. The list includes *FoodCHI Special Interest Group* (Khot et al., 2017b), *SIGCHI foodCHI network*<sup>7</sup>; *Facebook FoodCHI group*<sup>8</sup>, and an *ACM Future of Computing Academy working group on Computing and Food*<sup>9</sup>.

In this article, we offer a review of the still modest but rapidly growing body of academic literature on the topic of HFI. We present a structured overview of literature across four phases of HFI, namely, growing, cooking, eating and disposal. We systematically examine and outline the critical literature on each of the food cycles. In addition to summarising and analyzing critical works in each phase, the article offers a comprehensive picture of opportunities, challenges, and research gaps to guide further research. Our work is of importance as it offers a knowledge base through accumulating findings from a range of projects and studies, while for HFI researchers and scholars, this article presents opportunities for further research.

The article is structured in the following way. We first argue that designers need to pay attention to two core aspects when it comes to human-food interaction: *instrumental*, which refers to corrective use of technology, for instance, how

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<sup>6</sup> HFI Symposia: <http://datamaterialities.org/foodchi.html>, <http://foodchi.urbaninformatics.net/>

<sup>7</sup> SIGCHI FoodCHI network: <http://prior.sigchi.org/communities/foodchi>

<sup>8</sup> Facebook FoodCHI group: <https://www.facebook.com/groups/FoodCHI/>

<sup>9</sup> ACM group on Computing and Food: <https://acm-fca.org/2018/07/01/future-of-computing-food-manifesto/>

food is used as a source of energy and its relation to health and wellbeing; and *experiential*, which refers to how food affords rich multi-sensorial experiences and its relation to our identity, enjoyment, and society. These two aspects need to be considered across the four phases of HFI: *growing*, *cooking*, *eating*, and *disposal*. We categorize and disseminate existing works across each of these phases to unfold a rich design space to highlight underexplored areas that interaction designers might find intriguing to investigate. Using the design space, we articulate a set of opportunities with a particular focus on hardware to drive the human-food interaction field forward.



## 2

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# HFI: Instrumental and Experiential

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*“Choosing foods based on calories is like deciding how to talk to people based on their salary.”*

— Rujuta Diwekar

Over the years, our relationship with food is skewed more towards its nutritional value, and we are paying less attention to how food can bring joy and people together. The majority of the existing works prioritize the instrumentality of food. Technologies are used to help people in making the right choices of food, improving their culinary skills in preparing meals and guiding them in growing and disposing of food sustainably (Comber et al., 2014). Grimes and Harper (Grimes and Harper, 2008) refer to these technologies as "*Corrective technologies*" as they aim to improve shortcomings in people's capabilities or behaviors or to address issues that need fixing (e.g., uncertainty about what recipe to choose, food to eat or how to dispose of food sustainability). We refer to it as an "*Instrumental angle*" on designing technology for HFI.

While we agree that a corrective angle is pivotal to stem an upward rise to an obesogenic society and to mitigate unhealthy, and unsustainable behaviors, these efforts should not be at the cost of the pleasures that food and food-related practices inherently offer (Cabanac, 2010; Kringelbach, 2015; Somers et al., 2014). A recent study on weight management behavior (Hsu and Blandford, 2014) found that the need to restrict the pleasure of eating was one of the most widely experienced struggles. Pettigrew (Pettigrew, 2016) suggests that the health sector should incorporate and emphasise pleasures of eating a particular food product rather than just relying on individuals' judgement to make healthy choices based on the nutritional health information. As Block and colleagues (Block et al., 2011) state "*No one sits down to eat a plate of nutrients. Rather, when we sit down for a meal, we are seeking physical as well as emotional and psychological nourishment.*"

The corrective approach has been criticised in the recent literature for its optimization-focussed and deficit framing that ignores the lived reality of HFI (Block et al., 2011; Brynjarsdottir et al., 2012; Maitland et al., 2009; Prost et al., 2018). Prost and colleagues (Prost et al., 2018) worry that the modernist approaches to HFI position people as "*'mere' consumers, who receive disproportionate blame for 'inefficiencies' in food systems and are expected to change their behavior to meet expert-derived targets and guidelines*". Drawing on the concept of '*food democracy*', they argue for more socially and economically justifiable designs and giving voices to marginalized communities and the establishment of democratic governance where people are considered '*food citizens*' rather than just consumers or producers (Welsh and MacRae, 1998). Block and colleagues (Block et al., 2011) similarly echo for designing for food well-being that goes beyond the restriction and restraint and acknowledges the multidimensional role that food plays in our lives. They define food well-being as "*a positive psychological, physical, emotional and social relationship with food at both the individual and societal levels.*"

To complement the prevalent paradigm that "*food = nutrients = health*", it is also important to discuss more celebratory, non-instrumental design philosophies that draw on methods and values from the arts, humanities, and

social sciences. We refer to it as an “experiential angle” on designing technology for HFI.

We are however, not the first to acknowledge and emphasize on this angle. It echoes with the thinking and concerns of various scholars in related fields. Bell and Kaye (Bell and Kaye, 2002) were first to argue for a greater socio-cultural sensitivity for HFI research. They suggest that while designing technologies for a kitchen (domestic consumption), the focus should be on the people "*who are experiencing the space rather than the technologies that reside therein*" (p.60). Designers should also value "*experience over efficiency*", while "*understanding the cultural significances of the space, people and the objects*" and respecting the "*rituals of domesticity*". Grimes and Harper (Grimes and Harper, 2008), in their seminal paper, argue for a "*celebratory technology*" to support positive interactions during everyday mealtimes. They emphasize on the aesthetics, the creativity, endowment, relaxation, and nostalgia while designing HFI. Spence and colleagues (Spence, 2016; Spence et al., 2016; Spence and Piqueras-Fiszman, 2014; Zampini and Spence, 2004) suggest that the rich multi-sensory aspects of food are crucial aspects of food consumption and should be focussed upon. Similarly, Hassenzahl and colleagues (Hassenzahl et al., 2013) argue that pleasurable experiences should be at the center of design efforts. All these works guide our interest in discussing the “*Experiential*” angle of HFI.

Differentiating between the instrumental and experiential angles of HFI echoes with our understanding of body and interaction design (Mueller et al., 2018). We draw on prior work on embodied play (ibid) to highlight that with an instrumental angle, designers look at HFI from only a “*Körper*” perspective of the body, wherein food is treated as a sustenance for the active body. However, with an experiential angle, designers can also support a “*Leib*” perspective of the body, wherein food is treated as a nourishment to the soul. The word Leib has been used in German phrases to denote certain food related interactions. For example, “*Leibspeise*” refers to one’s favorite food (that makes me feel well), “*leibliches Wohl*” means personal wellbeing, and a “*Leibarzt*” is a personal physician who cares for me as an individual (Ots, 1994).

We wrote this article to motivate future works that take into account both these perspectives while designing HFI. With these perspectives in mind, we examined the existing literature across four phases of HFI to contribute an understanding of the scope and available opportunities to innovate. Before we describe the existing works across four phases of HFI, we offer a brief description of our methodology and the scope of this article.

# 3

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## Methodology & Scope

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In this section, we describe our methodology for the literature review. The review aimed at summarising the key findings from the existing literature, and identifying research gaps related to the following research question:

*“What is known from the existing literature about the design of technologies around food-related practices?”*

### 3.1 Methodology

We employed the *Grounded Theory Literature Review* method (Wolfswinkel et al., 2013). While following the Grounded approach, we sensitised our search criteria around the two perspectives of *Instrumental* and *Experimental* described earlier in Chapter 2. This method allowed us to frame the existing research space structurally and to ensure rigor in the process of selection.

To this end, our review process was divided into five stages:

**(1) Scope:** This review focuses on contributions to the field of HCI, which explicitly support HFI (food related practices using technology). Although food is a vast topic and has been studied across a wide range of disciplines, for the

scope of this article, we only selected works from related disciplines that involve some human-technology interaction while supporting food-related practices. We excluded studies that merely use technology as a research environment, for example, works that involve the use of a technology to collect data about food-related behaviors. On the technology side, however, we welcomed all forms of technology, ranging from interactive products, mobile and web-based solutions, physical and tangible prototypes and game-based solutions that address food-related problems.

**(2) Search:** The *ACM digital library* was our primary source to gain an overview of published research on HFI within the HCI community. Besides, ACM library, we also used *Google Scholar* to identify relevant articles from non-ACM venues, for example, reputed conferences, journals and different university's doctoral theses repositories. We recursively searched these review databases using commonly used terms in HCI to describe food-related practices. For example, “*growing food*”, “*cooking food*”, “*eating food*”, “*food design*”, “*food sustainability*” were some of the searched terms. The search was conducted from *December 2017* to *September 2018* for publications from 1990s until the most recent ones. Initially, we also included “*shopping of food*” as one of the terms and phases of human food cycle, however, we did not find enough literature on this topic to offer a critical review. As a result, in this article, our limit our focus on the following four phases: *growing*, *cooking*, *eating* and *disposal*.

**(3) Paper selection criteria:** We filtered the papers by their relevance to the topic at hand and given preference to contemporary papers and papers published in tier-1 conferences and journals like *CHI*, *DIS*, *TOCHI* and *IJHCS*. However, during the search process, we found that various works around technology intervention were also well investigated in non-ACM conferences and journals such as *Appetite*, *Journal of Sensors*, *JAMA* to name a few. Hence, we included articles from these sources too.

**(4) Analysis:** The collected papers were then analysed and synthesized them with affinity diagrams to identify recurring themes. We used our two perspectives: instrumental and experiential to identify the scope and angle of

each identified work, for example, whether the work is focussing solely on the corrective use of food such as a source of energy that is necessary for humans to survive? Alternatively, does this work also look into experiential and pleasurable aspects of food that unfold through our interactions with food, highlighting its rich multisensorial nature? Using these lenses, different themes emerged for each phase as shown in Table 1.

**(5) Insights:** The last stage of the review is to present insights for future directions through the analysis of the existing literature. Based on our understanding of the literature, we found that the experiential aspects are not explored for all the four phases of HFI. For example, in the growing and disposal phases, we identified that the focus has primarily been on the instrumental aspects and less emphasis is given to the experiential side of the interaction. These insights are described in Chapter 8 and 9.

<b>Stages (Main theme)</b>	<b>Sub-themes under each phase</b>				
<b>Growing</b>	Rural agriculture	Urban agriculture	Vertical farming		
<b>Cooking</b>	Instrumental cooking	Experiential cooking	Digital gastronomy		
<b>Eating</b>	Healthy eating	Mindful eating	Commensality	Solo- dining	Augmented Eating
<b>Disposing</b>	Food waste during production and retail	Domestic food waste	Food sharing		

**Table 1:** Summary of the themes and sub-themes derived through the analysis of the literature

## **3.2 Summary**

This chapter summarizes the methodology behind our review of this field. In the following part of the article, we discuss people's interactions with food across the following four phases: growing, cooking, eating and disposal. We will start with "*Growing*".



# 4

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## Growing Food

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*“Let us not forget that the cultivation of the earth is the most important labor of man. When tillage begins, other arts will follow. The farmers, therefore, are the founders of civilization.”*

— Daniel Webster

The first phase of the Human-Food Interaction is about “*Growing food*”. This phase describes the existing works on agriculture the science or practice of farming/growing food. Agriculture includes cultivation of the soil for the growing of crops as well as the keeping of animals for food and raw materials. The invention of agriculture dates back to at least a thousand years. The ability to cultivate the soil to grow crops was an essential step in human history leading to settlements and domestication of human species from hunter-gatherers to farmers. Agriculture in turn also affected the environment and the human carrying capacity of the planet. Forests and vast tracts of land became the lands for growing crops and raising animals. The global population also rose from being only 8 million people when humans were only hunter-gatherers to 7.6 billion as of today. Much credit for this growth could be accredited to interests and advancements in agriculture.

We categorise the existing works in this field into two broad categories: rural agriculture and urban agriculture. Each category offers its own set of challenges and opportunities. On the rural front, interactive technology, particularly the Information and Communication Technologies (ICT) are used for improving productivity through informed agriculture practice. For example, the existing works range from giving farmers the apt advice on soil cultivations to helping them market their food at the best price. On the urban front, the focus has been on encouraging city dwellers to take an interest in farming and also on identifying new ways of growing food in a confined city space such as vertical farming. Let us first look at ICTs' role in rural agriculture.

#### **4.1 Rural Agriculture**

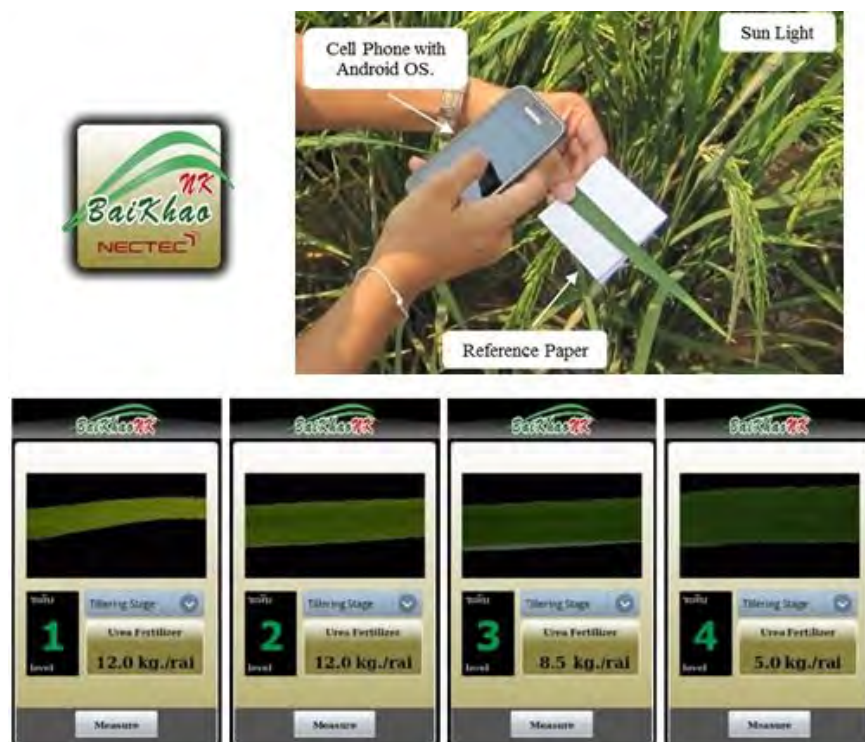
The use of Information and Communication Technologies has expanded rapidly in developing countries in the past decade. As a result, there is significant interest in using these technologies to support rural agricultural practices (Toyama, 2010) through the offering of expert advice and enabling ICT driven pathways of learning.

Unforeseen weather and environmental conditions drive much of the risk in food production. ICT technologies can help farmers in understanding and managing these risks by offering timely information about the weather and crop diseases at a low price (Aker, 2011). These technologies also offer support for understanding the factors influencing crop growth and yields, saving farm resources and, thus, contributing to an increase in farm output. Real-time monitoring and insights on crop conditions and management of resources (e.g., water, and pest) help farmers to respond to market needs and be efficient in production. This same data is also beneficial for banks to assess financial risks. For example, farms are less risky when they properly manage their natural capital such as soil, water, and biodiversity. Using ICTs can thus help promote more sustainable ways of growing food (Odom, 2010).

The majority of the literature on rural agriculture is focussed on mobile phones. Mobile phones are advantageous to agriculture as they offer easy and convenient access to cameras, microphones and recording software,

geographical information, and global positioning systems (GPS) from one single device. All these technologies can be used to create practical applications for farming concerning water and fertilizer management, disease detection and diagnosis, pest control, field mapping, crop monitoring, and networking. Pongnumkul and colleagues (Pongnumkul et al., 2015) offer a detailed review of the existing works in this space. Here we look at some of the critical works or directions.

**Resource management:** Various mobile applications are built to offer assistance on understanding the soil and crop condition; the required quantity of water and fertilizers for the given crop. The majority of these applications use image processing techniques to analyze the collected photographic data about the crop and soil. For instance, *BaiKhaoNK* (Sumriddetchkajorn, 2013) is a mobile application that analyzes the color level of rice leaves to recommend required amounts of nitrogen fertilizer (refer Figure 1). Gómez-Robledo and colleagues (Gómez-Robledo et al., 2013) similarly developed a mobile application to study soil conditions based on soil color using advanced image processing techniques.



**Figure 1:** *BaiKhaoNK* (Sumriddetchkajorn, 2013) is a mobile application that analyzes the color level of rice leaves to recommend required amounts of nitrogen fertilizer.

*PocketLAI* (Confalonieri et al., 2013) is another application that relies on image processing techniques to determine the Leaf Area Index (LAI) from collected pictures of leaf canopy to calculate crop water requirements. Taking a slightly different route, Aitkenhead and colleagues (Aitkenhead et al., 2013) developed *SIFSS* and *SOCiT* to offer detailed data on soil condition such as pH level, soil carbon content based on farms' geographical locations. *Hydrawise*<sup>10</sup> is another smartphone based application that uses local weather information to assist with the management of water and automated irrigation. The *eFarm* (Yu et al., 2017), on the other hand, uses crowdsourcing techniques to observe land conditions such as crop cover and growth.

**Pest control:** Mobile applications support pest control and disease detection or diagnosis through image processing techniques. Prasad and colleagues (Prasad et al., 2014) designed a computer vision-based system that supports capture and diagnosis of plant leaves for detecting any diseases. The application does the preprocessing on the captured photographs of plant leaves before they can be sent off to remote laboratories. *VillageTree* (Suen et al., 2014) is a pest management system that analyses crowd-sourced pest incidence reports through spatial-temporal analytics and image recognition algorithms to offer contextualized alerts and preventive measures. *Magri* (Wu and Chang, 2013) is a mobile application that utilizes self-reported pest and disease information to alert nearby areas. Finally, *MyPestGuide*<sup>11</sup> is a collection of reporting app, pest identification field guides, a decision tool and a collaborative community network of people to report and learn about local pests.

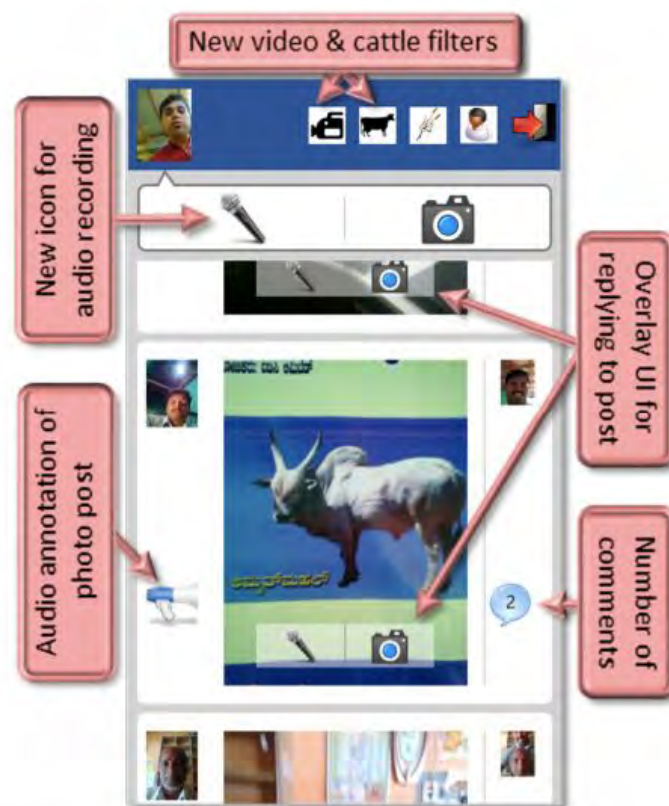
**Field mapping and crop monitoring:** Satellite imagery is also used to delineate large farming areas efficiently and to monitor changes in the crop conditions (Burke and Lobell, 2017). Drones and unmanned aerial vehicles are also explored as aerial field mapping and crop monitoring tools (Murugan et al., 2017). For example, *senseFly Ag360* is a commercial UAV system that provides in-depth aerial insights on crop development and also assists in mapping field boundaries during crop planning in the field by sharing information on when to seed, water, and harvest crops.

