Arm-A-Dine: Towards Understanding the Design of Playful Embodied Eating Experiences

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ABSTRACT
There is an increasing trend in HCI on studying human-food interaction, however, we find that most work so far seems to focus on what happens to the food before and during eating, i.e. the preparation and consumption stage. In contrast, there is a limited understanding and exploration around using interactive technology to support the embodied plate-to-mouth movement of food during consumption, which we aim to explore through a playful design in a social eating context. We present *Arm-A-Dine*, an augmented social eating system that uses wearable robotic arms attached to diners' bodies for eating and feeding food. Extending the work to a social setting, *Arm-A-Dine* is networked so that a person's third arm is controlled by the effective responses of their dining partner. From the study of *Arm-A-Dine* with 12 players, we articulate three design themes: Reduce bodily control during eating; Encourage savoring by drawing attention to sensory aspects during eating; and Encourage cross modal sharing during eating to assist game designers and food practitioners in creating playful social eating experiences. We hope that our work inspires further explorations around food and play that consider all eating stages, ultimately contributing to our understanding of playful human-food interaction.

CCS CONCEPTS
• **Human-centered computing → Ubiquitous and mobile computing design and evaluation methods** • *Human-centered computing → Interaction design*

Author Keywords
Human-food interaction; digital commensality; food games.

INTRODUCTION
Over the years, technology has played an influential role in enriching our interactions with food during eating [22, 26, 39, 89, 90, 100]. In particular, within the HCI literature, we see an increasing trend on human-food interaction that includes augmented cutlery [39, 50], interactive dining tables [40], digitally printed food [42], shape changing food [99] and even acoustically levitated food [98]. These works bring the field forward, however, we find that in most prior design explorations the focus seems to be on what happens to the food before eating and during eating, but no so much on the actual process of eating.

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Figure 1. Arm-A-Dine participants feeding each other using on-body robotic arms.

In this work, we explore the opportunity of using interactive technology to support the embodied interaction and the movement of food from the plate to the mouth during consumption. We find that the grasping and feeding of food [17, 71] is a rather underexplored facet of our interactions with food. This stage starts with selecting and then picking (sometimes with cutlery, sometimes just using the hands) the food from the plate. Using our arms, the food is then brought towards the face before being put into the mouth (sometimes in the mouth of others). This process often continues as long as we feel hungry and it normally stops once we are full. To this end, the process of eating is typically driven by one's own volition, desires and physiological needs.

Most of the time we feed ourselves, however, 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 [24]. 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 [28] and avoid malnutrition [103]. 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; our exploration might therefore be also seen as foundation for such future work.

When it comes to support the feeding interactions, we are inspired by the opportunities technological advancements afford to support embodied interactions [18], as previously exemplified in regards to embodied play [62] and human-computer integration [47]. We are also inspired by the use of robotic arms as serving and dining aids [59, 65, 87, 92], however, most of them are used to support the instrumental needs of people with physical disabilities and are therefore attached to a table, replacing a caretaker. In contrast, we are interested in how such technologies can support the experiential aspects of the eating experience, and therefore consider the role of technology to also contribute to the embodied and social characteristics of a shared feeding experience.

As part of our embodied focus on the feeding experience, we draw on the relationship between affect and food [94] that might play out interesting emotional dynamics in a social eating context. For example, we might experience joy and pleasant surprise if our dinner partner feeds us a food that we like, similarly, we can also experience disgust if we were fed food that we do not like. To this end, our facial expressions can illustrate our overall feeling about the food. We build on this to explore our primary research question: how do we design playful social eating experiences, with a particular focus on their embodied nature?

Playfulness is a mindset whereby people approach every day, even mundane, activities with an attitude similar to that of "paidia" - as something not serious, with neither a clear goal nor real-world consequences [54]. When it comes to designing technology for the mealtime, we often find a significant lack of playful attitude. The technology is often used to support a goal-oriented dining behavior, for example, eating healthy [12] or eating mindfully [23]. Through *Arm-A-Dine*, we believe that, by harnessing a playful attitude towards meals and social dining settings, we could further expand on the design space and offer complementary benefits through a playful engagement between technology, co-diner and the food.

Arm-A-Dine is our design exploration of a novel two-person playful eating system that focuses on a shared feeding experience (see Figure 1). In this experience, all three arms (the person's own two arms and the "third" arm, the robotic arm) are used for feeding oneself and the other person. The robotic arm (third arm) is attached to the body via a vest. We playfully subverted the functioning of the robotic arm so that its final movements (once it has picked up the food), i.e. whether to feed the wearer or the partner, are guided by the facial expressions of the dining partner. In order to understand the experience of engaging with *Arm-A-Dine*, we conducted a study with 12 participants (5 male, 7 female). Each session involved two participants eating together using the *Arm-A-Dine* system. As the design of *Arm-A-Dine* allowed the participants to move around, we studied its use in a casual social eating scenario, such as when eating finger-food at a conference event, rather than a fine dining restaurant, which restricts people to dine in one spot. This approach helped us to explore the playfulness of the design in a setting where the participants could move freely. The study revealed that embodied technology design can facilitate engaging conversations about food and the way we eat besides contributing incidental bodily movements and empathy towards the eating partners.

This work makes the following contributions: 1) By presenting *Arm-A-Dine*, we introduce a novel playful prototype that highlights the opportunities of interactive technology to support the feeding actions of social eating experiences. 2) We present the results from the *Arm-A-Dine* study to begin contributing an initial understanding of embodied system design when it comes to social eating. 3) Finally, we articulate three themes to expand our understanding of how to design playful human-food interactions.

RELATED WORK

Since this work revolves around the use of technology and eating, we have categorized the existing works in the area of Human Food Interaction (HFI) accordingly. We start by describing the works about technology used as a surrounding medium to enhance the eating actions, then we discuss the technology integrated in the eating process followed by the embodied technology used during eating. We also describe some playful works around embodied technology (robotic arms) that we learned from.