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<sup>10</sup> Hydrawise: <http://hydrawise.com>

<sup>11</sup> MyPestGuide: <https://www.agric.wa.gov.au/pests-weeds-diseases/mypestguide>

**Social learning:** ICTs are also used to provide farmers with better access to private information from their social networks, comprising of farmers, extension agents, and research centers. By increasing information flow between these parties, ICTs can support social learning and technology adoption through observation of and learning from one’s peers (Aker, 2011). For example, Opoku-Agyemang and colleagues (Opoku-Agyemang et al., 2017) designed and analyzed a voice-based social media platform called *Khedut Saathi* (meaning “Farmer's Friend”) where farmers can forward agriculture information through voice messages to one another. The *KrishiPustak* (Medhi-Thies et al., 2015) system connects low-literate farmers to agriculture extension workers of a non-profit organization. These workers act as human mediators to provide access and help farmers use the system. Farmers use the *KrishiPustak* system to make posts and add replies using the audio-visual content as shown in Figure 2.



**Figure 2:** *KrishiPustak* (Sumriddetchkajorn, 2013) is a mobile application that connects low-literate farmers to agriculture extension workers of a non-profit organization for agriculture advice.

*Avaaj Otalo* (Patel et al., 2010) is an online forum which farmers can use to ask questions and to browse related questions and responses on a range of agricultural topics. Besides text and voice, farming programs have been used to share knowledge between farmers and agricultural experts (Gandhi et al., 2007). For instance, *VideoKheti* (Cuendet et al., 2013) features a mobile system that helps farmers to find and watch agricultural videos in their language and dialect.

**Financial advice:** Besides offering advice on farming, research has also looked at facilitating improved access to financial services. Farmers in rural areas, for example, are often not well informed about prevailing market prices (Fafchamps and Hill, 2008). As a result, they sell their products in the less profitable markets and accept lower prices from the middlemen. As a remedy to such situations, existing works tried to link buyers with sellers and to facilitate agricultural data collection and improved access to financial services. Mobile phone services like SMS and hotline are used to keep farmers informed about market price information and reduced misallocation of resources and inefficiencies in the agricultural supply chain (Nakasone et al., 2014). Besides, Haushofer and Shapiro (Haushofer and Shapiro, 2016) explored the use of mobile money transfers to facilitate investments in agriculture. Finally, Blumenstock and colleagues (Blumenstock et al., 2015) investigated how mobile phone metadata can be used to predict poverty levels.

However, majority of these technologies often ignore the intuitions of the farmers while offering them advice. Farmers have little to no agency beyond consuming the information provided to them through these mobile applications, and then sharing the information by word-of-mouth to other farmers. Most ICT solutions fail to acknowledge the substantial evidence of horizontal knowledge sharing (e.g., word-of-mouth) that exists within traditional agricultural practices (Hamunen et al., 2015). Walker and colleagues (Walker et al., 2008) on the other hand, reported the lack of clear mental model among farmers for using technologies and often the use of such technology requires farmers to divert from their traditional farming practices, which can be challenging. Moreover, there is also an opportunity to look into the experiential aspects of farming to support increased motivation and interest in farming. This angle has been explored in urban agriculture, which we describe next.

## 4.2 Urban agriculture

Growing food in an urban environment presents a new set of challenges and opportunities different from rural agriculture. Unlike rural agriculture, efficiency is not the first or immediate concern in urban agriculture. Instead, the problems in urban agriculture revolve around the sight of the growing urban population, the diminishing state of the arable land, and the devoid of motivation towards farming. A variety of ways are explored in the literature that promotes civic participation in farming within urban environments, ranging from encouraging “grow your own food” movements, to establishing community gardens and farms, to encouraging sustainable agricultural and cohabitation practices and identifying and using new methods of space-optimized farming such as vertical farming. Let us look at these topics one by one.

**Community gardening and grow your own food movement:** The contemporary food production system in cities is highly industrialized and sophisticated to manage increasing demands for cheap and convenient food. As a result of the industrialization, the food production system has become increasingly internalized, leaving the majority of the consumers unaware about the origin and sources of food (the people and places that produce the food) (Kneafsey et al., 2008). Besides, there are also growing concerns over modes of production and distribution of the urban industrialized food system, including food miles, genetically modified food, pesticides, and labor conditions. For example, readily available processed food using industrial food systems often do not meet consumers’ nutritional needs (Pollan, 2014), and these foods are often found to be high in fat content and sugar (ibid.). As a remedy to these issues, the “*grow your own food*” movement has gained currency in recent years, which is evident from a growing number of community gardens, city farms, rooftop and vertical gardens surfacing in cities.

Within HFI, these topics on urban agriculture have been studied under the category of sustainable HCI and have been the subject of a variety of workshops and field studies. Works by Choi and Blevis (Choi and Blevis, 2010) and Stickel and Ludwig (Stickel and Ludwig, 2014) draw attention towards using ICT

technologies to cultivate sustainable food culture in urban spaces. Other researchers (Lyle et al., 2014; Odom, 2010) explored the values, needs, and practices of urban agricultural communities and described opportunities for designing with digital and computational technology to support these communities through information displays and dedicated apps, thereby extending the scope of sustainable HCI. For example, Lyle and colleagues (Lyle et al., 2014) described the preference of city farmers for face-to-face communication and the need for prudent investment in any new technology while also respecting the commitments of volunteers and offering better support for disaster management. In their follow up work with residential gardeners, the authors also identified that experimental and observational learning are more fruitful approaches than didactic learning when it comes to residential gardening (Lyle et al., 2015).

Secondly, many people undertake gardening merely as a recreational hobby. As a result, they cannot or are less willing to dedicate time towards discerning online information on gardening practices. Odom's study (Odom, 2010) on community garden highlighted diversity in the skillset and the fact that an urban gardener does not need to be a skilled gardener for maintaining the community garden. Heitlinger and colleagues (Heitlinger et al., 2013) suggest that urban gardening is and should be about relaxation and community building activity with a focus on inclusion and diversity. Finally, Hirsch (Hirsch, 2014) presents a framework for thinking about the different design opportunities urban agriculture by describing it as an urban innovation that coordinates activities among people, plants, machines, and institutions.

Kuznetsov and colleagues (Kuznetsov et al., 2016a) focused on food enthusiasts that routinely experiment with preserving, fermenting, brewing, pickling, foraging, and healing with their homemade food for a living. Their study showed that interaction with food often goes beyond the scientific knowledge of these experts and other factors such as human senses and intuition, specialized usage of everyday tools, community knowledge, social cooperation, and routine practices become essential. Similarly, Dolejšova and Kera (Dolejšová and Kera, 2016) developed the *GutHub* project, which is for peer sharing of knowledge, experiences, and material resources related to the practice of DIY home



fermentation. Through this open system of sharing, further augmented by the online *GutHub* platforms and DIY tools, the project aims to support citizens' hands-on engagements with sustainable food production.

On the technical front, Norton and colleagues (Norton et al., 2014) describe an online system to support the design and creation of backyard agricultural ecosystems. *The Talking Plants* (Heitlinger et al., 2014) is an interactive system that educates users on how to care for and prepare them, their medicinal and health qualities, and their histories. Carrozzo and colleagues (Carrozzo et al., 2018) came up with a playful hydroponic system called *Idropo* to educate children about gardening through play as shown in Figure 3. *Idropo* interacts with children through a virtual avatar.



**Figure 3:** *IDROPO* (Sumriddetchkajorn, 2013) is a playful hydroponic system.

Besides these academic works, a variety of smartphone-based apps exists to support gardening practices. *Smart garden watering*<sup>12</sup> is a smartphone-based app that allows users to monitor their garden water usages while also offering tips for saving water. *Garden Tags*<sup>13</sup> allows sharing of gardening tips and advice through a large community of friendly gardeners. *Garden Answers*<sup>14</sup> is another smartphone-based app that makes it easy for a user to identify a plant from its

<sup>12</sup> Smart Garden Watering: <http://www2.smartgardenwatering.org.au/>

<sup>13</sup> Garden Tags: <https://www.gardentags.com/>

<sup>14</sup> Garden Answers: <http://www.gardenanswers.com/>

photograph. The app currently can automatically recognize more than 20,000 plants. Finally, *Gardenate*<sup>15</sup> offers an inventory of plants based on their climatic requirement to guide users in planting across different seasons.

Besides community building activity, existing research also looked at addressing the call for lost connection with food origins. For example, Frawley and colleagues (Frawley et al., 2014) created the *Red Hen Recipes* site that provides a digital space for dialogic interactions between farmers, backyard growers, and shoppers through redesigning of the recipe format to include food origins. *The Open Food Network*<sup>16</sup> platform allows local producers to sell food directly to consumers and food hubs, thus increasing connections between producers and consumers. O'Hara and Stagl (O'Hara and Stagl, 2001) advocate for designing solutions that improve the visibility of how their food is produced amongst consumers, while a study by Svenfelt and Carlsson-Kanyama (Svenfelt and Carlsson-Kanyama, 2010) also found that face to face interactions with the producers increased trust and confidence in the quality and sustainability of the food.

**Agroecology and Cohabitation:** There is also an increasing interest in designing systems to support agroecological system design and human-animal cohabitation (Foth, 2017). Agroecology is an ecological approach to agriculture that views agricultural areas as ecosystems and is concerned with the ecological impact of agricultural practices. Raghavan and colleagues (Raghavan et al., 2016) draw from the natural phenomenon of perennial polyculture to design agroecological systems that extend the lifetime of agricultural systems. They propose a “*computational agroecology*” model that offers a systemic modeling of agroecological data and interactive agroecosystems and support for maintenance and harvesting in the long run. Similarly, Smith and colleagues (Smith et al., 2017) advocate a perspective of decentering humans and creating cities for cohabitation. To support this movement, Liu and colleagues (S.-Y. (cyn) Liu et al., 2018) proposed photography as a potential method to visually investigate spatiotemporal movements, sediment-like layers, various gatherings, formal homonyms, emotional experiences, and aestheticized expressions of the

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<sup>15</sup> Gardenate: <https://www.gardenate.com/>

<sup>16</sup> Open Food Network: <https://openfoodnetwork.org/>

style of urban agriculture. Liu and colleagues (J. Liu et al., 2018) presented a Hand-Substrate Interface (refer Figure 4) that offers direct engagement with the environment by requiring the wearer to physically insert their hands in the soil to obtain a digital moisture reading. *Lickable Cities* (Brueggemann et al., 2018), on the other hand, is a provocative gustatory project where authors licked hundreds of surfaces, infrastructures, and interfaces in cities around the world to raise questions on weather systems, and local microbiomes in an urban environment. We conclude this phase by discussing vertical farms, as they saw a lot of technological advancements in recent years.



**Figure 4:** *Hand-Substrate Interface* (Sumriddetchkajorn, 2013) offers a direct engagement with the agricultural environment, wherein the wearer physically inserts their hand in the soil to obtain the soil moisture reading.

### 4.3 Vertical Farming

Vertical farming is a simple concept of farming up rather than out (Despommier, 2013). According to many, vertical farms are sustainable solutions for addressing the diminishing state of the arable land in urban environments and to resolving the issues of food security to the world's ever-increasing urban population (Al-Kodmany, 2018; Despommier, 2013).

Experts argue for their benefits towards small and self-sufficient ecosystems that cover multiple functions, from food production to waste management (Touliatos et al., 2016). The benefits of vertical farming vary from organically grown produce, avoiding loss of crops due to inclement weather, reduced use of harmful herbicides and pesticides, a reduction in the carbon footprint, and effective management of water (Benke and Tomkins, 2017; Despommier, 2013).

A famous example of a vertical farm is a green or living wall that features on the exterior of urban buildings. Green walls not only offer a pleasing aesthetic to an urban architecture; they also have a variety of benefits ranging from food or fauna production to acting as a heating/ cooling mechanism for the interior of buildings. Vertical farming, however, does not have to be external like a green wall, indoor environments also offer a healthier environment to grow food (Healy and Rosenberg, 2013). Indoor farming can tolerate different weather conditions and thus can operate all year-round. Furthermore, as Al-Kodmany writes, “*Indoor farmers could also engineer the taste of produce to cater to people’s preferences*” (Al-Kodmany, 2018).

Vertical farms use sensor and LED technology to enable crops to grow in closed intelligent environments (Douceff, 2013). The LED light acts as an artificial sun, while sensors keep a close watch on the plants and adjust the system when needed. Vertical farming methods typically use a tray or rack system to adapt to a potential lack of space. Rotating tray units are also used in vertical farming to manage the light resources for photosynthesis efficiently. The existing literature mentions three different methods of vertical farming: 1) hydroponics 2) aeroponics and 3) aquaponics. Let us look at them one by one.

**Hydroponics:** Hydroponics is a method of growing food in mineral and nutrient-rich water without the need of soil (Jones, 2016). Since hydroponics do not use soil, it eliminates or reduces the traditional soil-related cultivation problems of insects, fungus, and bacteria growing in soil. Hydroponics is also low-maintenance, less labor-intensive and a cleaner method of farming. An example of a hydroponics system is The *Volksgarden* or *cylindrical Omega*

*Garden*<sup>17</sup>. In this system, the plants rotate around the centralized induction lights inside rotating wheels “to take advantage of orbital tropism (based on the impact of gravity on growth) to grow bigger, stronger and faster” (Al-Kodmany, 2018). Another example is *3Dponics*<sup>18</sup> that provides open-source, downloadable files for hydroponics equipment such as planters, sprinkler, and nozzles. Finally, Takeuchi (Takeuchi, 2016) experimented with the idea of creating small-scale printable hydroponic gardens using 3D printing.

**Aeroponics:** An aeroponic system is an enclosed air and water/nutrient ecosystem that fosters rapid plant growth with significantly little water (95 percent less water than traditional farming methods) and direct sun and without soil or media (Cooper, 2013). Unlike hydroponics, aeroponics systems do not use water. Instead, they rely on mist or nutrient solutions. An example of an aeroponic system is *Ecos GrowCube*<sup>19</sup>. In this cubicle system, a rotisserie wheel spins six plates under a strip of LEDs providing the necessary light for the plants inside each plate for photosynthesis. Additionally, the system also features an automated spray that provides nutrient-rich mist to the plant's roots to make plant growth much more efficient (Cooper, 2013). The functionality of the *Ecos GrowCube* is controlled and managed remotely via computer and software, which makes it convenient and portable option to farming.

**Aquaponics:** The final category is the Aquaponics. Aquaponics functions similar to hydroponics; where water runs over the roots of the plants to bring all the necessary nutrients. However, instead of adding nutrients to the water as it is done in hydroponics, aquaponics uses nutrient-rich waste from fish tanks to “fertigate” hydroponic production beds as seen in Figure 5. An example of aquaponics system is *AquaSprouts*<sup>20</sup> that features a compact indoor aquaponics system featuring the dual benefits of an aquarium and an indoor plant. Jacob (Jacob, 2017) also created a smart aquaponic system that offers remote control of the watering and lighting cycle, live visual updates of the system using a camera and water overflow detection and temperature monitoring of the aquarium.

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<sup>17</sup> Omega Garden: <https://omegagarden.com/>

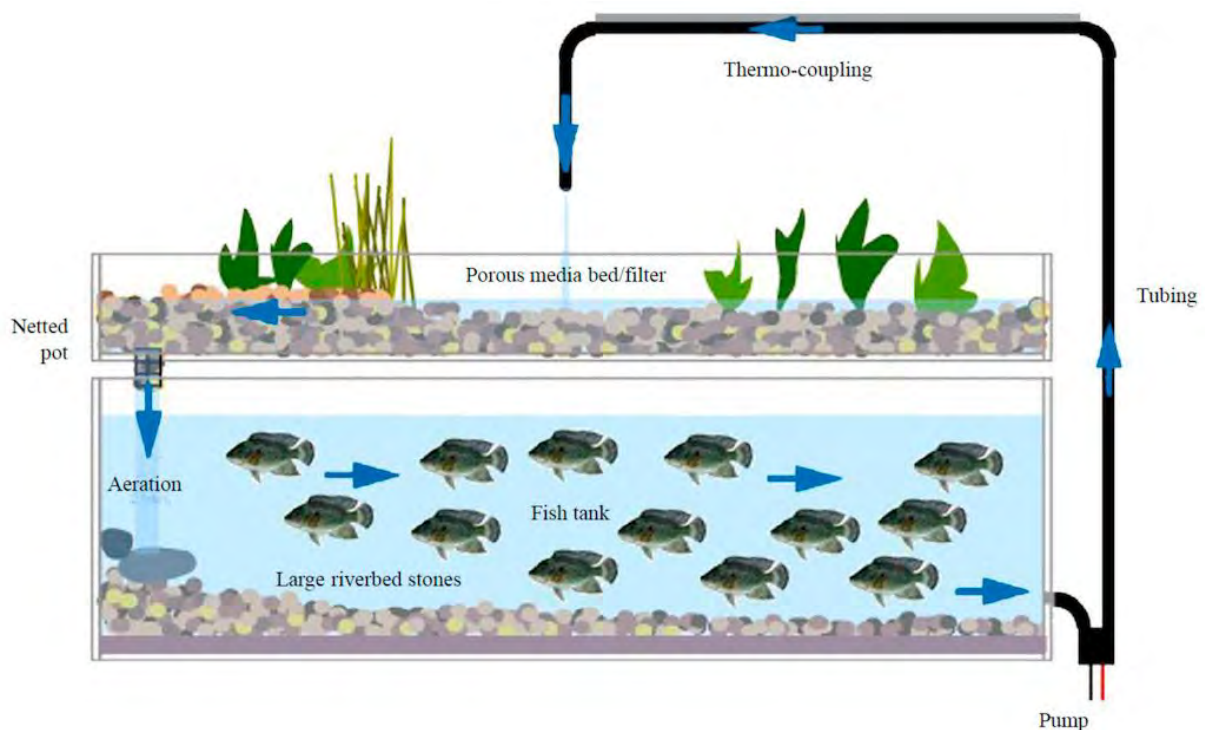
<sup>18</sup> 3Dponics: <https://www.3dponics.com/>

<sup>19</sup> Ecos GrowCube: <https://www.ecospheretechnology.com/environmental-engineering-technologies/ecos-growcube>

<sup>20</sup> AquaSprouts: <https://www.aquasprouts.com/>



One of the crucial components of successful vertical farming is artificial lighting. Artificial lights if correctly developed can match the photosynthesis needs of the plants, which could then lead to faster-growth rate and reduction in energy costs. Drawing on this, Dutch company *PlantLab* aims to provide ideal growing conditions in via red and pink LED lighting and promises to use only 10 percent of the water a traditional farm requires. Artificial lighting, in large quantities, however, is usually expensive and not environmentally sustainable (Doucleff, 2013). As such, this system is still far from mass adaptation, but inventors are confident that the reductions in the costs of LED lights will make their system scalable in very near future.



**Figure 5:** A model of the aquaponic system ( © Al-Kodmany).

#### 4.4 Summary

In this chapter, we examined the existing literature on growing food across two sites: urban and rural. We found that the approaches and the uses of technologies across these two sites differ, where instrumentality is the key focus in rural agriculture while experiential technologies are designed to encourage and support urban agriculture. We concluded the chapter by discussing vertical farming techniques, which we believe opens doors to new forms of interactions

when combined with sensing technologies. For instance, projects like *Go and Grow* (Botros et al., 2016) where there is a tighter correlation between growth of a plant and individual's activities, could redefine as well as question our relationships and approaches to agriculture. Researchers predict that farming operations will be fully automated in the near future. For example, monitoring systems will be widely implemented in the form of sensors near each plant bed to detect a plant's need for water, nutrients and other requirements for optimal growth and development. Sensors can also warn farmers by signaling the presence of harmful bacteria, viruses or other microorganisms that cause disease. Also, a gas chromatograph technology (L. Li et al., 2017) will be able to analyze flavonoid levels accurately, providing the optimal time for harvesting. These specific technologies are not entirely new. Their development has been ongoing and will likely proliferate in the near future.

# 5

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## Cooking Food

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*“Cooking is one of the strongest ceremonies for life. When recipes are put together, the kitchen is a chemical laboratory involving air, fire, water and the earth. This is what gives value to humans and elevates their spiritual qualities. If you take a frozen box and stick it in the microwave, you become connected to the factory.”*

— Laura Esquivel

The second phase of the Human-Food Interaction is about “Cooking food”. Cooking is an invaluable life skill of preparing food for consumption by combining, mixing, and heating ingredients. This activity is unique to humans, and its origin trace back to at least 1 million years ago. Cooking softens tough fibers to make them more time-efficient to consume and more comfortable to digest. Cooking is also an activity that connects the natural world with the social world and *“transforms humans from mere consumers into producers”* (Pollan, 2014). In the words of Albala and Henderson (Albala and Henderson, 2010), *“cooking provides sustenance for others with the labor of one’s own hands”* and can bring pleasure and satisfaction for those who cook together and share the meal. According to Herculano-Houzel (Herculano-Houzel, 2012), cooking also



contributed to our intelligence. Cooking allowed us to eat more per day, which increased our brain capacity and gave us spare time to spend on other tasks (ibid).

Over the years, cooking has seen many advancements with a goal of improving efficiency, economy, and sociality around cooking. Various technologies and appliances have paved their way into kitchens, replacing or refining the traditional methods of cooking. Commonly found electrical appliances like a microwave oven and a food processor allowed us to cook a variety of different foods with precision and little effort and investment of time. Emerging technologies like food printers are also being looked at as critical drivers of how we might prepare food (Khot et al., 2017b). Nonetheless, the motivation for cooking continues in the present age, as evidenced by the popularity of cooking books (Hudnall, 2017), and cooking programs on YouTube (Delgado and Johnsmeyer, 2014; Paay et al., 2013) and Television (Matwick and Matwick, 2015).

Existing work on supporting cooking practices within HFI can be divided into two broad categories. The first category deals with offering instructional guidance and multimodal feedback on cooking while the other category tries to support social and experiential aspects of cooking with technology. Let us first discuss the first category.

## **5.1 Instrumental cooking**

A critical element of cooking a perfect dish is knowing its recipe and following it in the correct order. A recipe is a set of instructions for preparing a particular dish, including a list of the ingredients required. Most beginners and even people with experience often struggle when preparing a recipe for the first time. Differently abled and older adults also bring in a different set of challenges when it comes to cooking. To aid beginners as well as experienced cooks in cooking, a variety of works within HFI have looked at various forms of instructional guidance and feedback on cooking.

**Instructional guidance on cooking:** *Cooking Navi* (Hamada et al., 2005) was one of the early systems to use multimedia (text, speech, and videos) to offer

in-situ instructional guidance for cooking. Using machine learning techniques, *Cooking Navi* tried to interpret the cooking workflow to reschedule recipe steps and optimize the cooking process. However, in the study of the system, authors found that rescheduling of cooking steps was unnatural to participants. *Smart VideoCooking* (Doman et al., 2012) is another system that offers in-situ browsing of cooking videos through an android app with integrated search and read-aloud functionality. *MimiCook* (Sato et al., 2013) uses Augmented Reality to project cooking instructions and immediate scale feedback directly onto the kitchen counter. *Shadow Cooking* (Sato et al., 2014) is another system by the same authors that use depth cameras and a projector to guide users with situated, step-by-step information projected directly onto the utensils and ingredients as shown in Figure 6.



**Figure 6:** In the *Shadow Cooking* system (Sumriddetchkajorn, 2013), cooking instructions are projected onto the kitchen counter and they move forward according to the user's progress.

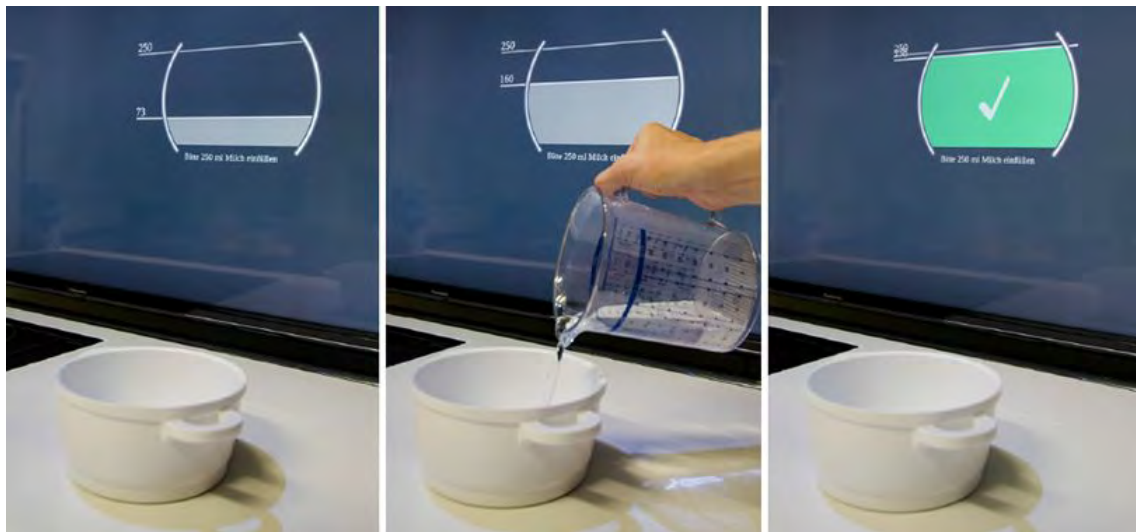
These systems aim to let beginners achieve cooking results as fast and efficiently as possible. These systems are useful in guiding the users in cooking, or they can check if the user is rightly following the steps. Unfortunately, these systems do not adapt well to the dynamic user actions (Nansen et al., 2014). Besides, Hashimoto (Hashimoto, 2008) found that many of these systems often

distract their users from their cooking process by demanding some input from them. As a remedy, they built *Smart Kitchen* to minimize the interference and offered help only when the user needed the aid. *Nintendo Personal Trainer Cooking*<sup>21</sup>, on the other hand, enabled voice input and eye movement to interact with a cooking guidance system whereas Panger (Panger, 2012) explored the use of depth cameras such as Kinect to offer touchless gestural control during cooking.

**Multimodal feedback on cooking:** *Panavi* (Uriu et al., 2012) offers a computer-enhanced cooking pan and an environment for domestic users to master professional culinary arts in their kitchens by managing temperature and pan movement properly. The embedded sensor in *Panavi* senses the temperature of the pan and guides the whole process of cooking with a display in front of them. In other works, Kita and Rekimoto (Kita and Rekimoto, 2013) used a thermal camera and a projection based Augmented Reality (AR) environment to acquire and display thermal information from the surface of the food on a cooking pan. *CounterActive* (Ju et al., 2001) is another system that projects a recipe to a kitchen counter that the user can operate by touching the counter. Other computer-enhanced cooking tools include coloring water according to its temperature (Arroyo et al., 2005) and projecting information in the kitchen (Bonanni et al., 2005). The work by Aoyama and colleagues (Aoyama et al., 2009) tried to detect the skill levels of a cook by tracking their hand and head motions. Head motion was detected in three different ways, and the index finger tracked the hand motions. Based on this information, the system advised the cook during cooking. Blasco and colleagues (Blasco et al., 2014) developed and assessed smart kitchens for older adults and evaluated simulated specific situations, such as making dinner or washing up. Finally, *KogniChef* (Neumann et al., 2017) is a smart and interconnected kitchen environment and software framework that integrates multimodal displays to assist users in cooking. Using computer vision techniques, it offers detection and assistance for stirring and filling (as seen in Figure 7), two everyday tasks in cooking.

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<sup>21</sup> Nintendo Personal Trainer Cooking:  
[https://www.nintendo.com/games/detail/0GH0z7XuqgMVHravefY0EVUR\\_xzNIXa7](https://www.nintendo.com/games/detail/0GH0z7XuqgMVHravefY0EVUR_xzNIXa7)



**Figure 7:** The *KogniChef* system (Sumriddetchkajorn, 2013) offers real time feedback on pouring actions.

## 5.2 Experiential aspects of cooking

Historically, the kitchen has been at the centerfold of the home experience (Schneiderman, 2010). Cooking is also a social practice that for many are more gratifying when done together with others: according to Short (Short, 2006), cooking knowledge is embedded within relationships and practices. Cooking recipes and techniques are shared within families over time through mostly informal and embodied interactions (ibid). Cooking food together thus affords opportunities for bonding with others through the sharing of stories, daily activities and swapping ideas on food preparation (Paay et al., 2012). Bell and Kaye (Bell and Kaye, 2002) point out that we should focus on the experience in kitchens rather than the underlying technologies to support the social richness of cooking traditions, rituals, and practices.

Various studies within HFI have looked at kitchens as “*sites where meaning is produced, as well as meals*” (Bell and Kaye, 2002). Studies by Paay and colleagues (Paay et al., 2015, 2012) discussed how people share, negotiate and interact with and within the kitchen environment with a special emphasis on the spatial arrangement and proxemics. Scholars have explored the opportunities of the kitchen design space, from the design of specific tools to reimagining the kitchen as a whole. Nansen and colleagues (Nansen et al., 2014) studied the

social, material and embodied contexts of kitchen kinesics – the non-verbal gestural communication observed in family cooking interactions and raised some contextual concerns for approaching the design and understanding of the role of gesture in familial cooking scenarios.

Schneider and colleagues (Schneider, 2007) drew inspiration from handwritten recipes that are passed down by previous generations, to develop a semantic cookbook. Similar to handwritten notes, the semantic cookbook enabled different parties to share their recipes through a shared display. Davis and colleagues (Davis et al., 2014) have described the homemade family cookbook while Terrenghi and colleagues (Terrenghi et al., 2007) created a *Living Cookbook* in which recordings of cooking are used to learn, share and educate from each other's cooking experiences. Scheible and colleagues (Scheible et al., 2016) developed *Smartkitchen* to incorporate social and emotional components in the cooking process. There has also been works around smart sensing devices to support novel and social cooking practice. For instance, Chai and colleagues (Chai et al., 2017) designed *Performance Apron* and *Talking Bottle* to enhance and share the experience of cooking together at a distance (refer Figure 8). These devices support an instant exchange of voice messages and cooking sounds through an augmented bottle controlled through a cooking apron.

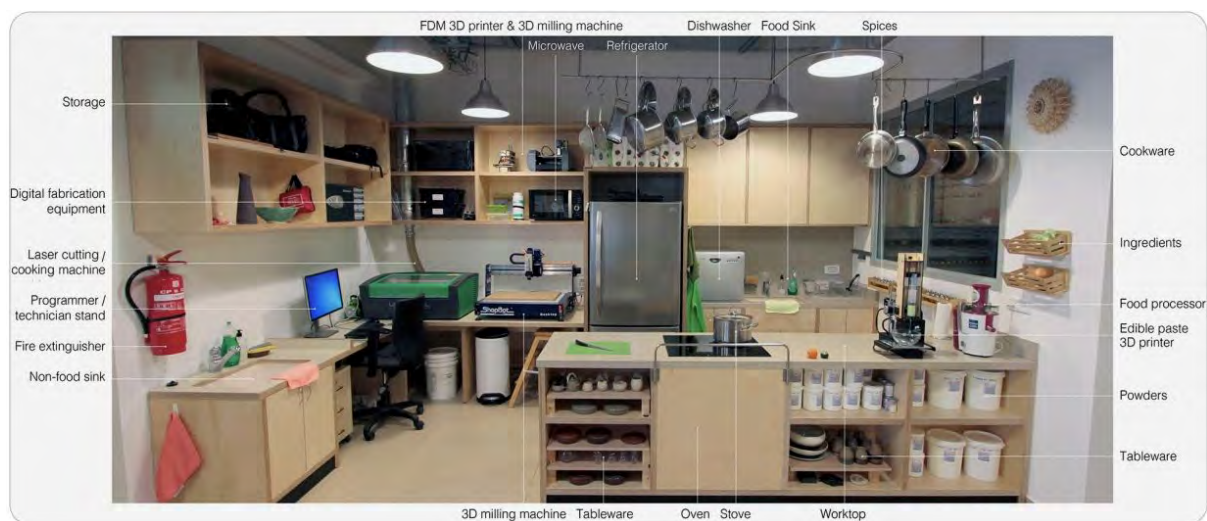


**Figure 8:** The *Talking Bottle* system (Sumriddetchkajorn, 2013) communicates the availability of voice messages or that someone is cooking in the remote kitchen through LEDs.

The final part of this chapter describes digital gastronomy, food printing in particular and how it could give rise to new ways of cooking.

### 5.3 Food printers and the rise of digital gastronomy

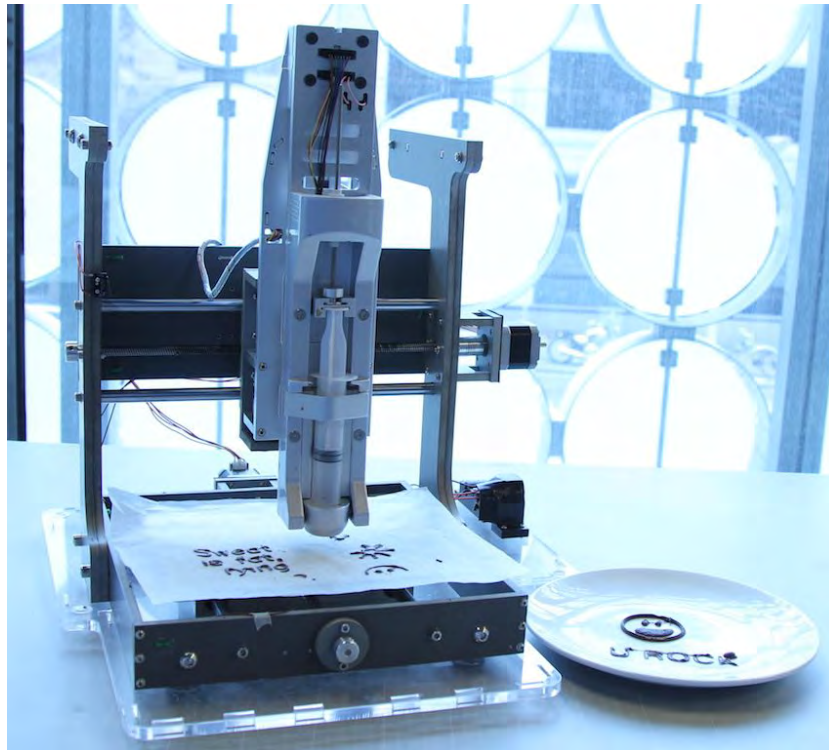
The concept of digital gastronomy is also gaining currency within HFI with the rise in food fabrication technologies. Researchers (Mizrahi et al., 2016; Olivier et al., 2009) envisioned hybrid kitchens (refer to Figure 9), where designers can evaluate novel cooking solutions that make use of food fabrication technologies.



**Figure 9:** The *Hybrid kitchen* (Mizrahi et al., 2016) features food fabrication tools to support traditional ways of cooking.

One popular food fabrication technology is food printers (refer Figure 10). Food printers are a special form of 3D printers that allow creation of edible artifacts from digital designs (Sun et al., 2015). Current food printers use viscous materials (e.g. cheese, marzipan, dough and chocolate) and powdered substances (e.g. sugar) to fabricate food. Food printing offers benefits in terms of customization, convenience and novelty. Instead of cooking food with hands or using traditional kitchen appliances, food printing adds a new dimension to cooking and other food practices and opens up possibilities for novel interactions and engaging experiences, wherein digital 3D prints can replace traditional recipes. (Khot et al., 2017b). For instance, the grocery stores and supermarkets can offer digital sketches of food recipes that users can download and print at home using a food printer.





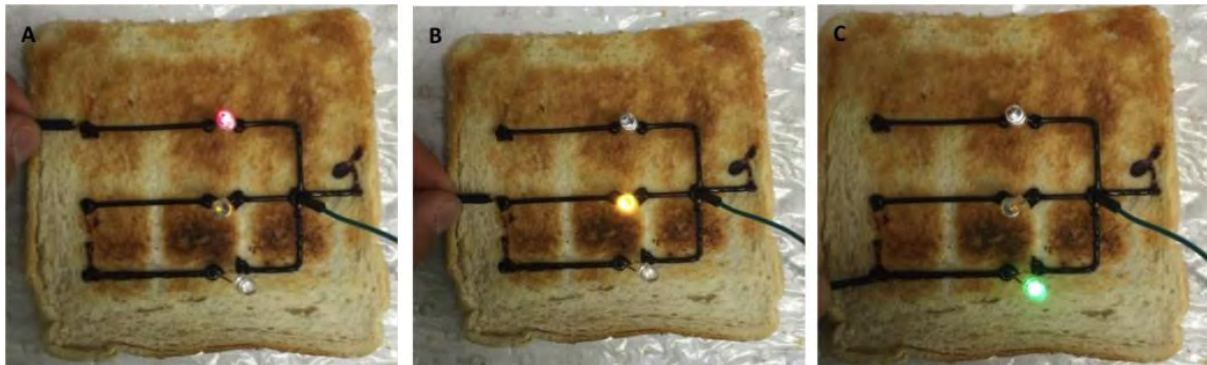
**Figure 10:** The *Food printers* © (Khot et al., 2015c) allow creation of edible artifacts from digital designs.

Food printing is still relatively new, costly and often a bit clunky. Attempts are currently being made to improve its efficiency and usability by experimenting with different kinds of food and printing techniques. Besides, researchers are also exploring application domains to which food printing can contribute. For example, food printing has been used to create smooth easy-to-eat food for the elderly who have difficulty in swallowing food<sup>22</sup>. Wei and colleagues (Wei et al., 2014) created a social food-based messaging system around food printing. Khot and colleagues (Khot et al., 2017a) created the EdiPulse system that prints 3D printed chocolates from measured heart rate data of physical activity. Hamilton and colleagues (Hamilton et al., 2018) fabricated edible circuitry using vegemite sauce on a toasted bread as seen in Figure 11. This novel conductive food patterning demonstrates the potential of food as edible electronics. For instance, food printing can potentially connect cooking with digital information, so that traditional recipes can be replaced by 3D print models. One day, supermarkets may offer digital sketches of food recipes that

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<sup>22</sup> SmoothFood: <http://smoothfood.de/>

users can download and print at home using a food printer, rather than selling prepared food products.



**Figure 11:** Hamilton and team described a technique for edible circuitry using conductive vegemite sauce © (Hamilton et al., 2018).

Researchers have also identified the potential of food printing in contributing to food sustainability with projects like *Edible Growth*<sup>23</sup>. The food printers could also be used to create personalised meals by allowing right mapping between the amounts of protein, carbohydrates, and fats in the meals. It is also believed that food printing can contribute to the alleviation of world hunger by reducing food waste and using materials that would otherwise not be eaten, such as algae and insects (Payne and Dobermann, 2016). Besides, a food printing conference<sup>24</sup> and active communities have also been set up. Despite these early efforts and interests, food printing is still a minor phenomenon, confined mostly to science fairs, universities and a handful of enthusiasts. However, researchers and practitioners see promise in this technology and speculate about various exciting interaction possibilities.