Technology Surrounding an Eating Experience

Numerous works within HFI explore the use of technology as a medium for creating engaging dining experiences [90] with Heston Blumenthal being one of its key advocates. CoDine [100] is one of the early examples that allow remote family members to communicate and dine together using interactive technology. Similarly, in the Inamo restaurant [39] interaction designers project on dining tables to give an impression of food coming to life [22]. In the Fat Duck restaurant [26] the "Sound of the Sea" dish aims to transform the dining experience by enhancing the taste of the food through sound [89]. Hupfeld [38] highlights that the artifacts at a dining table play a crucial role in facilitating social engagement and should be the focus during design activities. Similarly, Bekker et al. [5] discusses the use of responsive objects triggering conversations between diners, whereas Le Petite Chef [50] uses projection mapping on a table to facilitate social engagement. Works by Ferdous et al [27], O'Hara et al. [68] and Davis et al. [16] illustrate interesting playful ways of using and sharing personal devices during family mealtimes to encourage social interactions. Finally, the explorations have not been limited to a real-world dining context. Recently, Arnold et al. [2] explored cooperative eating as an interactive way to enrich virtual reality experiences while offering complementary benefits of social interactions around food. We learn from these works that technology, through using multiple senses, can enrich the social dining experience in novel and playful ways, however, we also note that the technology is mostly used as external, static architectural feature, that is, it is either fixed to tables or chairs, but never experienced on the body (while we know that social interaction is very much embodied [18]), which we consider a missed opportunity that we explore in this work.

Technology Integrated in an Eating Experience

Few works within HFI explore the integration of technology in an actual eating process and hence can guide the design of feeding actions. For example, Murer et al. [64] created a haptic input device "LOLLio" that dynamically changes its flavor thereby offering playful experiences around taste. The creation and manipulation of artificial tastes is an active research area within HFI [67]: Ranasinghe et al. [75] developed "Taste/IP", an interactive system to share taste over the internet by combining electrical and thermal stimulation of the tongue. In later work, Ranasinghe et al. [76] also developed a "Digital Flavor Synthesizing" device that uses perfumes to utilize smell as a supplement for their digitally created flavors. Ranasinghe et al. [77] also developed the Spoon+ and Bottle+ prototypes that can be used to virtually manipulate the taste of food. A similar approach to alter the gustation sense was followed by Narumi et al. [66] with "MetaCookie+" that uses augmented reality and smell to overlay a cookie with visual and olfactory information, thereby changing the perceived taste of the cookie. Mayne's work [57] on edible user interfaces replace the "painted bits" of a computer monitor with tangible "edible bits," thus taking advantage of the breadth of human senses. Finally, Khot et al. [41, 42] explored how eating can be made pleasurable by integrating it with personal data. For example, Khot et al. [41] created TastyBeats, an interactive fountain system that creates a fluidic spectacle by mixing sports drinks based on one's physical activity data. These works suggest that digital technologies can positively affect the actual eating process in general, and the feeding actions in particular, and we explore this further with our system *Arm-A-Dine*, which uses on-body robotic arms.

Robotic Arms and Its Use Towards Embodied Interaction

On-body robotic arms have been used to support embodied interactions. Leigh et al. [47] offer a detailed overview of existing works on embodied technology (robotic arms). For example, Gopinath et al. [33] created a three-armed drumming system where the attached robotic arm is controlled by brain signals. Stelarc [31] through his seminal artwork "The Third Arm" demonstrates how to control an on-body robotic arm through muscles around his abdomen whereas Horn [3] highlight the benefits of on-body robotic structures to heighten a wearer's senses. Sasaki et al. [82] created MetaLimbs that can be used as artificial limbs, increasing people's capability to multitask. We learn from these works that attaching robotic arms to the body can offer benefits, including supporting existing experiences in a playful way, however, to the best of our knowledge, none of the existing works explore the use of on-body robotics to support social eating experiences.

Traditionally, we see robots in regards to food when they are used for packaging food [81]. Recently, however, robots are also being used as comforting companions for eating [13], cooking [92] and serving [59, 65, 87]. Nevertheless, besides these more conventional uses geared towards efficiency and assistance, we see limited instances of playful human-robot integration [25, 43], where robots undertake a playful role, such as an entertaining medium to support existing movement-based interactions. An exception is the work by Lin et al. [51], who discuss how robotic arms can be used to play a traditional finger guessing game in China. Through their work, they show that people had a more enjoyable experience with the robot as compared to playing without the robot. Yamada and Watanabe [102] developed an arm-wrestling robot system that proved to be effective in terms of enjoyment. These works suggest that robotic arms can elicit playful experiences, however, so far, none of the existing works seemed to have explored the use of on-body robotic arms to support playful social eating and we see this as a missed opportunity.

In summary, we learned from existing works in HFI about the potential of technology to support the eating experience. Inspired by this, we see an opportunity for playful design to support social eating, often labeled as "commensality", that is the "practice of sharing food and eating together in a social group" [69]. We find that traditionally, research has argued that technologies detract from the experience of eating together, resulting in a negative impact on social interaction [36]. This prior work focused on the use of screens such as mobile phones, which might distract individuals from eating. For example, De Castro [11] discusses that the presence of other people at a meal increases intake by extending the time spent at the meal, probably as a result of social interaction, and that family and friends have an even larger effect by a consequent disinhibition of restraint on intake. However, if we take this insight into today's dining setting, then we also identify a strong presence of technology such as mobile phones on the dining table. These technologies also contribute to an increase in dining time but do not facilitate or support co-located social interactions.

We, on the other hand, are interested in designing an interactive playful experience that could support rather than distract individuals from their social eating experience. This exploration is driven by recent works that suggest positive benefits of modern technologies on how we eat [90]. For instance, the works by Ferdous et al. [27] highlight how repurposing technologies as a medium for facilitating shared activities could lead to positive experiences of eating together. Davis et al. [16] reveal how the use of digital technologies can serve to support interaction at the dinner table, allowing families to eat together longer. Mitchell et al.

[61] discusses a kinetic table mechanism that gauge the weight of food on the table and raise or lower it for a slow or a fast eater respectively. This subtle augmentation of the dining table helps the dining companions to mutually align their eating pace. Inspired by this, we have taken a research through design approach [104] to tighten the gap in our understanding of how to design interactive technology to support the embodied feeding actions as part of social eating experiences. As such, with our work, we are contributing towards answering the bigger question on how to design social eating experiences.

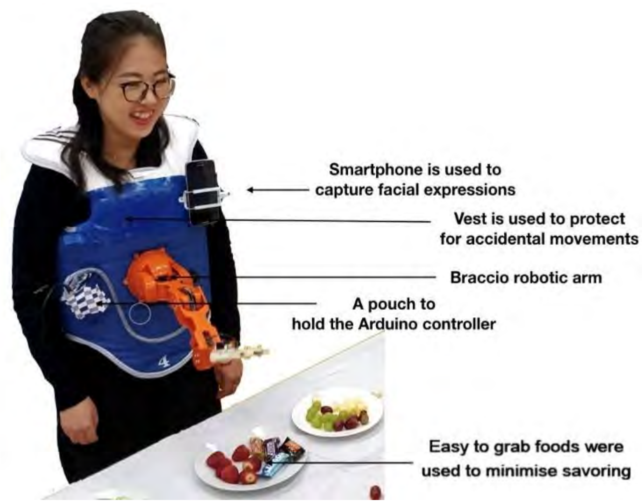

Figure 2. Arm-A-Dine features an on-body robotic arm (supporting the feeding action from plate to mouth) and an attached smartphone to capture facial expression of the eating partner.

ARM-A-DINE

Arm-A-Dine is a two-player interactive eating system where each participant wears a "third" robotic arm. The robotic arm is attached to a vest, making it a mobile solution that aims to not compromise the movement of the existing arms of the wearer (Figure 2). We connected the third arm wirelessly to a mobile phone (we only utilize the camera, not the display of the phone) that is attached to the other participant's vest, so that depending on the facial expressions of the wearer as captured by the mobile phone's camera, the robotic arm picks up food and presents it in front of the mouth of the wearer or the other participant. As the system is on participants' bodies, they also need to move their bodies in order to align the arm's gripper with the food on the table when picking it up, allowing to select certain foods by moving slightly around. Participants can pick the food up from the gripper with their hands or directly with their mouth. The decision to feed the wearer or the partner is controlled by the partner's facial expressions in the following way: If the camera picks up a rather "negative" facial expression, then the third arm will present the food to the wearer (Figure 3).

Figure 3. Any "negative" facial expression makes the partner's third arm feed himself.

If the expression is rather "neutral" (or could not be sensed) then the third arm will pick up the food and make ambiguous to-and-fro movements between the two eaters for about 5 seconds, suggesting it cannot decide who to feed, before either selecting to present the food to the wearer or the partner at random (Figure 4).

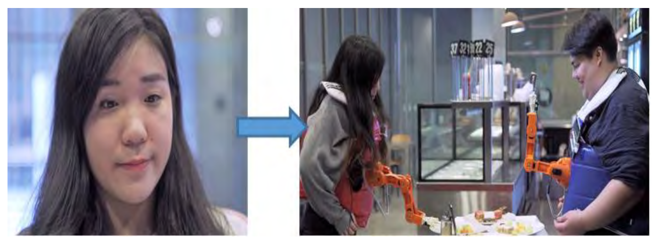

Figure 4. Any "neutral" facial expression makes the partner's third arm hesitate mid-air before finally deciding whom to feed at random.

If the expression is a "positive" one, the third arm will present the food to the eating partner (Figure 5**).**

Figure 5. Any "happy" facial expression makes the partner's third arm feed her.

As such, the system plays with bodily control, as it takes some control over what food a participant is being fed, asking the participant to control their body to select certain foods (when aligning the gripper), and controlling what the partner is being fed. We find this an intriguing opportunity, as prior work [56] has previously identified bodily control as intriguing element for interactive playful experiences. Given that this is the first exploratory work on this topic, we went with this particular form of mapping between facial expressions and who would get served the food in response, but other options are certainly possible. We envisioned that mapping facial expressions to arm movements could facilitate playful interactions (and laughter) around the eating process.

Technical Details

We used the Braccio robotic arm [95] that weighs 792 grams and is 50 cm in length (when stretched completely). We chose a gripper that is made up of plastic and rubber material. The gripper stops ca. 10 cm away from the wearer's mouth for safety reasons. We fixed the smartphone to the vest near the shoulder to capture facial expressions through the Google Face Tracker API [32]. Our software categorized the facial expressions into the value 1, 2 or 3. These facial expression values were wirelessly sent to an Arduino board (every 33 milliseconds) and stored for twenty seconds. This time period was selected based upon the time required for the arm to do the following: bend down, pick up any food item, come up, bring it near a mouth, wait for 5 seconds to allow participants to put the food in their mouth, and then bend down again. Our system then calculated the mean value (1, 2 or 3) and drove the next robotic arm movement based on the captured facial expression.

DESIGN PROCESS

The final design of *Arm-A-Dine* was a result of numerous design trials guided by focus group discussions.

In the first phase, the main concept of the prototype was fleshed out through 3 focus group discussions. These sessions lasted about an hour and each had 7 (5 male, 2 female) participants aged between 25 to 45 years. The participants came from varied academic backgrounds (food design, visual and interaction design, game design, engineering, psychology and HCI). Their diverse expertise helped us to discuss and refine various design aspects as described below.

Placement of the Robotic Arm

Robotic arms, when fixed on chairs or tables, restricts a person from moving around. For example, in our initial prototype, when the robotic arm was placed on a table, it forced us to maintain a particular distance and make a proper posture to make sure that the robotic arm feeds the food exactly in front of our mouth. It not only constrained us from moving, but also distracted us from paying attention to the food. We drew inspiration from earlier works such as "The Third Arm" [31] and the three-arm drumming system [33] that make the robotic arm a part of the body. Placing the arm on the body allowed us to explore the role of aligning our bodies to pick up any desired food. We then considered the positioning, drawing inspirations from earlier works [30, 31]. For example, we considered placing the base of the arm on the head, shoulders, chest, stomach, upper and lower back, hands and thighs. However, apart from the stomach and chest, all other bodily placements hindered the movements of the natural arms and caused discomfort during eating. We decided to place the third arm on the center of the chest. This placement not only helps the person to move his/her hands freely, but also the robotic arm to have access to the food and mouth directly. We used a Taekwondo vest [93] in order to protect individuals from any accidental damage caused due to unpredictable movements of the robotic arm and to have an easy mounting surface.

We also explored various options in terms of the movement of the robotic arm from the plate to the mouth. There are four components to the movement: the actuation mechanism, degree of freedom (DOF), picking mechanism and the required arm-length of the robotic arm. We discuss the actuation mechanism first. Pneumatics, hydraulics, suction force and electric motors are some of the commonly used actuation mechanism in robotic arms around food [65]. However, pneumatics and hydraulics are often used in industries where a high amount of force is desired, which is generally not required in an eating setting. Hence, we went with a robotic arm where actuation is done using DC and servo motors. Although DC and servo motors have the drawback of a persistent noticeable sound, it appeared not to be a distraction for the participants of the pilot as well as the final study.

Grasping Food

We identified that the robotic arm requires a minimum of 180 degrees of rotational movement for its base motor to bend and pick a food item to feed the user. It also requires at least 50 cm of arm length to help the user maintain a common distance from a table and also have access to pick up a food item and feed the user. Finally, we tried three options for picking up food from the plate: Suction force technology, scooping mechanism and use of grippers. The first option, the suction force, was only able to pick very light food items and hence it was not suitable for our purpose. The alternate scooping mechanism was better at picking up different kinds of food but it had a low success rate as learnt from the pilot study, which is explained further.