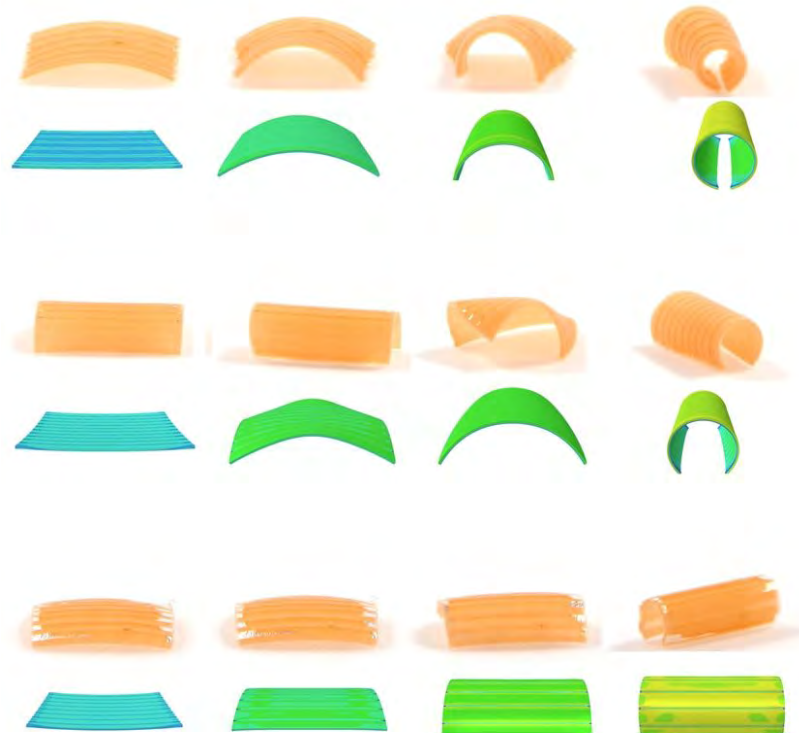
Besides food printing, people have also explored other ways of using digital technology to simplify or to make the cooking process more engaging. For example, *Transformative appetite* (Wang et al., 2017) is an autonomous system, modeled after “flat packaging” concept that allows customization of food shapes during cooking. The system utilizes various geometric techniques to transform an edible 2D films made by common food materials into 3D using water absorption. Users can also customize food shape transformations through a

<sup>23</sup> Edible Growth: <http://www.chloerutzerveld.com/#/edible-growth-2014/>

<sup>24</sup> 3D Food Printing Conference: <https://3dfoodprintingconference.com/>



pre-defined system and then use 3D food printing to fabricate these customized patterns, as seen in Figure 12. Fukuchi and colleagues (Fukuchi et al., 2012)



**Figure 12:** *Transformative Appetite* © (Wang et al., 2017) allows customization of food shape using digital fabrication techniques.

invented laser cooking that uses laser cutter and image processing techniques to cook food according to their shape and composition of ingredients allowing new tastes and textures to emerge.

Mizrahi and colleagues (Mizrahi et al., 2016) presented recipes that merge manual and digital cooking, allowing cooks to personalize the tastes, structures, and aesthetics of dishes. They introduced a parametric procedure to personalize the taste of soup by controlling the quantities of sauces served in 3D printed edible tofu containers. Zoran and Cohen (Zoran and Cohen, 2018) took this concept forward to create modular silicone based molds based on a genetic mold-arrangement algorithm to offer a variety of shape permutations to anyone who is making a dessert. Finally, Lee and colleagues (Lee et al., 2017) used 3D printing to simplify the complex cooking process of making Korean dumplings. With food printers becoming more efficient and potentially viable (Khot et al.,

2017b), we can expect further proliferation in their use in domestic and retail kitchens.

Digital technologies like food printing can revolutionize the cooking process, but we believe there remain more open challenges concerning its suitability, affordance, and need, which demands more collaborations between chefs, designers, and engineers. One popular challenge is the tradeoff between the prepared and palatable food. Food printing can alter the shape, texture, and flavor of food in unique and creative ways, but these changes are not necessarily attributed to creating palatable food. For example, Lupton and Turner (Lupton and Turner, 2016) found that individuals associate cultural meanings with food and 3D printed food contradicts the one's perception of 'natural' food. Something prepared with hands is considered healthy wherein something processed and came out of a machine is commonly perceived as unhealthy. As such, efforts are needed to tackle and build around people's perception of printed food.

## **5.4 Summary**

In this chapter, we looked at various cooking techniques and technology can be used to offer real time instrumental feedback on one's cooking behavior. We also discussed the role of kitchen as a domestic space for social interactions. In the future, we expect more inclusive designs offering agency and respecting one's creativity and style of cooking, further discussed in Chapter 8. Next we present the third phase of HFI, *eating*.

# 6

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## Eating Food

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*“One cannot think well, love well, sleep well, if one has not dined well.”*

— Virginia Woolf

The third phase of the Human-Food Interaction is about “Eating food”. The process of eating starts with fetching the food from the plate. Using the rotation of wrist and arms, the fetched food is then brought closer to the mouth for insertion. Once inserted in the mouth, the oral processing of food starts. Depending on the type of the food, it involves biting, licking, sucking and chewing to break the food into pieces and to make it easier to swallow. The processed food is then pushed back to the throat for swallowing with which the digestion process begins. If an individual is eating mindfully (Tapper, 2018; Warren et al., 2017), then he/she will pay attention to this process and eating will continue as long as he/she feels hungry and it will stop once the physiological signals of satiety (i.e., the feeling of full) reach the brain. However, in reality, the eating process is not always defined through physiological triggers, nor people pay enough attention to it, rather it is influenced by a variety of external factors (van’t Riet et al., 2011).

Over the years, we have developed rich culinary methods and acquired new distinct tastes. As a result, eating is no longer just an act of survival and consumption of energies. It has grown into a rich form of practice, we call "*dining*" that brings people together and helps in the progression of humankind and societies. Everyday eating habits include eating in front of the TV, favoring a certain kind of foods, making food and eating decisions under the social influence and favoring taste over nutrition. All these habits have varied yet significant impact on one's physical and mental health.

We have categorized the existing works around eating in the HFI literature concerning its central focus. The categories are: 1) healthy eating 2) mindful eating 3) commensality (social eating) 4) solo eating and 5) augmented eating. Let us first describe the works that focus on healthy eating.

## 6.1 Healthy Eating

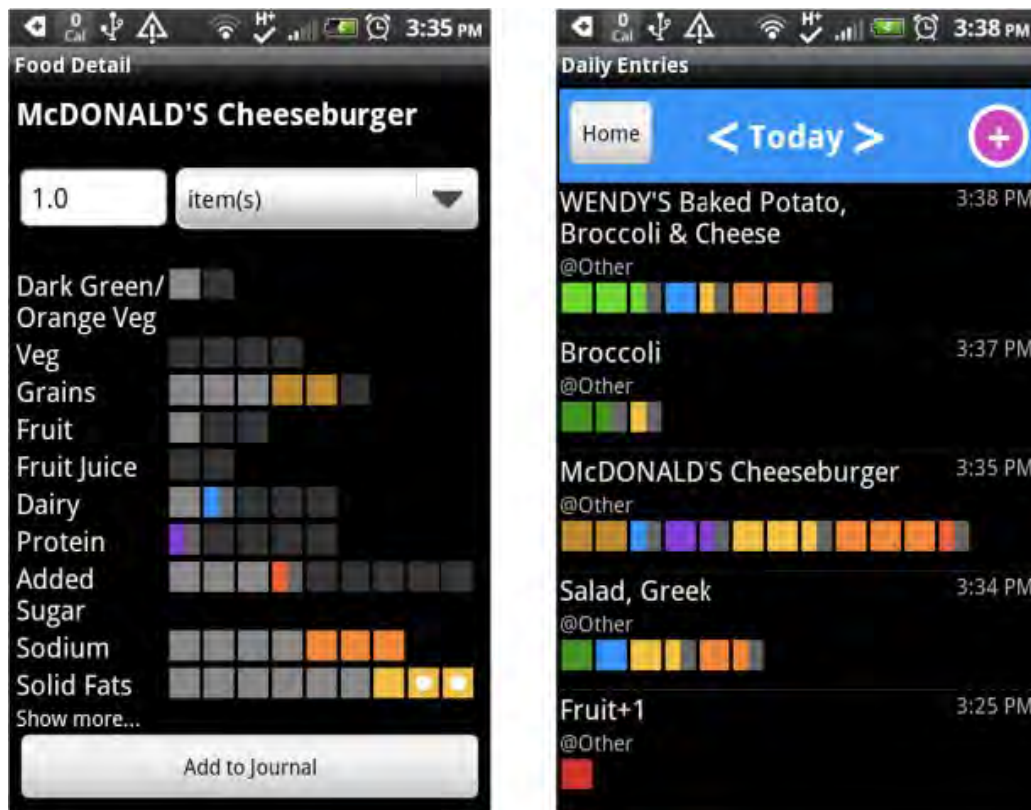
Having a well-balanced diet is essential for maintaining long-term good health. Most individuals, however, struggle to incorporate a well-balanced diet into their lifestyle. Instead, they consume a diet that is high in calories, saturated fats, and sugars, while being low in fruits, vegetables, and fiber. Such unhealthy eating contributes to adverse health conditions (Fraser and Shavlik, 2001), and it is one of the key reasons behind the global obesity epidemic (Camilleri et al., 2016). To remedy such behavior and to encourage healthier eating habits, existing research has explored the role of technologies to offer timely feedback on the eating activity with the hope that it may improve people's eating behaviors. The existing works range from smartphone-based apps for food journaling to automated dietary monitoring using various sensors to the use of persuasive games to support healthy eating. Let us start with food journaling.

**Food journaling:** Food journaling is a commonly used technique to encourage people to document their eating habits in order to reflect and seek feedback on one's eating behavior. A variety of works revolve around using smartphone-based apps that allow users to not only document their eating habits, but these apps also offer advanced search and feedback. For example, smartphone-based apps like *MyFitnessPal*<sup>25</sup> allow users to search for

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<sup>25</sup> MyFitnessPal: <https://www.myfitnesspal.com/>

components of a meal against a food database, retrieve calories and other nutritional information relative to their daily goal and consumption. The *POND* (Pattern-Oriented Nutrition Diary) is another example of a mobile-based food journaling, which allows users to create food entries via a traditional database lookup (Andrew et al., 2013). In the *POND* application, users can log their eating behaviors by searching for individual foods they ate or by breaking down their foods into individual components and adding portions of those individual components as seen in Figure 13.



**Figure 13:** *POND* © (Andrew et al., 2013) app allows lookup of common items for its ingredients and review of food entries.

*PmEB* is another system that lets users manually enter their diet activities on their smartphones (Tsai et al., 2007). These apps use the captured data to provide real-time, personalized feedback on performance to either reinforce the current behavior or highlight areas for improvement. However, traditional methods of manual text-based food journaling can be tedious. They take too much time and effort, and they are dependent on an individual's ability to accurately log their data. Besides, the reliability of food databases, forgetting to

journal, not logging unhealthy food, and unreliable food entries are other common concerns with this method.

As an alternative, photo-based food journaling is gaining currency that takes away the burden of manual text entry and allows more straightforward data entry through taking pictures of eaten foods. For example, Mamykina and colleagues (Mamykina et al., 2008) created a system called *MAHI* that helps diabetes patients in managing their eating habits and glucose readings. The system asks participants to capture photographs of their meal in order to keep track of their glucose readings in comparison to standard glucose readings. Kim and colleagues (Kim et al., 2010) have designed a system that supports a caloric assessment of users' photographic food journals through the use of image recognition software. Many other apps also support barcode scanning, shortcuts to commonly eaten foods and suggestions for recipes. For example, Siek and colleagues (Siek et al., 2006) created a food journal that allows participants to scan the barcodes of the foods they have eaten. However, current methods of recognizing food using image segmentation and pattern classification techniques have not yet matured, and efforts are needed to improve its reliability across different food datasets (Zhu et al., 2010). Besides the accuracy, photo-based food journaling also has other caveats. The photo food journaling of all meals is a habit difficult to adopt and maintain as item-by-item tracking is tedious (Chung et al., 2017). Finally, with photo-based food journaling methods, packaged or fast foods are most accessible to log as they come with barcodes, whereas home-made food is relatively complicated and tedious to document. As a result, the use of photo-based food journaling may prompt people to eat more packaged food, going against their healthy eating goals.

Besides, text and photo-based food journaling, existing works also looked at voice-based support systems to support healthy eating at a community level. For example, Grimes and colleagues (Grimes et al., 2008) created *EatWell*, a voice-based platform for people in a specific community to share their experiences and provide encouragement and tips for healthy eating. In this system, community members can share of voice memories of their healthy eating behaviors among people in their neighborhoods (e.g., at local restaurants) in order to nudge them to participate in a similar behavior.

Building on *EatWell*, Parker and colleagues (Parker et al., 2012) designed *Community Mosaic* to support sharing and public display of healthy eating habits using a large touchscreen display installed in a local neighborhood. Besides sharing, *Community Mosaic* (refer Figure 14) also allowed individuals interact with the displayed content by posting a personal note from a preset list of response options such as “*I am inspired to try this*” and “*I want to learn more about this.*” In a similar vein, Gerber and colleagues (Gerber et al., 2009)) developed a mobile messaging system where participants can send text messages to each other with tips about how to eat healthily.



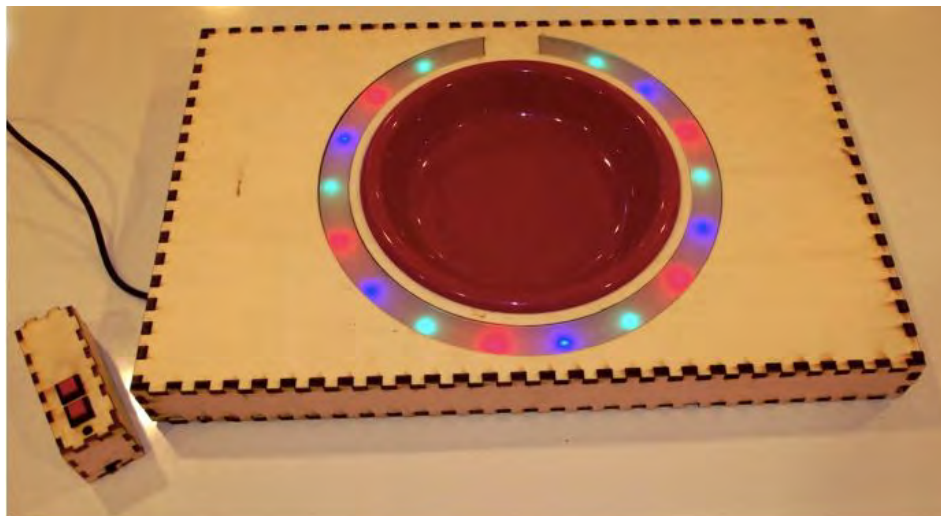
**Figure 14:** *Community Mosaic* © (Parker et al., 2012) support sharing and public display of healthy eating habits using a large touchscreen display installed in a local neighborhood.

However, all these food journaling methods work only if the user is actively participating and documenting his/her eating behavior regularly (Burke et al., 2012). Without sufficient data, recommendations cannot be made, or they are subject to low accuracy and sampling biases. For example, according to an



earlier study an active food-journaling user makes only about 3.5 entries per day (Cordeiro et al., 2015), while Krebs and Duncan (Krebs and Duncan, 2015) report that approximately half of health app users stop using it mainly due to loss of interest and a high data entry burden.

**Automated dietary monitoring:** Fueled by the recent advancements in sensing technologies, research has also looked at technologies to support automated tracking and monitoring of food intake, taking away the burden of manual tracking. Much research happened around augmenting utensils and cutlery to detect food and eating actions. For example, Lo and colleagues (Lo et al., 2007) created a Playful Tray that tracks children’s eating actions through a weight sensitive tray. *ExciteTray* (GalOz et al., 2014), on the other hand, focuses on rewarding the self-feeding activity through a colorful light display based feedback on the tray as shown in Figure 15.



**Figure 15:** *ExciteTray* © (GalOz et al., 2014) rewards healthy self feeding activity through a colorful light display.

Chang and colleagues (Chang et al., 2006) built a dining system that tracks the amount of food consumed by sensing the movement of food from the serving bowl to the plate. *HAPIfork*<sup>26</sup> is a commercial system that gives haptic feedback on one’s eating speed through vibration. Some other researchers have augmented cutting boards and kitchen knives with sensors (Kranz et al., 2007) to infer what people are eating. Besides, a range of devices starting from

<sup>26</sup> HAPIfork: <https://www.hapi.com/product/hapifork>



wearable cameras (Thomaz et al., 2013), to proximity sensors (Chun et al., 2018), to wearable acoustic sensors (Yatani and Truong, 2012) to on-body inertial sensors (Amft and Troster, 2009) to EMG-measuring eyeglasses (Huang et al., 2017) to in-ear microphones (Gao et al., 2016) have been explored to monitor eating activity.



**Figure 16:** Chun and colleagues used proximity sensors to detect eating episodes © (Chun et al., 2018) .

Vu and colleagues (Vu et al., 2017) offer a comprehensive review of existing food intake monitoring technologies. Besides monitoring eating behavior, existing works in robotics also focus on assisting users in eating. For example, *Liftware*<sup>27</sup> is a stabilizing handle designed to counteract hand tremor during eating. The device detects tremors and automatically moves in the opposite direction in order to stabilize the utensil. Another example is the *Obi*<sup>28</sup>, a domestic robot that assists diners with physical disability in eating.

Automated dietary monitoring technologies work well in controlled environments, but they struggle to offer consistent results in real-world environments (Thomaz et al., 2017). Besides, automatic dietary monitoring reduces the process of critical self-assessment and regulation that happens when individuals document behaviors themselves (Connelly et al., 2006). To this end, instead of entirely relying on automated techniques, it would be a good practice to supplement them with periodic journaling and self-assessment of food habits.

**Persuasive games:** Other works focus on designing persuasive games to promote healthy eating habits through education and play. For example, Thompson and colleagues (Thompson et al., 2010) created a persuasive

<sup>27</sup> Liftware: <https://www.liftware.com/>

<sup>28</sup> Obi: <https://meetobi.com/>

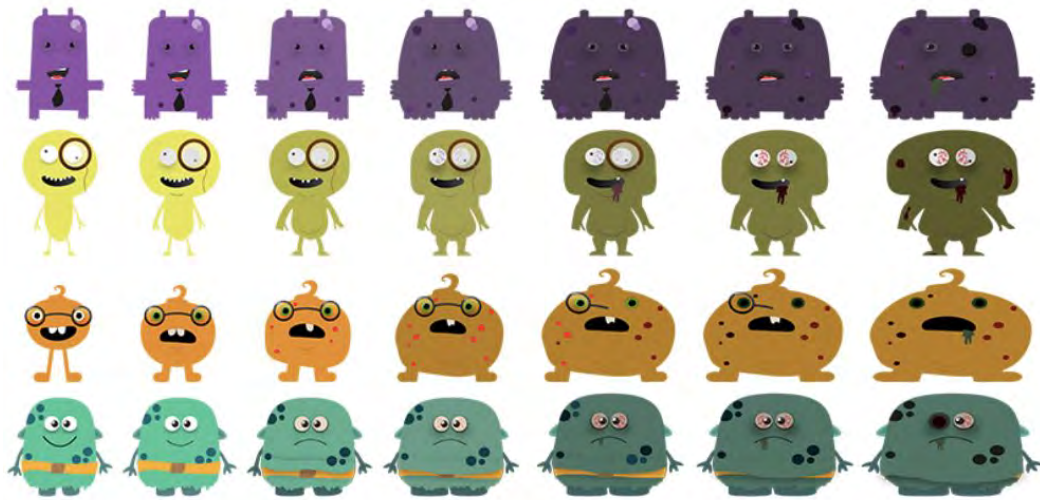
adventure game called *Escape from Diab* to promote healthy eating habits. In this game, the objective is to escape the dreary land *Diab* by training others to increase their physical strength through healthy eating and exercising. Orji and colleagues (Orji et al., 2013) also designed a persuasive game called *LunchTime*, where players play the role of restaurant visitors, and their goal is to choose the healthiest option from a list of food choices. In *OrderUP!* (Grimes et al., 2010) players need to recommend to their customers the healthy options to keep their job in a neighborhood restaurant. *FatWorld*<sup>29</sup> instead of just educating about healthy diet, focuses on the complexity of issues surrounding nutrition, such as budgets, the physical world, subsidies, and regulations. Interactive training chopsticks (Chia and Saakes, 2014) is another game that uses chopsticks as controllers for an augmented mirror application game in order to help children develop the skill of eating with chopsticks. Ganesh and colleagues (Ganesh et al., 2014) developed *FoodWorks*, a system that digitally augments the dining plate by projecting sad smileys when the diner avoids healthy food.