In the second phase, we conducted a study with 8 participants (5 male, 3 female) where we explored the design of a single player version of *Arm-A-Dine* with a scooping mechanism. The robotic arm was pre-programmed to pick (scoop the food) from two containers and then present it to users. Participants had to place their body so that the robotic arm would align with the container in order to be able to scoop the food. Volunteers participated in a two course (appetizer & dessert) eating experience. They were free to also use their hands and to decide whether and how much they would like to eat. We found out that participants had difficulties in successfully scooping up the food, as the robotic arm partially blocked the view of the food. It also required extra effort to align and grab the food. The participants also faced difficulties in aligning their bodies with respect to the containers. As a result, we went with the gripper.

Use Of Facial Expression

The results of the pilot study revealed that having a robotic arm attached to the body did not feel uncomfortable or distracting but rather rewarding. However, the pre-programmed actions felt a bit monotonous and participants wished the robotic arm could support more engaging interactions. Also, Herr et al. [35] discussed that people feel a need to alter allocations of robotic arms dynamically. Hence, we shifted from a one-player version to a two-player version, where some of the control of the arm's movement is given to the other player.

In the third phase, we decided to explore a two-player version by using a commodity item (a camera) to sense facial expressions (we use a basic "more positive expression", "more negative expression" and "neutral/cannot detect" state as starting point for our investigation) to partially control the arm's movement, complementing the wearer's arm control.

We focused on sensing facial expressions as they play a key role in communications between individuals and are excellent forms of expressing oneself [7]. They are also regarded to be a convenient way of identifying emotions [18, 19, 20]. Furthermore, communicating verbally while eating can be challenging, therefore facial expressions are also an important component of social interactions during eating [70]. We group Ekman's [18, 19, 20] basic emotion set into positive and negative (as well as neutral or non-detectable) responses we receive from the cameras we use. As we want to support the embodied character of a shared feeding experience, we want to support participants engaging their bodies in any way they liked, so we chose to mount the cameras on the partner's body (via the same vest that holds the robotic arm). This required participants to face each other in order for the facial expression to work and also restricted a more fine-grained classification of the sensed data due to changing shadows, focal distances, etc. yet it did not restrict participants to sit still as often required when working with a fixed camera. Hence, we designed a 2-player version, where the partner's facial expression decided what food the third-arm would pick.

Initially, we mapped the facial expressions to a certain food and allowed the third arm to pick up food accordingly. However, during trials, we found that this interaction forced people to stand in the same place and restricted their movements so that the third arm can fetch food from a desired plate. To overcome this, in our final design, we allowed participants to move freely and choose any food that they like using the third arm. Depending on the partner's facial expressions, the third arm would either feed the partner or oneself. The mapping of facial expressions to the wearer's third arm was decided based on our focus group discussions. For example, mapping of the partner's "more positive" facial expression to the feeding of food to the partner (via the wearer's third arm) we hoped would elicit joy, laughter and a sense of sharing based on the knowledge of feeding one another that is associated with positive emotions [24, 28, 103], however, this could also result in the perception of a loss of agency over what one eats. Through to-and-fro ambiguous movements of the third arm in the air (when sensing a "neutral" facial expression of the dining partner), it gave an opportunity to the diners to express their reactions more vividly, as we know that facial expressions become a key element to engage with a partner while eating [70].

USER STUDY

We conducted a study of *Arm-A-Dine* with 12 participants (5 male, 7 female) to gather insights into their augmented eating experience. The participants' ages ranged from 21-27 years with an average age of 24 and a standard deviation of 1.6 years. All the participants within the pairs knew each other. At the start of the study, participants received verbal instructions on how to use the system. We also gave a demo of how the system works and allowed them to explore the system extensively. Once they were comfortable with the system, the actual study began. During the study, we asked the participants to eat casually with their partner. We intentionally kept the interaction open and so did not give specific instructions, including whether to make certain facial expressions deliberately, use their other arms to eat, or how to pick up the food from the gripper.

We had prepared fresh food and arranged it on a height-adjustable table in an attractive way, similar to arrangements by a caterer. We followed a finger-food theme, where we normally eat while standing. The gripper was disinfected before each use. The study allowed participants to use all three arms and hence we put a glass of juice in front of the participant's left arm. In front of the right arm, we put a plate with cookies, chips and crackers. In front of the third arm, we put two plates containing strawberries, chocolates, grapes and cheese (to complement the cookies and crackers). We video recorded all sessions. At the end of the study, we asked participants to partake in a semi-structured interview together that lasted for about 20 minutes.

The topics discussed in the interview were: comfort and the user experience of *Arm-A-Dine*; the effects of its movements and the playful social interactions that emerged from the experience. The interviews were transcribed, where a question and its answer were considered as one unit of data. In total, there were 325 units included based on an inductive thematic analysis [6]. Three researchers independently read all units of the data twice, and each researcher identified every data unit with a category code. It was further discussed, refined and cross-referenced with the data to derive overarching themes following a thematic analysis process.

FINDINGS

The study revealed that *Arm-A-Dine* facilitated engaging conversations around food and the way we eat besides facilitating incidental bodily movements and empathy towards the eating partners. Based on the analysis of 325 units of collected data, we present 11 findings below.

F1: Participants Paid Attention to How They Eat

During the study sessions, we observed that participants were paying attention to the movement of the robotic arms and how food travelled from plate to mouth. Eight participants mentioned that normally they rarely pay attention to how they eat, but the *Arm-A-Dine* experience made them curious and they kept a keen eye on how the feeding action unfold. For example, Participant 3 said: "*when I think of a normal meal, I do not focus on the act of getting the food from the plate to my mouth. I take this act as granted. However, this experience of eating with robotic arms and sharing food with my partner pushed me to focus on those things*". As such it seems the novelty of robotic arms as well as the gameplay were contributing factors behind this altered focus.

F2: Extra Efforts and Time to Get Food in Mouth Felt Rewarding

Unlike the normal self-feeding process, *Arm-A-Dine* required additional effort and time to get the food into the mouth. The participants first had to look at the facial expression of their diner then think about which direction the arm would move and finally they must have also let the robotic arm move at its pace (which was intentionally slow). We initially thought that this slowness might annoy participants. However, to our surprise, this slow activity and the additional effort required did not felt like a punishment, instead participants enjoyed the overall process and found it a nice change to their routine action of eating food. They also felt rewarded when the robotic arm fed food to them. Participant 8 described the satisfaction of getting the food, he said: "*It pushed me to put an extra effort and attention to the eating process. But when I got the food after twisting, turning and slow movement of the robotic arm, I felt rewarded and satisfied*".