A couple of works also focussed on motivating people to fulfill their daily water intake through playful systems. For instance, *Playful Bottle* (Chiu et al., 2009) is an augmented water bottle that tracks water intake using a smartphone and uses it as an input to a mobile game. Fortmann and colleagues (Fortmann et al., 2014) designed *WaterJewel*, a fashionable LED-based bracelet that serves as an awareness and reminder tool for promoting water intake. Lessel and colleagues (Lessel et al., 2016) similarly developed *WaterCoaster* to motivate people to drink beverages more often. This app represents the beverage consumption as the water level in a tank holding a virtual character, which changes facial expressions to create feelings of empathy. Finally, *Monster Appetite* (Hwang and Mamykina, 2017) is a game that takes a subversive approach to educate people about healthy habits. In this game, consuming high-calorie food items will make the player's onscreen monster avatar unhealthy and overweight, as seen in Figure 17. Studies of these games showed an increase in the players' nutrition knowledge, besides raising awareness and commitment to initiate and maintain healthy eating behavior (Busch et al., 2015; Grimes et al., 2010). However, very few of these games have been scientifically evaluated through

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<sup>29</sup> FatWorld: <http://persuasivegames.com/game/fatworld>

longitudinal studies and as such there are concerns over the effectiveness of these games as an intervention tool in the longer run (Granic et al., 2014).



**Figure 17:** In *Monster Appetite* © (Hwang and Mamykina, 2017) game, player’s onscreen monster avatar becomes unhealthy and overweight if player consumes unhealthy food.

To date, most of the research on healthy eating primarily focus on increasing awareness and supporting motivations for eating healthy and weight loss, rather than improving people’s literacy about food or pleasures associated with eating healthy food (Hingle and Patrick, 2016). This focus can be problematic in the long run and could even have adverse effects on users with eating disorder behaviors, as observed by Eikey and Reddy (Eikey and Reddy, 2017). With a focus on data and its effect on the body, often the pleasures of eating get compromised for the sake of health. McIntosh (McIntosh, 1996) explains that “*people eat food, not nutrients. That is, they generally see the substances they ingest through the lens of culture and social relationships*” (p.4). A study by Hsu and Blandford (Hsu and Blandford, 2014) also report that the need to restrict the pleasure of eating was one of the most widely experienced struggles involved in weight loss. Therefore, more pleasurable and accessible ways to support healthy eating are needed that look at food beyond its nutrients. One such concept originated in Buddhist philosophy is of mindful eating, which we describe next.

## 6.2 Mindful eating

Mindful eating is a proven practice to regulate one's healthy eating behavior (Keesman et al., 2017). Mindful eating (Bays, 2009; Tapper, 2018) emphasizes eating slowly and without any distractions. Mindful eating also assumes that one is eating with the intention of caring for oneself, by noticing and enjoying the food, recognizing its effect on the body and knowing when to stop. To this end, an individual's eating behavior (i.e., how one eats) plays a crucial role in mindful eating. However, instilling such behavior is challenging in practice as it requires going against the existing practices of eating (van't Riet et al., 2011).

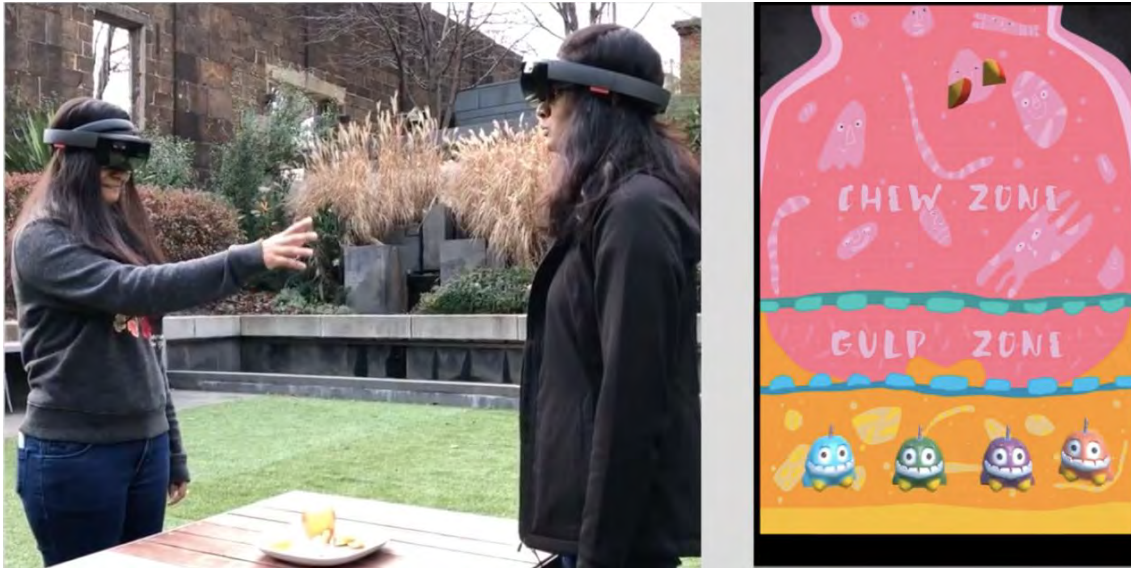
Today, fewer of us can have our meal without having our eyes glued to the television or smartphone screens. Consuming screen-based media while eating has become a norm despite its detrimental effects on physical and social wellbeing. Several studies point out that eating while watching television (Avery et al., 2017; Reid Chassiakos et al., 2016; Reid et al., 2017) and other forms of screen-based media (Kononova et al., 2018; Oldham-Cooper et al., 2011) is bad for our digestive health as it interrupts the physiological signals of satiety and hunger. As a result, people find it difficult to know when they are hungry or full. Additionally, because these distractions are immersive, people also forget how much they have already eaten and in consequence they often overeat, which over time manifests into much more significant problems such as obesity and heart diseases (Francis et al., 2017). The existing literature promotes mindful eating through 1) education 2) moderation and 3) self-reflection.

**Educational approaches:** These approaches promote mindful eating mostly rely on communicating the importance of mindful eating, with an assumption that with this knowledge, people could improve their eating behavior. Educational approaches to mindfulness include in-person sessions (Kristeller and Wolever, 2011) as well as daily mindfulness exercises that can easily be carried out at home (Epstein et al., 2016). However, such interventions are time-consuming and demanding of participants. Increasingly it is being proven that nutritional education alone is inadequate to bring changes in people's dietary behavior (Chandon and Wansink, 2012). For example, asking people to eat a moderate amount of food leaves the decision of portion size and frequency

to the individual. Since the term “moderation” is ill-defined, most people cannot judge the right or appropriate amount of food. Besides, previous research also suggests that humans are poor judges of portion size and they underestimate the amount of food that they have just eaten (Almiron-Roig et al., 2013).

**Moderation based approaches:** These approaches to mindful eating include reducing the availability of food (Rozin et al., 2011), regulating the portion size (Levitsky and Pacanowski, 2011) and by moderating or minimizing distractions during eating (Hiniker et al., 2016; Mazmanian and Lanette, 2017). However, these approaches have met with limited success (Rekhy and McConchie, 2014; Tuorila, 2015).

**Reflection based approaches:** Finally, self-monitoring and reflection based approaches have also been proposed and studied to promote mindful eating. Unlike earlier prescriptive techniques of education and moderation, reflection based techniques are more open-ended but require commitment from the participants. These techniques encourage individuals to maintain a food journal and reflect on their eating behavior using paper-based diaries, smartphone-based apps such as *myFitnessPal* and food photography (Chung et al., 2017; Goyal et al., 2017) as explained earlier in the healthy eating section. For example, Robinson and colleagues (Robinson et al., 2013) developed an app in which users take pictures of their food and review these pictures when deciding what to eat next. The app does not ask or try to infer nutritional info, but instead, it encourages users to reflect on how they felt after eating the food. *National Mindless Eating Challenge* (NMEC) is a smartphone-based game (Kaipainen et al., 2012) that asks players to take care of a virtual pet by following a variety of healthy eating recommendations. Arza and colleagues (Arza et al., 2018) created an AR based game called *Feed the Food Monsters* that educate people about their chewing behavior in a social dining setting as seen in Figure 18. This game detected chewing actions through EMG sensors and the captured data is then used to feed virtual monsters, overlaid on co-diner’s body. Although these solutions ease the burden of manual monitoring to a certain extent, these solutions are still tedious, and they often fall out of habit (Cordeiro et al., 2015).



**Figure 18:** In *Feed the Food Monsters* © (Arza et al., 2018) game, player needs to chew their food properly in order to feed and satisfy virtual monsters, overlaid on their body.

Practicing mindful eating is thus challenging because of the limited understanding of the eating behavior and a variety of social, economic and psychological factors that influence this behavior. Moreover, the majority of the existing solutions are stand-alone solutions that do not integrate with existing eating practices and require strong motivation and commitment. Instead, a different perspective is needed that takes into account the social, economic and psychological factors associated with eating to allow individuals “to make food choices without experiencing guilt or an ethical dilemma, honoring hunger, respecting fullness and enjoying the pleasure of eating” (Tribole and Resch, 2012). Research has argued for designing celebratory technology that utilizes positive aspects of technology to make the dining experience more indulging and playful (Ferdous et al., 2017). For example, commensality or the act of eating together is a crucial aspect of eating experiences, which we describe next.

### 6.3 Commensality

Greek philosopher Epicurus once said that “*We should look for someone to eat and drink with before looking for something to eat and drink, for dining alone is leading the life of lion or wolf.*”

Commensality is typically defined as “*the practice of sharing food and eating together in a social group such as a family*” (Ochs and Shohet, 2006) p. 37). Commensal dining span across time and culture (Fischler, 2011; Kerner et al., 2015) and in many cultures, eating is a sort of “*social ritual*” that should be done in the company of others. Commensal dining in families are essential mechanisms to fosters togetherness and nurtures familial ties (Fischler, 2011). It also nurtures children’s socialization into language, customs, and social expectations both in families and in broader society (Fulkerson et al., 2006). Studies by Grimes and colleagues (Grimes et al., 2009) also highlight the importance of having meals together in a family as mealtime affords opportunities for families to notice changes in each other’s habits and to make suggestions for improvement and change. Sharing meals also means sharing experiences, establishing essential social attachment and cherishing the feeling of togetherness (Sobal and Nelson, 2003).

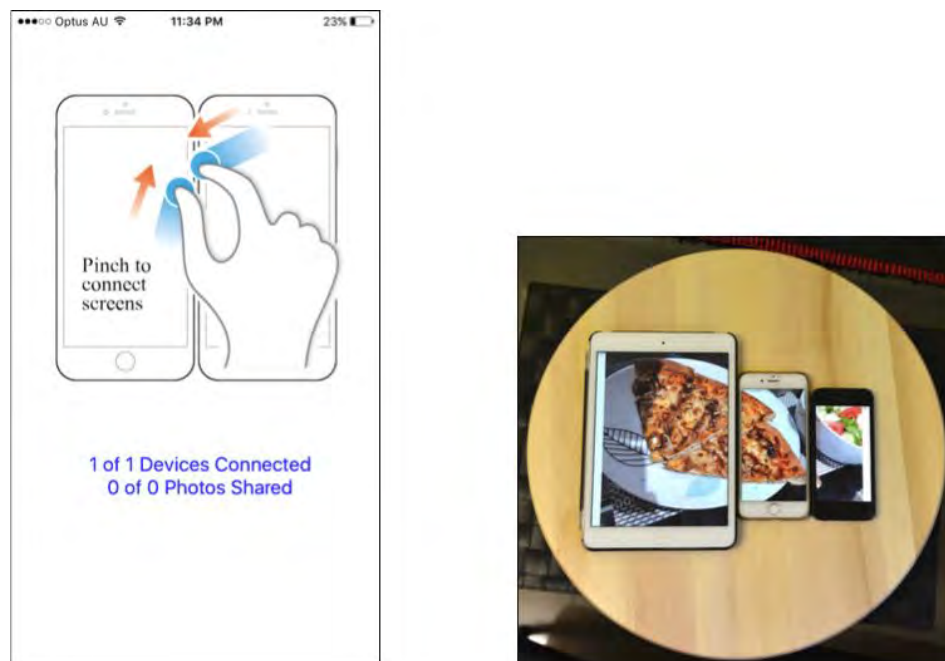
When people eat together, people experience comfort, positivity and social bonding, which in turn leads to social facilitation of eating (the food tastes better, and individuals consume more food) (Herman, 2015; Nakata and Kawai, 2017). Eating alone, on the other hand, is less motivating and those who are eating alone could have a high risk of developing poor nutritional intake (Davis et al., 2000). The results are consistent across various age groups. A study by Salvy and colleagues (Salvy et al., 2008) shows that children who ate alone consumed less than children who ate with their siblings. Another study by McAlpine and colleagues (McAlpine et al., 2003) found that elderly peoples’ food intake increased by 60% when they dined with others. A study by Gustafsson and others (Gustafsson and Sidenvall, 2002) further illustrates the importance of commensal eating when they found that the elderly described eating with others as a pleasurable dining activity while eating alone felt like a necessity to them.

Earlier research also suggests that individuals model their intake on the consumption of the dining partner (Herman, 2017). Since overeating is negatively stereotyped, individuals at a dinner table often turn to their dining partner as a guide on how much can be eaten without appearing excessive (Howland et al., 2012).



Owing to the benefits of commensal eating, a variety of existing works have looked at using technology to support social dining experiences. Traditionally, the stance of research is against the use of technology during mealtime. Existing research argues that technologies detract from the experience of eating together and can negatively affect the nutrition, social interaction and commensality, particularly for significant social groups, such as families (Hiniker et al., 2016; Robinson et al., 2013).

In contrast, recent works have shown that digital technologies can have a positive impact on what we eat, how we eat, and the spaces in which we eat. The works by Ferdous and team (Ferdous et al., 2017, 2016a) suggest how repurposing technologies act as a medium to facilitate shared activities that can lead to a positive experience of eating together. For example, the authors presented a novel system called *TableTalk*, which transforms personal devices into a communally shared display on the table to enrich mealtime interactions as shown in Figure 19. *4Photos* (O’Hara et al., 2012) is another social dining system that displays photos from diners’ Facebook collections through a centralized display placed in the middle of the dining table.



**Figure 19:** *TableTalk* © (Ferdous et al., 2017) support enriched mealtime conversations through a shared display of interconnected devices.



The *Tea Place* (Li et al. 2007) is an ambient multimodal display that responds to the color of tea placed on the table, whereas *History Tablecloth* (Gaver et al. 2006) adds a digital layer on top of the dining table to trace back the food prints of objects placed on it to unveil various commensal patterns within the home. Bekker and colleagues (2009) discuss the use of responsive objects triggering conversations between diners. The *Table Talk Enhancer* (Ogawa et al. 2012) is another interesting system to encourage conversations at mealtime. This system visualizes mealtime communication (utterance rates of individuals in particular) by illuminating the dining table surface with three LED lights (red, green, and blue). The system records the utterance rates of people sharing a meal using directional microphones and changes the illumination patterns of the table surface accordingly. *Gamelunch* (Polotti et al. 2008) takes an acoustic route to enhance dining engagement. In this system, different dining actions, such as cutting and slicing are mapped onto corresponding music to create a sound synthesis. Kadomura and team (Kadomura et al., 2014) designed a range of interactive tableware devices to make eating more enjoyable by emitting sounds based on the eating activity.

Other works in this arena include the use of robotic technology to facilitate innovative social eating experiences. For example, Mitchell and colleagues (Mitchell et al., 2015) developed a novel augmented table which is designed to guide diners in keeping pace with others. Actuators gradually raise the dish of a slower eating partner and lower the dish of a faster eater by a corresponding amount. These discrete movements act as nudges to guide the diners. Nabil and team (Nabil et al., 2018) designed *ActuEating* that uses actuating dynamic material to develop a dining table which changes shape and color in response to diners' actions. *Arm-A-Dine* is an augmented social eating system, consisting of wearable robotic arms attached to the diners' body for eating and serving food. However, unlike the normal biological arm, whose actions are guided by one's own volition, in *Arm-A-Dine*, the movements of the third arm are controlled by the affective responses of the eating partner (refer Figure 20). This research showed the value of robotic technology to positively affect the social eating experience going beyond the current paradigm of assistive technology.



**Figure 20:** *Arm-a-Dine* © (Mehta et al., 2018) support playful mealtime conversations through on-body robotic arms.

While the majority of the works mentioned above focus on home dining, Davis and team (Davis et al., 2012) also reveal that even in semi-public spaces, the use of digital technologies can serve to entertain, support and bridge intergenerational interaction at the dinner table, allowing families to eat together longer. In their work *Chorus*, a technology is designed to orchestrate the sharing of personal devices and stories during family meal times.

Within the commercial arena, many top restaurants are increasingly collaborating with architects and designers in order to create unique dining atmospheres. Two of the well-known examples are the sensory play of Heston Blumenthal (Blumenthal, 2008) and Ferran Adria's work on "molecular gastronomy" (Adria et al., 2006). In the *Inamo restaurant*<sup>30</sup>, projectors are used on dining tables to give an impression of food coming to life. For instance, diners can customize the dining tablecloth by uploading their images or company logo in advance before dining. Similarly, *Le Petit Chef*<sup>31</sup> uses projection mapping on a table to facilitate social engagement. In the Fat Duck restaurant, the sound of the sea dish transforms the dining experience by enhancing the taste and flavor of the food itself (Muir, 2014). Other interesting examples include the use of augmented reality (AR) techniques to modify food textures (Okajima and Spence, 2011), modification of food sounds during biting

<sup>30</sup> Inamo Restaurant: <http://www.inamo-restaurant.com/promos/tablecloths/>

<sup>31</sup> Le Petit Chef: <http://www.lepetitchef.com/>

to change people's perception of crispness and freshness of the chips (Zampini and Spence, 2004) and study of "sonic seasoning" (Spence, 2015) to understand different pitch sounds and its influence on food taste perception. Spence's books "the perfect meal" (Spence and Piqueras-Fiszman, 2014) and "gastrophysics" (Spence, 2017) offer a comprehensive review of the works in this space.

All of the works mentioned above bring in a playful aspect to the traditional commensality by using various existing and emerging technologies. However, commensal dining is becoming increasingly difficult in today's era. Industrialization and globalization have prompted families to move away from each other, and as a result of the geographical distances and the varied time zones, families find it incredibly hard to have a meal together and enjoy the benefits of commensality. Even for the co-located families, work-related commitments and irregular work hours, prompt people to dine alone most of the time (Nea et al., 2018). Eating alone, however, can be tedious, less motivating and shown to have a negative impact on health and well being of a person. To remedy such situations, a variety of works have explored a celebratory view on designing technology to offer unique opportunities for solo-diners to feel engaged and indulged in dining. We describe these work next.

## **6.4 Solo-dining**

French philosopher Jean Baudrillard once wrote, "*Sadder than destitution, sadder than a beggar is the man who eats alone in public. Nothing more contradicts the laws of man or beast, for animals always do each other the honor of sharing or disputing each other's food*".

It is thus no surprise that eating alone is boring and less motivating, despite its prevalence in today's era. Solo dining can have a significant impact on the social, mental and the physical well being of a person. Studies suggest that eating alone increases anxiety, a risk for heart diseases, diabetes, metabolic syndrome and loneliness (Lahad and May, 2017; MacMillan, 2017). Within the HFI literature, various techniques and methods have been proposed to overcome the adverse effects of solo dining and to make people feel more engaged when eating alone. We describe some of the critical works below, which we have categorized under virtual dining and co-dining companions categories.

**Virtual dining companions:** Numerous works within HFI have investigated the use of video communication technology for tackling the solo dining problem. For example, Wei and colleagues (Wei et al., 2011) created a dining table embedded with interactive subsystems to create a sense of coexistence among remote family members. However, for such a system to work, dining participants must be available at the same time to eat together. Because of time-zone differences and other such contingent factors, this condition can often be hard to fulfill. As a remedy for such a situation, Nawahdah and Inoue (Nawahdah and Inoue, 2013) developed a system called *KIZUNA*, a time-shifted dining system which enables people to enjoy a meal together in a virtual environment (refer Figure 21). In this system, a person can also enjoy a meal while watching an earlier recorded video of a remote person's dining.