F3: Incidental Bodily Activity to Get the Food Was Appreciated

The movements of the robotic arm were not always perfectly aligned with the diner. Sometimes the participants had to align and twist their body to a certain angle to grab the food from the robotic arm, as illustrated in Figure 6. This incidental bodily activity was enjoyed by the participants. Seven participants mentioned in the interview that the required body-technology coordination was worth the effort. For example, Participant 7 said: "*I had to focus on the robotic arm and the food in order to pick it up properly. Although the table was set to my height I had to sway my body and coordinate it with the movement of the arm to pick up food perfectly*". Participant 10 similarly said he had great fun in twisting his bodies to pick the food.

F4: Exchange of Control on the Movement of the Robotic Arm Was Intriguing

Participants were not disappointed by the fact that they were not in control of their robotic arm that is on their body. Instead, they were happy in giving control of its movement to another person (an eating partner who was in front of them) since they knew that they are also in partial control of the robotic arm that the partner is wearing. Participant 4 said: "*I really like the twist that Arm-A-Dine unfolds that my arm is controlled by my partner and my partner's arm is controlled by me*".

Participants noted that they were aware of the fact that even though the arm was being controlled by their partner's facial expressions, they did not lose total control over their arm. For example, Participant 10 said: "*Having the robotic arm on my body means I still have some sort of control over it. For example, I can at least decide what food to pick*".

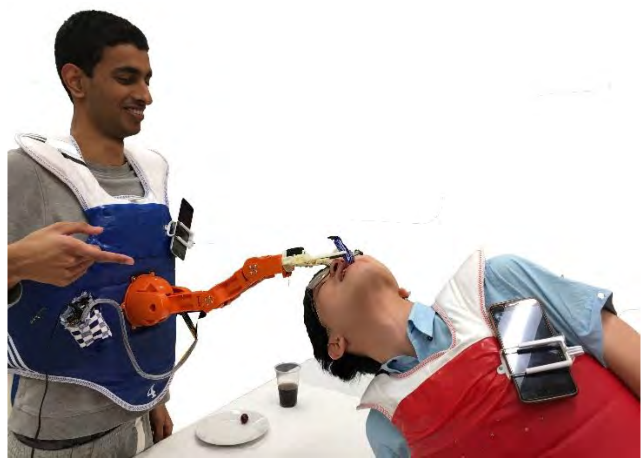

Figure 6. Participants experiencing playful social eating

F5: Unpredictable Movements of the Arm Was Enjoyed

In *Arm-A-dine*, the dependency on diners' facial expressions added an element of surprise and unpredictability. As such, it was hard to predict how and to which direction the arm would move. Specifically, when the diners' facial expressions were neutral, the arms behaved a bit randomly so it was hard to predict whom it would serve in this situation. This unpredictability, however, was taken positively by the participants, and they felt that it brought humor and playfulness to dining. For example, Participant 5 articulated how imperfect movements during dining can actually be valuable, she said: "*Although I would love perfect arm movement each time but it is too boring. If the arm is too perfect, then there is no chance of anything going wrong or something unexpected to happen and so there is no element of surprise. I think unpredictability of the arm's movement was great and made the eating experience more playful by increasing the conversation time I had with my partner*". On the other hand, participants also liked and got excited about strange mid-air arm movements when the system detected a neutral facial expression. Participant 2 said: "*The most exciting bit was when the third arm moved strangely in the air. It felt as if the arm was teasing us by fluttering between both our mouths. It was like: 'Wow!' And it felt good to see something like this*". For nine participants, this unpredictability of the arm in picking up food turned into a challenge. Participant 10 said: "*Making facial expression to get the food was challenging but it felt very satisfactory, when you got what you wanted*".

F6: Participants Devised Strategies to Make the System Work to Their Advantage

Six participants reported that they combined their efforts to operate and pick up food with their arms, and they felt this was a playful social part of the experience. For example, participant 10 said: "*My opponent and I found out the technique, if you put the gripper along the edge of the food, then it can easily grab the food. It was not hard, just needs a little bit of combined practice*". Participants were speaking about how they guided each other as sometimes the wearer or their partner understood how the arm was going to move better. For example, participant 16 said: "*Sometimes I was* *focusing more on eating the food I guess [laughs] and I missed a bit of the arm movement and lost track. During these times my partner helped me understand the arm's next movements and this made the experience more fun*".

F7: Paying Attention and Altering Facial Expressions

Participants suggested that they had to visually focus on their partner's facial expressions while also coordinating their own facial expression, which was challenging but also intriguing and fun. Surprisingly, this became a contest of who will succeed in this activity. For instance, participants tried to get to fed the food that they do not like to their diners by altering their facial expression. Participant 14 said: "*I was paying attention to [our] facial expressions: depending on what my [partner] picks, I used to change my expressions and try to feed him the food that he doesn't like [laughs]*". As such, the mapping of facial expressions to the movement of the arm and eventually to what is being eating facilitated participants to play around with their facial expressions. For example, participant 9 said: "*I felt like my arm was more in control than my [partner's] and I felt as if I was being fed by both, my arm and my partner's arm as well. I think this might be because I figured out the connection between emotions and how the arms picked up the food [giggles]. Eventually I tried to focus on my emotions and shape my facial expressions in a way that would make the arm pick food for me all the time [laughs].*"

F8: Time Gap Between Robotic Arm Movements Facilitated Bonding

Seven participants liked the slow speed of the third arm that maintained a time gap in between each repetitive cycle of the robotic arm. It allowed them to bond with each other, for example, participant 1 said: "*We keep meddling with our phone generally when we are eating. In Arm-A-Dine, we used the time when the robotic arm was doing its movement, to chat about each other's boyfriend. We have been having some trouble lately [laughs]*". Similarly, participant 11 said: "*The time gap between when the arm was feeding us helped focus on each other's facial expressions and interact with each other to influence how my partner was feeling*".

F9: Getting Fed by and Feeding Another Person Was an Enjoyable Social Activity

Ten participants said that they enjoyed feeding the other person more than feeding themselves. For example, participant 13 said: "*It was more fun to feed food to the other person, as it involves more interaction with the other person*". Participants also believed that such a system could act as an icebreaker between strangers as it pushed the participants to interact with each other: "*It is a good way of interacting with a person you are meeting for the first time*" (participant 8).

F10: Dining Became Enjoyable with the Addition of Smiles and Facial Expressions

In *Arm-A-Dine* smiling was a crucial element to affect the movement of the arm. As such, participants could have smiled only when it was required. However, we found that participants kept smiling more often because they were also enjoying the experience, and smiling did not occur just to satisfy the goal (i.e. smile to affect the movement of arm). To this end, participants seemed to be happy about smiling more even though they knew that this action might not help them eat more. For example, participant 4 said: "*Although I knew that her facial expressions control my robotic arm, [I] still wanted to smile more, it helped me in enjoying the experience more*".