**Figure 21:** *KIZUNA* © (Nawahdah and Inoue, 2013) supports virtual dining through time-shifted virtual environments.

Through this kind of virtual responsive setting, the authors observed that the individual might feel less alone when eating alone. Barden and colleagues (Barden et al., 2012) designed a virtual telecommunications platform that supports remote people in experiencing a sense of meaningful and playful mealtime experience within the practices of a traditional dinner party. Similarly, Grevet and colleagues (Grevet et al., 2012) developed a technology probe which provides social awareness during mealtimes to help alleviate the loneliness of

dining alone. From these works, we learn that video-based communication technologies could be a potential medium to connect remote diners. However, such technologies do need a remote presence (either live or recorded) of another person to function. In the absence of it, people often rely on static multimedia and social media content mediated through television and smartphone devices to feel engaged in solo dining. For example, in restaurants as well as at home, solo diners are often found holding the fork or chopsticks in one hand and the smartphone in the other hand.

Existing research also looked at dining in virtual reality settings. Arnold and team (Arnold et al., 2018b) developed a Virtual Reality game called *You better eat to survive!* that utilized eating as a game mechanic to facilitate an engaging cross-modal gameplay experience. In this game, a player needs to survive a virtual island by chewing real food that gives him/her energy (and time) to explore the island and to find a rescue flare gun. If the player does not eat in time, the screen fades to black, signaling the loss of energy. A second non-VR player acts as the VR player's arms, feeding him/her when necessary and eating actions are detected using a microphone as seen in Figure 22.



**Figure 22:** *You better eat to survive!* © (Arnold et al., 2018a) explores playful social dining in VR through cross modal interactions.

Harley and colleagues (Harley et al., 2018) designed two proof of concept multisensory VR experiences. The first concept simulates a moment at the beach, including heat, sunscreen, sand underfoot, and a fruit drink while the

second concept sketch out a moment spent in a forest with a looming presence of a virtual wolf, real wind, grass underfoot, and freshly baked bread in a basket nearby. A gastronomical VR experience called *Project Nourished*<sup>32</sup> also focuses on allowing its users to experience a new way of dining with no calorie intake but offering gustatory, olfactory, and haptic cues. For instance, in this experience, instead of eating regular food, people eat 3D printed hydrocolloid food made with algae and yeast. All these works illustrate engaging crossmodal gameplay allowing individuals to dine in a setting of their choice.

**Co-located dining companions:** A variety of works explored the use of co-located dining companions to support solo dining. For example, a famous *Hotpot* restaurant in China provides a group dining service to solo diners (Huang, 2018). Waiters will bring in a virtual character, a stuffed Teddy bear as a companion which enables the solo dinner to feel that he/she is sharing the hotpot with the co-diner. The idea is to make the solo dinner feel less lonely by making the teddy bear enact the role of a dining companion by making it sit in the diner's seat and also by providing it with a knife, plate and other cutlery. A Japanese restaurant *Moomin cafe* (Arakawa, 2014) also implements a similar idea, where diners get the company of giant stuffed animals. The stuffed animals are the characters from a Finnish picture book series. Besides stuffed toys and virtual characters, a few restaurants also welcome pet dogs and cats as eating partners. Restaurants like *Cat cafe*<sup>33</sup> and the *Therpup cafe*<sup>34</sup> enable people to have their food with their dogs and cats roaming around. The popularity of these restaurants suggests to us that non-humans could be dining companions.

The final part of this phase describes works that go beyond the traditional consumption experiences and explore new technology augmented ways of eating and using food as a representation medium. Let us first describe works on the augmentation of eating experiences with digital technologies.

## 6.5 Augmented eating

Augmented eating systems within HFI look at altering the perception of food through crossmodal interactions and creating simulations of eating experiences

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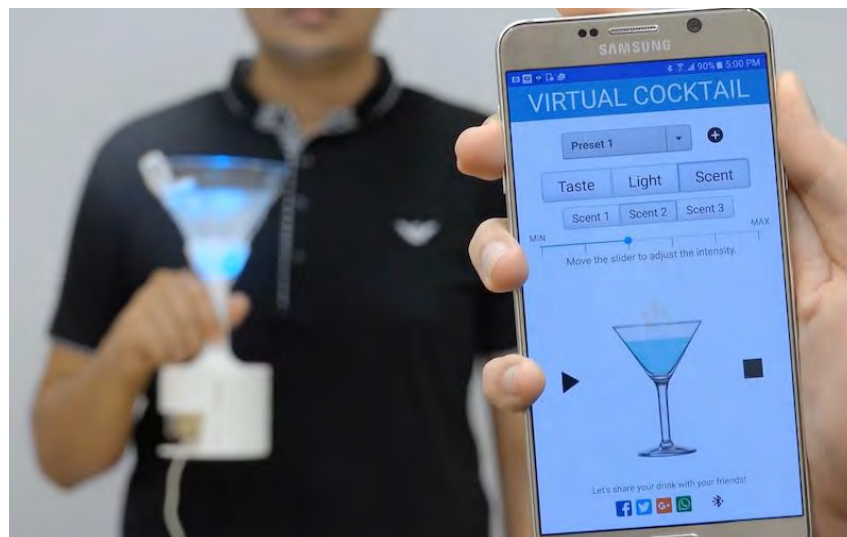
<sup>32</sup> Project Nourished: <http://www.projectnourished.com/>

<sup>33</sup> Cat Cafe: <https://catcafemelbourne.com/>

<sup>34</sup> Therpup Cafe: <http://www.therpup.com/>



using various technologies. Ranasinghe and team (Ranasinghe et al., 2017a, 2017b, 2015, 2011; Ranasinghe and Do, 2016) for example, offer a range of systems that demonstrate an artificial sensation of taste (gustation) through electrical and thermal stimuli. Instead of relying on chemical stimuli, one can also achieve the sensation of sweet and sour by warming and cooling the tongue (Cruz and Green, 2000). Additionally, electrical and thermal stimuli are easy to store and manipulate. Drawing on this, Ranasinghe and colleagues (Ranasinghe et al., 2015) presented a digital taste interface containing a 2×2 grid of Peltier elements that can deliver heating and cooling stimuli to the tongue. The authors proposed a *Vocktail* (Virtual Cocktail) that allows users to experience virtually flavored drinks on top of the plain water or an existing drink (Ranasinghe et al., 2017b) and a *Digital lollipop* that digitally simulate the sour sensation at three intensity levels (Ranasinghe and Do, 2016). The authors also used this approach to virtually share the flavor experience of a glass of lemonade remotely between diners using sensors that capture the color and the corresponding pH value of the lemonade and a customized tumbler to virtually simulate these properties using plain water (Ranasinghe et al., 2017a).



**Figure 23:** *Vocktail* © (Ranasinghe et al., 2017b) allows users to experience virtually flavored drinks on top of the plain water or an existing drink.

A different approach to alter the gustation sense was made by Narumi and colleagues (Narumi et al., 2011) by presenting *MetaCookie+* and Augmented Satiety systems. In *MetaCookie+*, AR headset overlays a virtual cookie onto a plain cookie and then pumps a scent into the user's nose through a set of tubes,

resulting in customized tastes of the same cookie. *Augmented Satiety* (Narumi et al., 2012) is also an AR system that affects perceived satiety by altering the volume of food visually. The food simulator (Iwata et al., 2004) offers a haptic interface that simulates a sense of chewing by generating a force on the user's teeth as an indication of food texture. In related work, Niijima and Ogawa (Niijima and Ogawa, 2016) explored the use of electrical muscle stimulation to mimic and modify food textures virtually.

Hashimoto and colleagues (Hashimoto et al., 2006) came up with a straw-like user interface that virtually model a pseudo drinking experience. Using servo motors, solenoids and air pressure sensors, it reproduced pressure, vibration and sound sensation associated with drinking with a straw despite the lack of liquid in their setting. *FunRasa* (Ranasinghe et al., 2013) is an interactive drinking platform that expands the drinking experience by electrically stimulating the user's tongue as well as superimposing virtual color onto the drink.

*LOLLio* (Murer et al., 2013) is a gustatory interface for playing games by using a lollipop as a haptic input device that changes flavors. In this playful system, small amounts of thinned citric acid pumped from the grip through to a hole in the candy of the lollipop and by varying the rate of injected sour liquid, different tasted in the interval sour-sweet are achieved. *Chewing Jockey* (Koizumi et al., 2011) is another playful system that focuses on improving the eating experience by experimenting with chewing sounds. This system augments food sounds generated during a mastication process to affect the perception of food texture. It utilizes a bone conduction speaker, a microphone, and a photo reflector sensor to track the user's jaw movement, and a program to control the sound that matches the process of eating food. For example, while chewing gummy sweets, participants can hear sounds of screaming creatures to facilitate playful enjoyment with the food. *The singing carrot* is another playful system that detects our food consumption using capacitive touch sensing to generate unique digital sounds (refer Figure 24). These digital sounds promote a playful side of gusto sonification. Finally, *TastyFloats* (Vi et al., 2017) is a novel system that uses acoustic levitation to deliver food morsels to the users' tongue. Users can potentially use such technology to enjoy tasty little bits of food during movie watching and in virtual reality and desktop gaming environments.





**Figure 24:** *The Singing Carrot* © (Wang et al., 2018) allows users to experience new gustosonic experiences while eating carrot.

Both electrical and thermal stimulation of taste requires more focused experimental studies considering aspects such as material characteristics (i.e., gold vs. silver), position on the tongue, and the waveform of the electrical signal. Moreover, it is essential to experiment with different physiological and psychological aspects of the sensation of taste at the intersection with other sensory cues. Obrist and colleagues (Obrist et al., 2014) studied the design qualities and user experiences of five basic tastes (i.e., sweet, sour, salty, bitter and umami) to highlight three important themes for designing taste experiences: temporality, affective reactions, and embodiment. These works suggest that digital technologies can positively affect the eating experiences through digital augmentation. They illustrate the playful potential of how technology and dining could interplay in the near future.

**Food as an expressive medium:** Besides simulating and augmenting eating experiences, existing research also explored the use of food as an expressive representation medium. Resner (2001) was the first to introduce the concept of an *Edible User Interface* (EUI) that inspired Maynes-Aminzade (Maynes-Aminzade, 2005) to design *TasteScreen* and *BeanCounter*. The *TasteScreen* project enabled users to virtually taste different food items by licking their photographs displayed on an LCD screen. The taste was simulated by dripping of liquid residue of different flavors onto an LCD screen as seen in

Figure 25. *BeanCounter* is a data-driven project that displays network traffic data (e.g., events of memory and data transmissions) via jellybean dispensation.



**Figure 25:** *The TasteScreen* © (Maynes-Aminzade, 2005) allows users to virtually taste different food items by licking their photographs displayed on an LCD screen.

Adding to that, recent advancements in digital fabrication technologies with devices like food printers and laser cutters have allowed the creation of digitally enhanced food from digital designs (Schoning et al., 2012). For example, *Procusini*<sup>35</sup> and *ChocEdge*<sup>36</sup> are commercially available 3D food printers that create 3D printed candy and chocolates from digital 3D models. Inspired by these developments, few works have attempted to create unique, personalized and engaging experiences around edible forms of data representation, also called “*data edibilization*” (Wang et al., 2016). Wang and colleagues (Wang et al., 2016) described five advantages of data edibilization in terms of attractiveness, richness, memorability, affectiveness and sociability, which our study confirmed. Learning from these insights, designers have looked at various ways of amalgamation of data with food design.

<sup>35</sup> Procusini: <https://www.procusini.com/>

<sup>36</sup> ChocEdge: <http://chocedge.com/>

Artists like Elizabeth Willing<sup>37</sup> and Tisha cherry<sup>38</sup> experiments with innovative food arts by presenting food in unique design while Wei and team (Wei et al., 2014) created a system to support food based messaging between friends and loved ones. Khot (Khot, 2016) explored food as an appealing medium to represent physical activity data and to nudge people towards an active lifestyle. The author developed and studied *TastyBeats* that provides users with personalized sports drinks, where exercise data define the quantity and flavor. *TastyBeats* (Khot et al., 2015a) also utilized an engaging water fountain based interaction to create a fluidic spectacle of mixing the drinks, thereby offering a public and vibrant vista of someone's active life. The accompanying study highlighted that having an engaging process that connects data with sports drinks facilitated social interactions and increased motivation for physical activity.



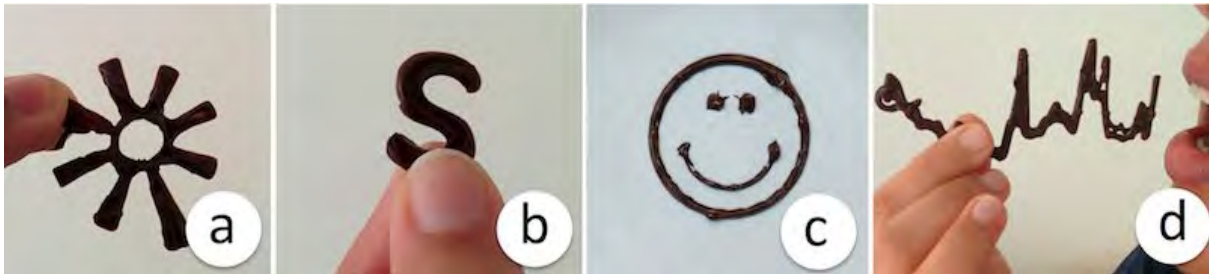
**Figure 25:** *The TastyBeats* © (Khot et al., 2015b) creates visual fluidic spectacle of someone's physical activity.

Their next work, *EdiPulse* (Khot et al., 2017a) transformed self-monitored data from the physical activity into delightful 3D-printed chocolate treats to inspire new ways of engaging with self-monitored data. Studies showed that these systems successfully moderated individuals' snack eating habits. For example, in *EdiPulse*, the link between data-driven chocolate and an active life affected participants' eating choices so that most users refrained from eating chocolate

<sup>37</sup> Elizabeth Willing: <https://elizabethwilling.com/>

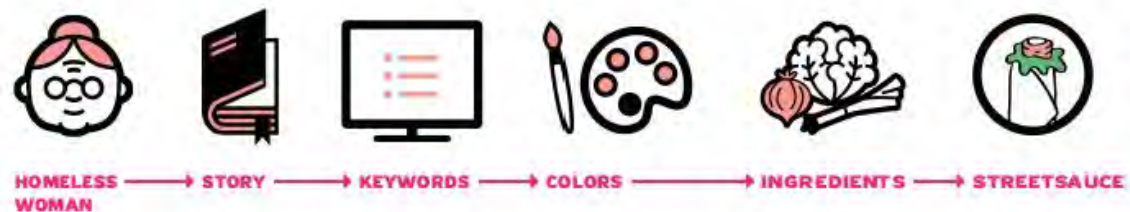
<sup>38</sup> Tisha Cherry: <https://www.instagram.com/tishacherry/>

only on days they were inactive, even if the chocolate was right in front of them. The *EdiPulse* system became a motivational anchor and brought unexpected positivity and determination towards leading an active lifestyle.



**Figure 26:** *EdiPulse* © (Khot et al., 2015b) represents physical activity data through 3D printed chocolates.

*StreetSauce* (Dolejšová and Lišková, 2015) is another data edibilization project, featuring a menu made of carrot hotdog and data-based sauces created out of the life stories of homeless chefs as seen in Figure 27. This work aims to support public engagement in the issue of female homelessness.



**Figure 27:** *StreetSauce* © (Dolejšová and Lišková, 2015) features a menu made of carrot hotdog and data-based sauces created out of the life stories of homeless chefs.

## 6.6 Summary

In this chapter, we examined various methods and technological solutions to support eating practices. Although, the focus has been on instrumentality, i.e., encouraging people to eat healthy and mindfully, increasingly new works are surfacing that look at pleasurable side of eating. We believe that interactive technology can be designed to support eating as a form of play, similarly to how research on bodily game design has previously argued to facilitate "*experiencing the body as play*" (Mueller et al., 2018) rather than using the body as a mere input controller alternative): we argue that food-technology interactions are not just an alternative input to gameplay, but rather a unique

opportunity to facilitate experiencing eating as play. Prior work on the non-serious play inspires us and describe playfulness in regards to eating as a mindset whereby people approach the eating activity with an attitude similar to that of "paidia", as something not serious, that does not have a clear goal nor real-world consequences (Caillois, 2001) to address misaligned relationship with food (ranging from obesity to eating disorders). The next chapter describes the final phase of HFI, disposal.

# 7

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## Disposing Food

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*“Animals feed; man eats; only a man of wit knows how to eat.”*

— Jean Anthelme

The final phase of the Human-Food Interaction is about *disposing food*. This phase is concerned with food loss and food waste, which occur across all phases of the food supply chain from initial production down to final household consumption<sup>39</sup>. The food waste may be accidental or intentional; ultimately it leads to less availability of food for all. It is estimated that at least 30% of all produced food items end up being wasted (Parfitt et al., 2010). Current processes of food production are also resource intensive. As a result, food waste also has a significant environmental impact in the form of soil erosion, deforestation, water pollution and greenhouse gas emissions (Mourad, 2016). For example, Kummu and colleagues (Kummu et al., 2012) mention that a food waste measuring 614 kcal/cap accounts for the loss of 24% of the freshwater resources used, 23% of the cropland areas and 23% of the fertilizer used.

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<sup>39</sup> Food and Agriculture Organisation: <http://www.fao.org/home/en/>

Moreover, composting methods and food donations can recover only less than 1/3 of food waste, and unfortunately, the majority of the waste (over 72%) is landfilled (Parfitt et al., 2010). In general, vegetables, animal products, and commodities are the most contributors to the generated waste. Besides, wasting pre-packaged foods also contribute to the loss of natural resource invested in refrigeration, packaging, and transport (Schmidt and Matthies, 2018) accounting 19% to 29% of the CO<sub>2</sub> footprint per capita. In light of the widespread food scarcity<sup>40</sup>, these figures highlight the importance of reducing food waste.

Existing literature has looked at various techniques to remedy such behavior and to encourage more sustainable food management across each phase of the food supply chain with domestic food waste being the key area that received maximum attention. Before we describe issues and approaches to tackle domestic food waste, let us first describe food waste that happens during production and retail and existing solutions to address it.

## **7.1 Food waste during production and retail**

During production and retailing, food waste happens mainly because of the biased food quality standards. For instance, during the production stage, many of the edible vegetables and fruits get thrown out even before they reach the supermarket because they do not pass the “quality” standards concerning the size, shape, and appearance – such as bananas that are too small, or apples that are too red. Besides, bruised food items are also thrown to landfill as consumers judge bruises and blemishes as a sign of spoiled food (Grunert, 2002). However, farmers or food producers have to meet these food quality standards in order to retain their access to approximately 70-80% of the fresh food market, as observed by Devin and Richards (Devin and Richards, 2016) in Australia. Although there exist no technical solutions to deal with these issues at this moment, supermarkets and governments from different countries have introduced campaigns and taxation to manage food waste during production. For example, French supermarket chain *Intermarché*<sup>41</sup> launched a campaign encouraging consumers to purchase less than perfect food and introduced taxation on food wasted at the supermarkets. Italy has offered tax breaks on

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<sup>40</sup> Global Food Scarcity: <https://sdn.unl.edu/global-food-scarcity>

<sup>41</sup> Intermarché: <http://itm.marcelww.com/inglorious/>



supermarkets donating surplus food to charities. Australian Supermarkets have aligned with food rescue organizations to donate unsold or “surplus” food. However, a study by Devin and Richards (Devin and Richards, 2016) criticised the approach of judging food price concerning its appearance (beautiful or ugly food) and reinforcing values that perfection (beautiful looking food) comes at a premium and ugly food should be price discounted.

Food waste also occurs significantly in restaurants, and various attempts are also made to prevent this from occurring. For example, *MintScraps*<sup>42</sup> is an online platform that empowers restaurants, hotels, and food businesses to track, reduce, and divert their waste. This platform uses gamification techniques to increase engagement and awareness of waste management practices. *Wise Up on Waste*<sup>43</sup> is an application by *Unilever* that offers professional kitchens the ability to track their waste generation and by offering them tips on potential cost savings from its management. Despite these attempts, food waste has not yet been tackled on a large scale in restaurants. The majority of the attention is on domestic food waste, which we describe next.

## 7.2 Domestic food waste

On the food supply chain, households represent the largest food-waste faction. Households contribute to food waste in the form of 1) unconsumed and expired food 2) leftovers 3) preparation residues 4) the packaging of food (Schneider 2008). The prevention of domestic food waste is of utmost importance (Parfitt et al., 2010) because the food wasted by households has a significant environmental impact as it undoes all the efforts put into its production, processing, transportation, cooling and preparation besides contributing to wastage of all (fossil) energy (and greenhouse gas emissions).

A substantial obstacle to the reduction of food waste in the household is consumers’ beliefs about the safety of perishable products and health (Schanes et al., 2018). Often consumers have a misguided idea about what constitutes an edible product and will throw items away that still retain consumption potential. To consumers, the appearance of the food is a more assuring indicator of its

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<sup>42</sup> Mintscraps: <http://www.mintscraps.com/>

<sup>43</sup> Wise up on Waste: <https://www.unileverfoodsolutions.com.au/chef-inspiration/chef-training-and-resources/managing-food-waste/wise-up-on-waste-toolkit.html>



quality rather than its nutritional value, which is invisible (Green et al., 2003). There is also ambiguity over commonly used terms such as “use by”, “best before” and “expired by”. This ambiguity often prompts people to throw out perfectly edible foods just because it has passed its “best before” date (Meah, 2014). Halloran and team (Halloran et al., 2014) argue for a unified standard for date labels to avoid misconception whereas Farr-Wharton and colleagues (Farr-Wharton et al., 2014) suggest the use of sensory cues, as smell and taste, to evaluate the edible quality of food rather than merely relying on food labels.

A range of studies has investigated the social, economic and ethical dimension of food waste. According to Parizeau and team (Parizeau et al., 2015), consumers who think that food waste is a social problem, tend to produce less waste. People are also uncomfortable with wasting food due to the ethical concerns and the perceived value of the food itself (Ganglbauer et al., 2013). Age also plays a significant role in determining the potential waste. A UK based study revealed that the people aged over 65 waste significantly less food than the people below the age of 65 (Quested and Luzecka, 2014).

Household economy is also a crucial factor behind food waste. With more money, people tend to overbuy food contributing to excess food and its subsequent waste (Parizeau et al., 2015). Besides, a busier schedule also contributes to bulk purchases and reliance on convenient ready-to-eat food (ibid). The price of a product, as well as attractive deals at the supermarket also influence buying or buying in bulk (Ganglbauer et al., 2013). Halloran and colleagues (Halloran et al., 2014) observed that consumers prefer buying in large packages as they offer better value for the money, even though they may not end up in consuming all purchased food. The price tag of a food product is also a key criterion concerning how it is going to be consumed or deposited. For example, Beretta and team (Beretta et al., 2013) found that consumers are okay with wasting a product that is cheap than a product that they bought at a higher price. To deal with these issues, Parizeau and others (Parizeau et al., 2015) suggest resizing packages and prompting buyers to buy the appropriate amount of food may help in reducing the waste.

Nonetheless, the onus is here on the consumer to make the right decision, i.e., avoiding the temptation for attractive sales offers and large packages and stopping the habit of purchasing too much. Promoting sustainable cooking practices is also a solution proposed to tackle over-reliance on ready to eat food. However, for this to happen, the economic value produced by the activities for waste prevention should be higher than that of other activities (Britz et al., 2014). For instance, comprehensive cooking practices could lead to a reduction of waste, but they would also need additional time and energy that could be spent working or at leisurely activities.

### 7.3 Technological solutions

Current methods to tackle the food waste problem typically revolve around raising consumers awareness, for example, through public campaigns (Lim et al., 2017). Public campaigns, however, are less effective as they deliver information in a context that is irrelevant to the food practices at hand. Within HFI, researchers have tried to integrate interactive technologies to raise awareness and to influence strategies and decision making within the context of household food waste. Existing works include the use of mobile applications, sensor-based systems (RFID tagging or camera based tracking) and to track and maintain a log of food-related activities and to raise awareness through self-reflection.

**Household food management:** Much work has been centered around the refrigerator, given its influential role in household food management. For example, the size of the refrigerator influences food shopping and food storing practices (Schanes et al., 2018). Large capacity refrigerator enables the purchase of more number of items, but in doing so, it also prompts food waste as stored items tend to get forgotten inside the fridge. To remedy such situations, one of the strategies explored was to increase the visibility of already purchased and stored food through camera-based tracking (Ganglbauer et al., 2013). The verification of what is inside the fridge or cupboard before shopping for food would help in meal planning and prevent unnecessary purchases and forgotten items that in turn would minimize leftover and food waste. Drawing on this, Ganglbauer and team (Ganglbauer et al., 2013) developed *FridgeCam* to allow the users to view the contents of their refrigerator remotely (refer Figure 28).



**Figure 28:** *FridgeCam* © (Ganglbauer et al., 2013) allows the users to view the contents of their refrigerator remotely.

Farr-Wharton and team (Farr-Wharton et al., 2014) designed a mobile application that alerts the user about the expiration of food inside a color-coded refrigerator. This application tracks the ingredients of food using image recognition techniques. Similarly, Xie and colleagues (Xie et al., 2013), used radio frequency identification technology to locate foods inside the fridge and to improve food management by suggesting recipes to the users. *FoodWatch* is another online application that allows users to track their food flows concerning the purchase, consumption, and waste (Harder et al., 2014). Bucci and others (Bucci et al., 2010) examined a fridge that scans expiration dates of foods placed inside and then alerts the user (through SMS or email) about the food items that near their expiry date. Rouillard (Rouillard, 2012) similarly investigated the use of mobile device to inform and encourage the consumption of near-expiry food, by attaching it to a household fridge. Other examples that successfully increased awareness involved interactive appliances for cooking practices with eco-feedback of resource use (Clear et al., 2010; Kirman et al., 2010).

Finally, Oogjes and team (Oogjes et al., 2016) developed a fridge hearing aid called *Lyssna* that uses sound to express the state of the food items placed inside the fridge. These available solutions, however, are somewhat informative but rely on an individual's motivation to pay attention to the conveyed information. They lack intention. Through making food-related data visible, they aim to persuade users about the need for more sustainable food consumption, but the onus remains on users to take actions based on this gathered knowledge.

**Leftover management:** Food waste also happens due to the lack of awareness and attention to the leftover foods. Leftover food is the food that is bought or cooked but left unconsumed or partially consumed. Many families often try to reuse the leftovers (prepared or bought food but partially consumed) for another subsequent meal (Cappellini and Parsons, 2012). Some cultures also repurpose preparation residues as ingredients for cooking (e.g., using vegetable residues to prepare vegetarian stocks for soups) and also use them as animal feeds and fertilizers (Walker, 2007). However, predominantly, any food purchased or prepared for a specific mealtime if not consumed in entirety tends to get thrown out. Leftover management thus includes educating people about proper storage of leftovers, reuse, and modification of already prepared meals to make them more attractive to consume again. In support of these practices, existing works again looked at persuasive and self-monitoring techniques.

Thieme and colleagues (Thieme et al., 2012), for example, created *BinCam*, a camera-based system that works like a traditional kitchen bin. In this system, a camera is attached to the underside of the lid of a trash bin that automatically captures digital images of the inside trash and posts them on the Facebook for all users of the system to see and reflect.



**Figure 29:** *BinCam* © (Thieme et al., 2012) automatically captures digital images of the inside trash and posts them on the Facebook.

The *E-COmate* (Lim et al., 2015) is an augmented bin that captures and visualizes domestic food waste data with the intention to elicit reflection on what it means to waste food on a daily basis but without the requirement of cognitive effort. For instance, *E-COmate* measures the weight of food waste and communicates this information directly to users in easy to understand metaphorical units. The *Grumpy Bin* (Altarriba et al., 2017) adds a playful twist to the idea of the smart bin by giving the bin a personality. Like *BinCam*, the *Grumpy Bin* also takes pictures of the food thrown into the bin and sends them to all the members of the house through an app. However, it also engages the members in a QnA to determine who was responsible for the food waste and then posts a sarcastic message on the Instagram account of the responsible.

Taking a slightly different route and drawing inspiration from the popularity of food journaling apps, Ganglbauer and colleagues (Ganglbauer et al., 2015) also explored the use of mobile-based diaries and journaling techniques to stimulate self-reflection on domestic food waste habits. The study found that people took efforts and provided detailed personalized reasons for domestic waste, rather than merely offering direct answers to where and how something is thrown away. *Save the Kiwi* (Aydin et al., 2017) is another smartphone-based app that uses personified icons such as food warrior and food murderer to elicit emotional responses among its users and to motivate them to consume purchased food products before they expire. For example, a food warrior is someone who is successfully reducing a lot of food waste while food murderer is someone who is struggling to reduce food waste.

Other ways to tackle this problem could be through optimal cooking behaviors such as peeling vegetables optimally to reduce unnecessary waste ((Britz et al., 2014). A technology like food printing can also be used in this regard to support optimal cooking patterns.

All the approaches described above focus primarily on individuals or small households but lean on the concept of social norms (Cialdini and Trost, 1998) to influence corrective food behaviors. For example, by using social media such as *Facebook*, *BinCam*, leveraged on individual's self-interest to be socially accepted and to avoid public scrutiny for irresponsible behaviors. The onus

remains on the individuals to act accordingly. Few works also look at the broader social context of food waste and how communities collectively could drive the change, mainly through sharing, which we describe next.

## 7.4 Food sharing

Food sharing is also an excellent way to prevent avoidable waste, but it requires the knowledge of the amount of leftover food and where they can share it (Beretta et al., 2013). *Shareyourmeal*<sup>44</sup> is a website that allows the sharing of food in the neighborhood. It allows users to see cooking and food sharing patterns of the nearby households and nudges them to participate in the same behavior. *The Hate Waste Love Food*<sup>45</sup> application, allows users to share recipes instead of the actual food. *Menus4Moms*<sup>46</sup> is another website that promotes self-management of food leftovers by ensuring all ingredients bought at the start of the week are used up in the meal.

Similarly, Kanai and colleague (Kanai and Kitahara, 2011) designed a menu-planning support system for the neighborhood, encouraging people to eat together. Their system allows users to find neighbors and food recipes for a get-together meal and facilitates the sharing of cooking ingredients owned by individuals. *Foodmunity* (Gross et al., 2011) is a platform through which community members can share personal experiences about meals. Choi and team (Choi et al., 2011) also developed a mobile app called *I8DAT* that allows users to share photographs of their food and food experiences with their friends on a social networking site. Finally, Lim and others (Lim et al., 2017) developed *Social Recipes*, a platform to encourage food sharing by suggesting recipes based on ingredients from different individuals or households. All these works aim to facilitate a sense of community by encouraging them to come together for a noble cause such as food waste through the sharing of food, ingredients, recipes and sustainable eating behaviors.

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<sup>44</sup> Shareyourmeal: <https://www.shareyourmeal.net/>

<sup>45</sup> The Hate Waste Love Food: <https://www.lovefoodhatewaste.vic.gov.au/>

<sup>46</sup> Menus4Moms: <https://www.menus4moms.com/>

## **7.5 Summary**

To conclude, food waste is a complicated problem with a complex array of factors influencing food practices that also vary significantly between individuals, demographics and across cultural boundaries. What people purchase, consume, and waste is influenced by things like availability, price, and individual and household diets and tastes, and we need a comprehensive understanding of how food is currently interacted with in everyday life. In the next chapter, we describe our reflection of the field HFI, articulating underexplored areas and opportunities for further research.



# 8

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## Reflections on HFI

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*“I’ve long believed that good food, good eating, is all about risk. Whether we’re talking about unpasteurized Stilton, raw oysters or working for organized crime associates, food, for me, has always been an adventure.”*

— Anthony Bourdain

In this section, we describe our reflections on the field of HFI, drawing on the existing literature from related areas. We believe that given the transdisciplinary nature of HFI that intersects multiple fields including food science, health, dietetics, sociology, psychology, and technology design to name a few, it requires a grounding in literature from these diverse fields to flourish in its approaches. We, therefore, use our two lenses (instrumental and experiential) to articulate following design themes.

### **8.1 Artisanship in cooking**

“Artisan” is a term used to describe food produced or prepared by humans using non-industrialised methods<sup>47</sup>. Artisan skills are often passed from one generation to another usually through oral communications.

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<sup>47</sup> The School of Artisan Food: <https://www.schoolofartisanfood.org/>

Although a recipe for a particular dish defines the required materials and their quantities, every individual brings their artisan skills and variations on the final flavors and aesthetics. Some people put much energy into cooking, and they follow the recipe very closely, while others aim to get things done. Artisan skills, style, and purpose also vary based on the context and gender (Hartel, 2010). For example, how one cooks in someone else's kitchen or for a special occasion can significantly differ from everyday cooking. Besides, traditionally, females are often taken for granted as a person who would cook at home and cooking in turn also becomes a form to gain recognition and appreciation from the family (Lupton, 2000). Cooking is also a symbol of compassion. For instance, when asked about one's favorite food or expressing nostalgic memories around food, people often quote their mother or grandmother and rate their dish as one of the best if not the best dish they have ever tasted. Cooking traditions are also passed on through generations with families often having a specific (secret) ingredient to a family's trademark dish, which is often lesser known outside.

When it comes to designing a technology to support cooking, these aspects of individuality do not often receive the attention they deserve, which we think is a missed opportunity. Some even argue that with the rise of food fabrication (Sun et al., 2015) and robotic dining systems (Laursen et al., 2015) these artisan skills are in danger of being lost with time. However, instead of approaching it as an issue to worry about, designers can think about tapping artisans into the digital realm and reinventing these skill sets. For instance, a technology like food printing could connect cooking with digital information; wherein traditional recipes can be replaced by 3D print models. As such, supermarkets can also offer digital sketches of food recipes by famous chefs that users can download and print at home using a food printer. This is also not the first time that we see a need for a revamp of the artisan skills. If we look back in history, the techniques and the cooking styles of our ancestors were vastly different than what is currently prevalent. We are also eating foods that have never grown on the soil we live. Individuals today could harness the interactive technology to customize and reign a digital artisanship and designers should help individuals in achieving this. Instead of designing fully automated cooking systems,

designers can give users the "agency" to vary the scope and workflow of the cooking system to match their artisan skills.

## **8.2 Involvement in cooking through curiosity**

Not many people cook at home on an everyday basis due to lack of time, engagement and skills. With the prevalence of takeaway foods and supermarket meals, one could also argue whether cooking skills could sustain in the future. Besides, it is also increasingly difficult to use cooking as an instrument for identity forming (Fischler and Chiva, 1986). However, encouraging people to cook is vital as home-cooked or self-cooked food leads to better diet quality, weight-loss intention (Wolfson and Bleich, 2015) and enriched family food practices (Simmons and Chapman, 2012).

The act of cooking can make someone so submerged that he/she can forget the social expectations and one's place in the world (Crabtree et al., 2013). However, if everything is foretold to users and it is quite clear for the user on what should be done first and what next, there is not enough challenge during the cooking process for it to stay exciting. For those who love to cook, the act of cooking can be rewarding and pleasant in itself, without knowing what the result will be. The pleasant experience holds true as long as there are enough challenge and curiosity. One could relate this to reading a mystery novel or a movie spoiler free. If we already know all the twists and the turns, then the act of reading or watching becomes dull and unengaging. It is important to not to foretell everything and keep people enthusiastic about cooking and learning something that is unknown through trial and error.

By automating cooking tasks, we could run into the risks of cooking becoming passive, lazy, and boring activity (Mennicken et al., 2014). A study by Hassenzahl and Klapperich (Hassenzahl and Klapperich, 2014) showed that the process of making coffee was perceived as less pleasurable when the process was automated. They argue that even though cooking-related activities take a lot longer when performed manually, they offer more possibilities to experience the process, for the senses to get involved, and to experience competency. Cooking, in a nutshell, is also an embodied experience that connects us with materials across all our senses. As Vannucci and team (Vannucci et al., 2018)

argue, cooking should be about the craft and a reflective conversation with the material (Schon, 1984). By involving users in touching, smelling, tasting, listening, speaking and enacting choreographies with the cooking materials at hand, designers can bring richness to food-related technologies (ibid). As Lipson said in an interview, “*technology should not define someone’s cooking*” (Huen, 2015), but rather the technology should be designed to make cooking a pleasurable activity to participate in.

### **8.3 Food and cultural identities**

According to Ristovski-Slijepcevic and colleagues (Ristovski-Slijepcevic et al., 2008), people’s ideas of healthy eating is not solely dependent on the nutritional content, but rather it is rooted in the traditional, cultural and ethical discourses. However, the official health and nutrition guidelines are often generic in their tone and do not take into account the individual’s nutritional needs and work lifestyles. Existing literature and studies also bring forward the fact that most users are not expert in identifying the nutritional content of the food and making a judgment based on that. For example, a study by Oakes (Oakes and Slotterback, 2005) found that people rated a small portion of unhealthy food (chocolate bar) as more weight gain promoting in comparison to large portions of healthy food (cottage cheese) even though the latter had ten times more energy than the former. The findings of the study by Niva and team (Niva et al., 2013) also suggest that lay understandings of foods are not based on simple measures such as energy, fat, and sugar, but also on a complex set of generalized food ideals. Food literacy is thus an ill-defined/understood topic, and efforts are needed to improve people’s understanding of food and one way to do this could be by looking at the social and cultural conventions and habits and design solutions to match these beliefs.

Haraway (Haraway, 1988) wrote that individual’s understanding of the food is situational, embodied, partial and embedded in language, culture, and community. Individuals and groups construct their identity biologically, socially and psychologically by the food they choose to consume (Conner and Armitage, 2002; Fischler, 2011). Food often serves as a means of expression and matters of self-presentation. On the other hand, Giddens (Giddens, 1991) recollect that as human race advanced from the hunter-gathering era to agriculture to current

digital age, we no longer eat just for survival and sustenance of energy. Neither we are required to hunt for food. The food is readily available and in many countries in abundance. As a result, most of us today enjoy the luxury of "choosing" the kind of food we want to eat. Eating and cooking a dish also enables us to be something or to stand for something. Food allows us to project our identity, views, and state of mind. The act of eating breaks the barrier between the "outside" world and "inside" body and "*we become what we eat*" (Fischler, 1988).

The belief that one becomes what one eats has led to many intriguing food habits. For example, many cultures believe that the shape, color and the texture of the food define the body part it will benefit the most. As such, eating walnut is good for the brain as its shape resembles that of a brain while ginger is good for stomach and carrot is good for the eyes as their shape resemble. Eating beetroot seems to be suitable for blood cells and hemoglobin production as it is dark red. Some cultures do not eat vegetables that are too soft out of the fear that it will make them weak (Fischler and Chiva, 1986). In India, people of Jain religion do not eat root vegetables like onion, garlic, and potato, because these foods grow under the ground and are home to many organisms living beneath the soil, which we may or may not be visible with naked eye. Not eating them knowingly or unknowingly is done in the light of non-violence. Although there are no scientific pieces of evidence to back these theories (Simon et al., 2014), these practices have been prevalent in cultures and passed along orally from one generation to another and provide a collective identity of a society.

Despite the significance of cultural identities, the majority of the HFI works concentrate on individuals or small households. The designed solutions also do not scale beyond the targeted small sketch out scenarios. Only a few works also look at the broader social context, cultural habits, and beliefs and how communities collectively could drive the change. This collective identity can be expressed through food. As a group eats certain foods or does not eat particular foods, it shows what the group stands for and who is included or not included in the group culture. The same holds for personal identity; people can show who they are and what they think is essential, and can develop their style. Because of this social mechanism, people can use food to distinguish themselves from

others. By using food as an identity indicator, they can show which social group they belong to. Designers can draw on these aspects to design solutions that take these social and cultural beliefs into account. Designers could use technologies like food printing to reshape healthy foods that look like body parts to influence and motivate consumption. For example, as walnut is considered to be a brain food because of its shape, designers could print foods in shapes similar to eat.