F11: Feeding Each Other Made Participants Nostalgic

The participants felt nostalgic at times as it reminded them of the times they spent with their family. For example, participant 13 said: "*I enjoyed the experience a lot, especially the bit where my partner was feeding me as it reminded me of my mother feeding me when I was a child*". Participant 2 said: "*The experience reminded me of gathering with friends and family to eat and it felt good.*" Although we do not aim to infer cultural inferences, our study participants came from different countries and cultures with different eating habits, some use forks and spoons while some cultures also eat with their hands. *Arm-A-Dine* involved eating with hands. Participants who did not come from a culture that share this norm were at first a little apprehensive but enjoyed this new mode of interaction and eating with hands (even though it is the robotic hand). It reminded them of times when they travel to such countries where eating with hands is common. For example, participant 2 said: "*It is not common in our culture to eat with hands, but this experience reminded me of travels to Sri Lanka where I saw people eating food with their hands and it was very interesting to see people eating this way*".

THEMES

In this section, we group our findings to inform a set of three overarching themes. We unpack each theme based on our findings before discussing implications for design for each theme.

Theme 1: Reduce Bodily Control During Eating

Eating and in particular feeding is a bodily activity that involves our arms, shoulders, fingers etc. and normally we are in control of these bodily parts and therefore their actions. With *Arm-a-dine*, however, we revealed that altering some of this control can contribute towards an engaging eating experience. This theme advocates considering reduced bodily control during eating and 96 of the total 325 units of data were described by this theme.

Reduce bodily control to encourage new bodily ways of eating

Finding F3 suggests that eating with a third arm required the participants to give up some bodily control over their feeding actions and they had to coordinate their existing actions with the third arm. Sometimes, it involved twisting their bodies (See Figure 6) and aligning it with the movement of the third arm in order to get the desired food. On inquiry, participants said that they were happy to give away such partial control as it provided them with an opportunity to be physically agile and social and they also liked these new ways of eating and feeding their partner (as discussed in F3 and F8). Participants thought that this was "fun" because feeding with reduced control required them to emote (as discussed in F4) and interact more.

Encourage simpler control scheme

The mapping of facial expressions to arm movements also resulted in reduced bodily control for participants, as discussed in F7: as only three basic facial expressions where mapped to limited robotic movement (move towards the wearer, move towards the partner, or "undecided"), participants might have experienced this "limited" (at least in comparison to "regular" eating) control over their eating. However, participants seemed to have appreciated this reduced bodily control, in fact F7 suggests that it facilitated participants focusing on their own and their partner's facial expressions, which led to engaging conversations and an overall positive experience.

Allow machine to take partial control over eating

Another way, reduced bodily control was experienced by participants was through the third arm executing bodily actions on its own i.e., when the machine was controlling the pre-programmed movement actions of picking up the food, moving it up from the plate, and then releasing it from the gripper. These actions were pre-programmed and as such the participant did not have much control over them. Nevertheless, our findings suggest that participants enjoyed watching this bodily control unfold as part of their eating experience. It is important to note that these pre-programmed actions could have been improved upon with more advanced hardware, allowing for more smooth motion, for example. However, it appears that the more rugged control given to the machine was part of the appeal to see the feeding action unfold over time. Investigating the impact of hardware advances to notions of bodily control could therefore be interesting avenues for future work.

Implications for design

Integrating technology and food (e.g. [41, 42, 57, 64, 67, 75, 76]) can often be perceived as an attempt to give away control over what we eat. In contrast, we refine this and argue that reducing some bodily control can actually positively contribute to the eating experience, in particular, we argue that reducing bodily control is something that designers should consider when aiming to develop embodied eating experiences. This confirms existing theory on the benefits of reducing bodily control in entertainment experiences [56], here, we extend it to social eating. We argue based on our findings that designers interested in embodied eating experiences should consider bodily control as key design opportunity. In particular, we found reducing bodily control an intriguing design resource for playful social eating experiences. Other augmented eating systems could benefit from this, for example, we can envision a future version of the LOLLio interactive lollipop [64] that uses reduced bodily control to facilitate a more playful experience: through including a haptic output device in the stick between the base (which the user holds) and the candy, the computer could sometimes control how the candy moves and turns. This could be particularly playful if the candy is in the user's mouth.

Theme 2: Encourage Savoring by Drawing Attention to Sensory Aspects During Eating

This theme is derived from F1, F2, F5, F6, F7 and F8 and is concerned with how an embodied eating experience is facilitating savoring. Savoring is the capacity to attend to, appreciate, and enhance the positive experiences in our life [101]. It is one of the key principles behind eating mindfully [88] and aims to prolong and intensify the enjoyment of a consumption experience by drawing attention to sensory aspects of an experience that might otherwise be missed [8]. Here, we describe participants' experiences around savoring and how the design drew attention to sensory aspects to facilitate it. It is a combination of 85 of the total 325 units of data.

Make eating slow to draw attention to sensory aspects to facilitate savoring

Based on F1, we believe that participants savored the food they were being fed as the experience helped them focus on the sensory aspects of the food they were eating. This seemed to be facilitated by the fact that the movement of the robotic arm was rather slow to allow individuals to eat slowly. Despite the fact that food was so much more accessible to participants (as they had an extra arm), F6 and F7 suggest that the underlying interaction mechanics nudged individuals to eat slowly. In addition, F1 suggests that this focused participants on what they were eating and how much they were eating. While robotic arms like uArm Pro [96] offer much faster workflows, we suggest that instead of making robotic arms always faster, we can also benefit from their movement to be slow as a way to draw attention to sensory aspects and facilitate savoring. This is also in line with existing work on 3D-food printing [42] that previously found that a slow 3D printer can facilitate savoring and does not always need to be faster.

Make eating strange to draw attention to sensory aspects to facilitate savouring

Finding F4 suggests to us that learning how to control the third arm through facial expressions made the usually very easy and common task of feeding rather "strange", and participants had to learn anew how to feed themselves and their partner. Having to re-learn how to feed appeared to draw attention to the sensory aspects and therefore facilitated savouring. As such, we find that giving participants an extra arms that requires learning a new way to control it is one possible approach towards re-designing familiar embodied actions during eating as a way to draw attention to sensory aspects. This extends existing theory around making the familiar strange [52] that discusses making strange bodily movements serving the purpose of breaking out of old patterns of perception to arrive at fresh appreciations and perspectives for design. Similarly, we suggest to make familiar eating actions strange as a way to draw attention to sensory aspects as one way to facilitate savouring.

Implications for design

Existing eating technologies such as the Chewing Jockey [44] system is already making eating strange by playing augmented sound effects as a result of chewing. However, by looking at the theme, designers might come up with additional ways to make the eating strange, for example by playing sound effects also during the feeding as a way to focus one's attention to the audio during eating.

Theme 3: Encourage Cross Modal Sharing During Eating

In social eating experiences, sharing of food is a commonly observed activity. The sharing of food is often a sign of bonding and intimacy while contributing to conversations.

Cross modal design is the idea of involving two or more bodily senses into an experience to create playful experiences [14]. Our study findings, in particular F1, F5, F6, F8 and F9, suggest that cross modal sharing contributed positively to the eating experience. Our participants shared not only the food, but also the table, smell and conversations as a result of them being co-located. Here we describe how design can facilitate cross modal sharing beyond those aspects. 66 of the total 325 units of data were described by this theme.

Share bodies during eating to facilitate social interaction

Our findings F5, F6 and F8 suggest that the participants enjoyed that the design of *Arm-A-Dine* allowed them to experience shared eating over a local network: a participant's facial expression controlled the third arm of the other person as a result of being wirelessly connected. As such, we can say that participants experienced a "shared" body, as one's bodily actions (facial expression) affected the other person's bodily action (arm movement). This shared body experience action appeared to facilitate conversations and contribute positively to the social character of the experience. Prior work has already explored shared bodies, for example see [37], here we extend this work and argue that sharing bodies as part of the eating process can be an intriguing design resource to support embodied eating experiences.

Share control over eating to facilitate social interaction

Our findings suggest that participants found the shared control over the eating engaging as it facilitated social interaction. Theme 1 talks about reduced control, here we highlight that participants also experienced shared control: for example, when aiming to pick up the food, a participant shared control over the gripper with the system: the system determined when to close the gripper while the wearer was moving his/her body to position the gripper. Both participants were invested into this interaction, as it determined which food they will eat (and when, as it sometimes needed several attempts to get the picking right). Then participants shared control over the feeding action, as one participant determined who gets to be fed, while the other moved his/her body to align the gripper with the mouth. This coordination facilitated lots of laughter and contributed to the social character of the experience. Prior work has already highlighted the benefits of sharing control in embodied games (for example see Mueller et al. [62], Altimira [1], Garner et al. [29], Wilson [83]) to facilitate social interaction [37]. Here we extend this to eating by highlighting the potential of shared control over eating to facilitate social interaction.

Implications for Design

Other works can use this theme to stimulate design ideas around sharing when it comes to eating. For example, the Chorus system [27] that orchestrates the sharing and revisiting of personal stories through a connected collage of personal devices during family mealtimes could be extended through the notion of sharing bodies: the connected devices could encourage their respective owners to link arms while eating at significant points in the story to facilitate an even more "connected" embodied eating experience; this would probably contribute to the social character of the eating experience.

LIMITATIONS AND FUTURE WORK

We acknowledge that our work has limitations, like all design work. For example, we acknowledge that repeated use of the system might reveal additional insights. Also, the mounting of the third onto the vest felt generally comfortable, however, it might feel a bit heavy after prolonged use. Moreover, while working with limited facial expressions proved to be beneficial, we acknowledge that we can incorporate more bodily input in the future. Furthermore, the robotic arm was able to move in a few directions only due to its hardware constraints, this could also be built-upon to support enriched eating experiences. Nevertheless, we believe that our findings based on a first explorative study of an embodied eating experience still offers valuable first insights. We believe that, as technology advances, there will be more opportunities to augment the social eating experience and, in the future, we would like to see more work being explored around this area.

CONCLUSIONS

In this paper, we described the design and study of an embodied eating experience called Arm-A-Dine that focuses on a social and playful engagement around food. By presenting Arm-A-Dine, we introduce to the community an opportunity of combining embodied technology with the eating process to facilitate an engaging social eating experience. Along with the details of the design process, we describe the insights collected from interviews of the participants trying out Arm-A-Dine. We hope that the described themes and its design implications are useful for game designers and food practitioners to create playful social eating experiences. Rather than considering technology as a distraction during eating, we believe it can play a positive role if we design it right. As a step towards this, we illustrated how interactive technology can facilitate a playful social eating experience. We invite more explorations on such playful eating experiences in order to enrich our understanding of computer mediated human-food interactions.

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REFERENCES

1. David Altimira, Florian Mueller, Jenny Clarke, Gun Lee, Mark Billinghurst, and Christoph Bartneck. 2017. Enhancing player engagement through game balancing in digitally augmented physical games. *Int. J. Hum.-Comput. Stud.* 103, C (July 2017), 35-47. DOI: https://doi.org/10.1016/j.ijhcs.2017.02.004
2. Peter Arnold, Rohit Ashok Khot, and Florian Mueller. 2018. "You Better Eat to Survive": Exploring Cooperative Eating in Virtual Reality Games. In *Proceedings of the Twelfth International Conference on Tangible, Embedded, and Embodied Interaction* (TEI '18). ACM, New York, NY, USA, 398-408. DOI: https://doi.org/10.1145/3173225.3173238
3. Yuan Bao-Zong. 1989. Robot vision series: MIT electrical engineering and computer science series: Berthold Klaus Paul Horn The MIT Press/McGraw-Hill

Book Company, New York, 1986, 509 pp.,£ 40.50 ISBN 0-262-08159-8 (MIT Press); 0-07-030349-5 (McGraw-Hill).