## **8.4 Hedonic indulgences**

Hedonic indulgences describe pleasures drawn from naturalistic, everyday activities that typically increases positive emotion and happiness, such as eating. Eating provides an everyday source of happiness for most people (Kringelbach, 2015; Linley et al., 2013). The psychology literature report that taste is one of the key sensory sources of pleasure (Rozin, 1996; Veldhuizen et al., 2010) and happiness may be derived from the taste of specific favorite foods. As such, hedonic indulgences of eating favorite food provide people with experiential enjoyment, satisfying both psychological and physiological needs that necessities may not meet. For instance, humans can experience as many as 22 different emotions involving food, whether they are consuming it or just being around it (Desmet and Schifferstein, 2008). However, these emotions can also lead people to eat even when they are not hungry. Consequently, people pursue opportunities that would allow them to consume ‘mood foods’, just because they are highly desirable. However, in doing so, they often overindulge, consuming more calories than what they should typically consume. A solution to such a practice could be through education, moderation or restriction, but such solutions have shown to be a limited success (Hsu and Benford).

For example, chocolate is one mood food that can bring sheer pleasure from its moderate consumption (Cabanac). In the words of Lupton (1996), “chocolate is culturally understood as the symbol of love, packaged with high emotions to inspire the feeling of self-indulgence and hedonistic ecstasy”. Besides, studies report that eating moderate amounts of dark chocolate is, in fact, good for cardiovascular health (Alkerwi et al., 2016) for improving cognitive abilities (Crichton et al., 2016) and helping in post-exercise recovery (Allgrove et al., 2011). However, like other "mood foods", chocolate is also associated with both positive and negative connotation. For example, chocolate, on one hand, is a

desirable food, but on the other hand, it is also considered as calorie laden. Therefore, when it comes to good health and wellbeing, the common perception is that one should avoid hedonic indulgences like chocolate. We agree that "over" indulgence of chocolate could cause weight gain, although research findings on this topic are inconclusive (Farhat et al., 2014). However, instead of completely denying the pleasure of eating chocolate, a playful solution like EdiPulse (Khot et al., 2017a) could be tried to support moderate indulgences and to mitigate the resultant conflict and guilt. In EdiPulse, the consumption of chocolate was related to physical exercise and achievement of physical activity goals. However, instead of simply rewarding users more chocolate for doing exercise, EdiPulse looked at improving the shape and visual look of the chocolate while keeping the quantity constant.

Besides moderating the quantity, designers can also experiment with the smell, quantity, and sound properties of the food and intervene them within an eating experience to make guilt-free pleasurable eating.

## **8.5 Savoring**

Savoring involves a focus of attention on the sensory input of a consumption experience. It involves a "*heightened awareness*" that makes consumers "*more fully conscious of the pleasurable things we see, hear, smell, touch, or taste*" (Bryant and Veroff, 2017). Savoring prolongs and intensifies the enjoyment of a consumption experience by drawing attention to sensory aspects of the experience that might otherwise be missed (ibid). As such, eating fine chocolate is a consumption experience that particularly lends itself to savoring (LeBel and Dube, 2001). Often, the pleasure experienced in anticipation of a consumption event exceeds that experienced during actual consumption (Areni and Burger, 2008). Hence, a person who likes chocolate, and who is just about to taste a piece expected to be enjoyable, can enhance the overall pleasure derived from the tasting it, by contemplating the experience before taking the first bite.

Savoring is a form of emotion regulation used to prolong and enhance positive emotional experiences (Bryant, 2003). Researchers have identified four common strategies - that can be employed alone or in combination—to savor a positive event, including displaying positive emotions nonverbally, staying



present in the moment, thinking about the event before and afterward, and telling others (Quoidbach et al., 2009; Tugade and Fredrickson, 2007).

## 8.6 Playful commensality

The field of domestic and personal robots has proliferated over the course of the last few years. We see robots being used in automation industries for doing sequential and repetitive work (Shi et al., 2012) and within food industries, robots are increasingly being used for packaging food items<sup>48</sup>. When it comes to food, robots are also being used for cooking and serving (Naotunna et al., 2015). However, besides the traditional views geared towards efficiency and assistance, we see limited instances of human-robot integration, where robots undertake a playful role, and we see this as a missed opportunity to augment the eating experience, particularly to tackle solo dining.

So far in the literature, solo-dining has been approached from a variety of angles, starting from the use of interactive media to using virtual telematic dining, to even using pets and stuffed animals to make solo dining less distressing and pleasurable. To the best of our knowledge, robotic technology has rarely been explored as a dining companion to support solo-dining. Given the rapid advancements in domestic and personal robotic technology, we, however, envision that it will not be long before we see such technology at a dining table. *Obi* is a domestic robot that assists diners with physical disability in eating. However, the predominant stance taken by these technologies is to assist or to correct the user's dining behavior, and people rarely look at this technology as a companion or a co-diner.

As a step towards this, we believe a robotic technology could be used to playfully support solo dining, allowing people to find moments of pleasure through a company of mischievous robotic dining companion. We invite more explorations on robot-food interactions that contribute a vibrant dining experience and enrich our understanding of Human Food Interaction. Designers could think of building a mischievous robotic dining companion that acts and behaves like a human co-diner but never tries to educate or correct the diner's behavior, Since it is a co-diner, it should also participate in the eating activity

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<sup>48</sup> Packaging Robots: <https://www.robots.com/applications/packaging>

and could offer burps, and the belly expansion much like human if he overeats too many batteries. In doing so, the design can also reorient the perception that robots are not always meant to be infallible. They could be erroneous and clumsy like we humans are (refer Figure 30).



**Figure 30:** *Robots* can be looked at playful companions for dining.

Besides co-diner, robots can also play a role of a feeder. Feeding others is also common in a social eating context, for example when trying someone else's dish or in a romantic relationship, which is believed to facilitate bonding and empathy as inspired by literature on mother-infant feeding (Eyer, 1992). Feeding is also an important area of research for people with specific physical disabilities, as the feeding stage has been identified not only as a high source of stress for both caregivers and care-receivers, but also an opportunity to motivate patients to eat, enjoy the food (Ford, 1996) and avoid malnutrition (Yasuda et al., 2017). As such, we believe by further understanding the feeding stage, and the opportunities afforded by technology to support it, we have the potential to not only support social eating experiences, but might also influence more directly how and what one eats.

## **8.7 Summary**

In this chapter, we articulated a set of opportunities that highlight the underexplored design spaces within HFI. In the next chapter, we describe what

technologies can learn from our food practices, and highlight design space to design novel interactions with technologies.

# 9

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## The Future of HFI

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*“An onion can make people cry, but there has never been a vegetable invented to make them laugh.”*

— Will Rogers

In the previous chapter we described how technologies can be designed to support our food practices like cooking and eating. In this chapter, we highlight opportunities for designing novel interactions with technologies by taking motivation from our traditional food practices. We describe how technologies can learn from the way we grow, prepare, cook and eat food, so as to provide a more immersive and intuitive user experience. We argue that technology so far is mostly designed to support the instrumental aspects of human-food interactions. However, to support the experiential aspects, significant technological advancements are still needed. With these opportunities, we aim to inspire developers and makers to look at the affordances of traditional food practices and use them as inspiration to create novel technologies and experiences, which will allow us to explore some of the previously underexplored areas of human-food interaction.

## 9.1 Cutting and sharing

Almost all food can be cut into pieces or separated in some way. This not only means that the food can be more easily chewed, but it also means that food can be easily divided into a wide variety of proportions, allowing to create a sheer endless variety of dishes. We also cut food to share it with others, facilitating the social experience that food is strongly associated with.

If we compare food's ability to be cut with technology, we find that software does not support cutting, e.g., we can easily copy and replicate software to support sharing, but not in the way that each person gets a portion of it. For example, when a person shares any digital object with someone, she also retains a copy, which she could later use for herself or even for others. Food, on the other hand, feel more unique as the original sender does not retain a copy, although the inherent property (e.g., ingredients, flavor) of the food can remain the same amongst all the pieces.

Additionally, for most food items, once they are cut and shared, it is difficult to retract to reassemble and regain the same shape as the original food. Sharing physical objects like food means that one has to give away some of its possession in order to allow someone else also to possess something (Petrelli et al. 2010). In other words, if a person shares his/her food, he/she is giving away a portion of their food, which makes them more vulnerable from an instrumental perspective, as they will have fewer calories to consume. However, if we look from an experiential angle, the act of sharing is a gain, allowing individuals to build a social rapport through this act.

We acknowledge that software could be “cut” in portions, for example, we can cut and share lines (modules) of code with another person. However, this will break the code, making it useless for both parties unless we strictly follow modular programming principles. In contrast, when it comes to cutting food, there are no strict rules. Even if the food is cut abruptly, it can still be enjoyed and consumed.

When we look at the hardware side of cutting, the notion of cutting highlights the limitations of technology even more prevalent: to date, we cannot cut any technological system the same way we can cut physical items like food. For example, we cannot cut a smartphone in order to give half of it to a friend. To clarify: we can cut a mobile phone using individual saw machines. However, this will render the device defect and therefore unusable. Furthermore, we cannot even cut an Arduino into separate pieces without destroying it the same way we can cut any apple.

Some early attempts in making hardware cuts exist, for example, see the modular building block approaches around hardware (e.g. *cubelets*<sup>49</sup>), these systems consist of individual hardware pieces that can be assembled to form a bigger system. As such, they can also be taken apart. However, when taken apart, they usually are of no use on their own. Furthermore, they currently only support “cutting” at precise seams and in particular ways, allowing for only a small amount of variety regarding separation lines and proportions, therefore making these approaches still far different to what we experience when we cut food.

## 9.2 Washing

Almost every kitchen in the world has a sink with a water tap, and water is critical as part of a human’s food intake. Most food can be washed, and mixing food with water and water-like liquids can result in exciting dishes. In fact, like our bodies, most food produce contains mostly water. When we wash food with clean water, we are cleaning it from dirt and unwanted germs, making it more palatable for consumption. Food can also be boiled or cooled with water based on the needs, but the same cannot be said for all technologies.

So far, most of the mealtime technologies, e.g., smartphones and tablets (Ferdous et al., 2016b; O’Hara et al., 2012) use traditional ways of interacting with the digital content i.e., through touch, swipe and pinch. These kinds of interactions are not only hard to perform but they also increase the risk of spoiling the technology when used along with dining. Similarly, augmented cooking technologies (e.g., thermal displays) could also have higher chance of

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<sup>49</sup> Cubelets: <https://www.modrobotics.com/cubelets/>

getting dirty when operated with dirty hands. Interactions analogous to our mealtime practices, where the dirt can be cleaned with water are not yet supported by any technology. Washing a technology would support seamless interactions with technology and would make them better embedded in the real-world kitchen setting.

If we compare the relationship of water with the technology, we quickly find that technology and water does not “mix” well, in fact, most technology carries a label warning of not to use it and often even near water. Only recently mobile phones have emerged that can be used near and (to a certain depth) in water. Recent work has highlighted the potential for new interactions if technology could be used with water (Häkkinen and Colley, 2016; Khot et al., 2015b; Raffe et al., 2015), and we echo this call here concerning how technology could learn a lot from the way food profits from and interacts with water.

### **9.3 Mixing**

Majority of the recipes we create require mixing of different food items (e.g., vegetables, meat) and spices. Such a mixing supports making of a tasty food. However, technologies designed to create food, e.g., food printers, are still limited to the use of one food material. For example, the state-of-the-art 3D printers can efficiently print one kind of food, such as chocolate, but does not allow mixing of different food materials. This is because the cooking time and the temperature settings of most food items are not the same.

While mixing is fundamental to cooking, it is challenging to allow mixing with technologies because mixtures demonstrate much more complex behavior. For example, to print a pyramid of salmon and mashed potatoes through 3D printers, care is required to understand when to cook what during the printing process because both the salmon and potatoes possess very different cooking times and temperatures. Additionally, it is difficult to predict how different foods will fare when combined. Further research and new techniques are needed to allow proper mixing of food allowing to control the temperature and time settings for different materials on the fly.



## **9.4 Satiety**

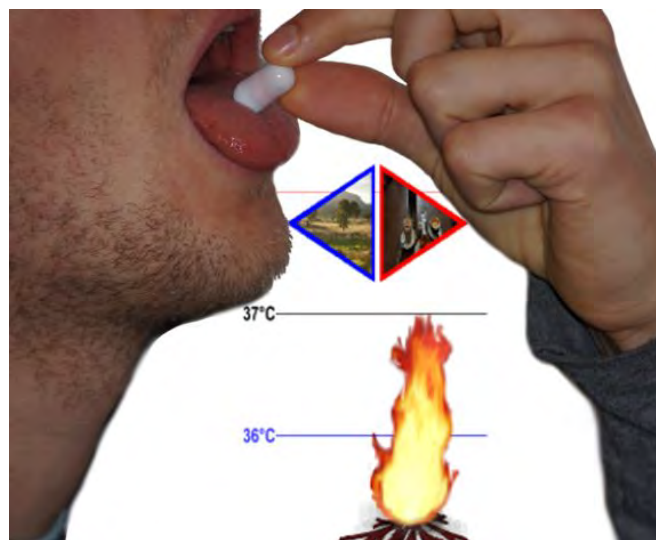
Our interactions with food in comparison to our interaction with digital technology or physical artifacts reveal a distinctive pattern. For example, we interact with digital technology for instance smartphones frequently but in short bursts of time. On the other hand, our interaction with physical artifacts is often undefined as such artifacts tend to disappear in the surrounding (Miller, 2010). However once noticed, our interactions with them might last for a long duration. Food, in comparison, inhibits a scheduled pattern of interaction. For example, most cultures eat food three times a day or only when one feels hungry. Moreover, once the satiety levels are reached, food is no longer consumed. Satiety as such is an essential facet of our interaction with food particularly defining the frequency of our food consumption. However with digital technology, there are no defined satiety levels, and as a result, we witness an information overload today. Technology, however, is being designed for a digital detox. More research is required to understand and support technological satiety.

## **9.5 Swallowing**

Humans consume food, and this means swallowing it. This action is necessary to survive, and the way infants instinctively know how to consume food. Some advancements are already made to develop technologies that can be swallowed or inserted into the body. Main investigation around this line has been for surgical purposes. For example, certain types of cameras can be inserted or swallowed during surgeries to guide the tasks of surgeons. Similarly, a pacemaker is an established technology that is surgically inserted in the body to help control the abnormal heart pumping. These systems are however, designed for very specific instrumental needs and are not yet available to the designers and researchers for playful explorations, in the same way as Arduinos for example, are.

Only recently, some technologies are developed to support the experiential or playful interactions. For example, sensing pills containing ingestible sensors and batteries have been developed, which can record and wirelessly transmit the information of our core body temperature (Melanson et al., 2017). Similar to

food, these pills are also flushed away from the body within 24-36 hours. However, other bodily data is still challenging to sense and obtain. Researchers are investigating the influence of these pills on individuals in everyday routine (Z. Li et al., 2017) as shown in Figure 31. Similarly, there is also a more recent trend of hobbyists inserting technology into their body like RFID tags (Heffernan et al., 2016). These insertable chips are inserted into the body through a specialized procedure and are inside the body until surgically removed, therefore being significantly different the frequent and rapid swallowing interaction. These RFID chips can be used as a key to get access to your home or office, or to save passwords.



**Figure 31:** Li and team examined new playful ways of using ingestible sensors © (Z. Li et al., 2017).

We believe the design of technology, in particular, hardware technology, can learn from food and the ability to swallow it: if we could swallow technology in the same way we swallow food, there could be a plethora of new interaction possibilities.

## 9.6 Tasting through Body receptors

Taste along with smell was among the very first of the senses to develop and evolve in human species. The ability to recognise chemicals in the environments and to make a judgement about what one should consume helped human progress and survive in hostile environments. The taste receptors, usually around 5000 to 10000 in numbers, reside in our tongue, upper part of the mouth

and inside the throat. These receptors gives us the sense of taste and the ability to differentiate between different chemicals for salt, sweet, sour and bitter.

However, unlike the common belief, the taste receptors can also be found inside variety of the other parts of the body (Herz, 2017). For instance, we have taste buds inside our nose that let us fight infection. We also have taste receptors in our lungs that signals our brains to let us expel unwanted particles through cough. We also have taste receptors in our gut that influences our perception and judgement about food. Any disturbance to these receptors can cause diet-induced illness ranging from Irritable bowel syndrome to diabetes (Depoortere, 2014). By looking at bodies as taste receptors, we could potentially influence new ways of building digital taste interfaces.

## **9.7 Chemical reaction**

Many foods are cooked in order to prepare them as the desired dishes, here we highlight the use of heat as a way of cooking food as a primary way to start a chemical reaction with the ingredients. We are wondering, what would it be like if we could cook an Arduino? What would happen to technology if it would allow for chemical reactions to be applied in order to create new experiences?

We acknowledge that most technical hardware devices undergo a chemical process (for example the cooking of the PCB) during its creation. However, the chemical reaction process is not available to the end user in order to shape the final experience. Hobbyist approaches have attempted to bring the technology production process from the producer more to the consumer (Schoning et al., 2012), and the rise of fabrication technology is a driver in this direction. However, we believe that technology designers can still learn from food when it comes to allowing the end consumer to experience and engage with the chemical reaction of its ingredients in order to experiment with different reactions to create a wide variety of end-products.

## **9.8 Shelf-life**

Every material has a shelf life after which they decay or lose their beauty. Food becomes stale and unpalatable with time or under environmental factors. People may decide to throw away foods after a certain storage time independently of

the food's actual edibility (Beretta et al., 2013). This happens because most people have vague understanding of whether the food is perished or can it still be consumed (Vidgen, 2014). Often they base their judgement on physical characteristics of the food, such as the appearance, texture and color. Chenhall and colleagues found that most adults are also not be skilled in freezing and canning foods, abilities that might hinder food waste (Chenhall, 2010).

Beretta and team (Beretta et al., 2013) believe that by increasing the awareness about the shelf life of the food product, issues of food waste can be tackled. Currently, the most common way of informing people about the food content is through labels that are posted on food that consumers buy. These labels detail out a variety of information, including the nutritional content, source of origin, pricing and a static expiry date. *Bump Mark Label*, on the other hand, is a sticker that reacts to the state of the product instead of showing a static expiry date (Jones, 2014). Besides food labeling, advancements in molecular sensing or food spectroscopy (Jiang et al., 2018) might afford new ways to understand food. Development of plastic films for food packaging is also a promising step, as packaging that allows the product to breathe (Buzby, 2014) therefore extending the product's shelf life.

Taking motivation from the shelf-life of food, we can also design certain technological interactions to illustrate the working of the technology. For majority of the technologies, it is challenging for users to know if there is a technological breakdown or if the shelf-life of the product is over unless there are particular signs, e.g., burning fumes or a sparkling sound when the PCB OR Arduino board breaks down. Smell can be utilised to highlight the working of a technology. For instance, shelf-life of a battery can be communicated through fading of smell over time.

## **9.9 Summary**

In this chapter, we presented a set of opportunities in no particular order that describes new ways of thinking about HFI inspired by traditional ways of interaction with food. We also point out that our set is not an exhaustive list, but rather the beginning of a structured understanding that should be complemented with further explorations. Nevertheless, we believe our work can serve as a

starting point towards understanding how to design interactive technologies to facilitate both instrumental and experiential experiences.

# 10

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## Conclusion

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*“There is no love sincerer than the love of food.”*

— George Bernard Shaw

Food has always played a crucial role in the lives of all living bodies, but its importance is now more crucial than ever to consider, as our contemporary concerns about food expand with technological, environmental, and social disruptions (e.g., ranging from food security to agricultural sustainability to rising obesity and diminishing commensality). Through this article, we offered an overview of the existing literature and outlined various opportunities for researchers to take this field of HFI forward.

We invite designers and researchers - both in academia and industry alike - to challenge common notions of using technology to support food practices. As technology evolves, it is important that we as designers harness and explore the exciting opportunities that HFI can offer. This requires both serious academic explorations and discussions, but also a playful lightness – that sees what we currently have as only a shadow of what we could imagine.

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