4. Pollie Barden, Rob Comber, David Green, Daniel Jackson, Cassim Ladha, Tom Bartindale, Nick Bryan-Kinns, Tony Stockman, and Patrick Olivier. 2012. Telematic dinner party: designing for togetherness through play and performance. In Proceedings of the Designing Interactive Systems Conference (DIS '12). ACM, New York, NY, USA, 38-47. DOI: https://doi.org/10.1145/2317956.2317964
5. Tilde Bekker, Janienke Sturm, and Berry Eggen. "Designing playful interactions for social interaction and physical play." *Personal and Ubiquitous Computing* 14.5 (2010): 385-396. DOI=http://dx.doi.org/10.1007/s00779-009-0264-1
6. Virginia Braun and Victoria Clarke, 2006. Using thematic analysis in psychology. Qualitative research in psychology 3, 2, 77-101.
7. Wender LP Bredie, Hui Shan Grace Tan, and Karin Wendin. 2014. A Comparative Study on Facially Expressed Emotions in Response to Basic Tastes. Chemosensory perception 7, 1: 1–9. https://doi.org/10.1007/s12078-014-9163-6
8. Fred B. Bryant and Joseph Veroff 2007. Savoring: A new model of positive experience. Lawrence Erlbaum Associates Publishers.
9. Vishalini Bundhoo and Edward J. Park. "Design of an artificial muscle actuated finger towards biomimetic prosthetic hands." In *Advanced Robotics, 2005. ICAR'05. Proceedings., 12th International Conference on*, pp. 368-375. IEEE, 2005.
10. Ole Caprani. 2016. Robot-Supported Food Experiences. In Cultural Robotics: First International Workshop, CR 2015, Held as Part of IEEE RO-MAN 2015, Kobe, Japan, August 31, 2015. Revised Selected Papers, 107. Retrieved from http://link.springer.com/content/pdf/10.1007/978-3-319-42945-8.pdf#page=112
11. De Castro, John M. "Family and friends produce greater social facilitation of food intake than other companions." *Physiology & behavior* 56, no. 3 (1994): 445-455.
12. Keng-hao Chang, Shih-yen Liu, Hao-hua Chu, Jane Yung-jen Hsu, Cheryl Chen, Tung-yun Lin, Chieh-yu Chen, and Polly Huang. "The diet-aware dining table: Observing dietary behaviors over a tabletop surface." In *International Conference on Pervasive Computing*, pp. 366-382. Springer, Berlin, Heidelberg, 2006.
13. Wan-Ling Chang, Selma Šabanović, and Lesa Huber. 2013. Situated Analysis of Interactions between Cognitively Impaired Older Adults and the Therapeutic Robot PARO. In Social Robotics (Lecture Notes in Computer Science), 371–380. https://doi.org/10.1007/978-3-319-02675-6_37
14. Catherine Chapados and Daniel J. Levitin. 2008. Cross-modal interactions in the experience of musical performances: physiological correlates. *Cognition* 108, 3: 639–651. https://doi.org/10.1016/j.cognition.2008.05.008
15. Felipe Reinoso Carvalho, Kris Steenhaut, Raymond van Ee, Abdellah Touhafi, and Carlos Velasco. 2016. Sound-enhanced gustatory experiences and technology. In Proceedings of the 1st Workshop on Multi-sensorial Approaches to Human-Food Interaction (MHFI '16), Anton Nijholt, Carlos Velasco, Gijs Huisman, and Kasun Karunanayaka (Eds.). ACM, New York, NY, USA, Article 5 , 8 pages. DOI: https://doi.org/10.1145/3007577.3007580
16. Hilary Davis, Frank Vetere, Martin Gibbs, and Peter Francis. 2012. Come play with me: designing technologies for intergenerational play. Universal Access in the Information Society 11, 1: 17–29. https://doi.org/10.1007/s10209-011-0230-3
17. Direct comparisons of hand and mouth kinematics during grasping, feeding and fork-feeding actions https://www.frontiersin.org/articles/10.3389/fnhum.2015.00580/full
18. Paul Dourish. Where the action is: the foundations of embodied interaction. MIT press, 2004.
19. Paul Ekman. 1993. Facial expression and emotion. The American psychologist 48, 4: 384–392. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/8512154
20. Paul Ekman. 1992. An argument for basic emotions. Cognition and Emotion 6, 3-4: 169–200. https://doi.org/10.1080/02699939208411068
21. Paul Ekman. 2007. Emotions revealed: Recognizing faces and feelings to improve communication and emotional life. Macmillan. Retrieved from http://www.academia.edu/download/46126161/emotions-revealed-by-paul-ekman1.pdf
22. El Celler de Can Roca. http://vimeopro.com/user10658925/el-celler-de-can-roca/video/40919096
23. Daniel A. Epstein, Felicia Cordeiro, James Fogarty, Gary Hsieh, and Sean A. Munson. 2016. Crumbs: Lightweight Daily Food Challenges to Promote Engagement and Mindfulness. In Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems (CHI '16). ACM, New York, NY, USA, 5632-5644. DOI: https://doi.org/10.1145/2858036.2858044
24. Diane Eyer. "Mother-infant bonding." *Human Nature* 5, no. 1 (1994): 69-94.
25. Umer Farooq and Jonathan Grudin. 2016. Human-computer integration. *interactions* 23, 6 (October 2016), 26-32. DOI: https://doi.org/10.1145/3001896
26. Fat Duck Restaurant http://www.thefatduck.co.uk/
27. Hasan Shahid Ferdous, Frank Vetere, Hilary Davis, Bernd Ploderer, Kenton O'Hara, Rob Comber, and Geremy Farr-Wharton. 2017. Celebratory Technology to

Orchestrate the Sharing of Devices and Stories During Family Mealtimes. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17), 6960–6972. https://doi.org/10.1145/3025453.3025492

28. Ginger Ford, "Putting feeding back into the hands of patients." *Journal of psychosocial nursing and mental health services*34, no. 5 (1996): 35-3

29. Jayden Garner, Gavin Wood, Sebastiaan Pijnappel, Martin Murer, and Florian Mueller. 2013. Combining moving bodies with digital elements: design space between players and screens. In *Proceedings of The 9th Australasian Conference on Interactive Entertainment: Matters of Life and Death* (IE '13). ACM, New York, NY, USA, , Article 17 , 10 pages. DOI=http://dx.doi.org/10.1145/2513002.251301

30. Francine Gemperle, Chris Kasabach, John Stivoric, Malcolm Bauer, and Richard Martin. "Design for wearability." In *Wearable Computers, 1998. Digest of Papers. Second International Symposium on*, pp. 116-122. IEEE, 1998.

31. Jane Goodall. 1999. An Order of Pure Decision: Un-Natural Selection in the Work of Stelarc and Orlan. Body & Society 5, 2-3: 149–170. https://doi.org/10.1177/1357034X99005002009

32. Google Facetracker API https://developers.google.com/vision/android/face-tracker-tutorial

33. Deepak Gopinath and Gil Weinberg. 2016. A generative physical model approach for enhancing the stroke palette for robotic drummers. Robotics and autonomous systems 86: 207–215. Retrieved from http://www.sciencedirect.com/science/article/pii/S092188901630536X

34. Andrea Grimes and Richard Harper. 2008. Celebratory Technology: New Directions for Food Research in HCI. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '08), 467–476. https://doi.org/10.1145/1357054.1357130

35. Sascha Herr, Tom Gross, Michael Gradmann, and Dominik Henrich. 2016. Exploring Interaction Modalities and Task Allocation for Household Robotic Arms. In Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems (CHI EA '16), 2844–2850. https://doi.org/10.1145/2851581.2892456

36. James C. Hersey and Amy J. 2007. Reducing Children's TV Time to Reduce the Risk of Childhood Overweight: The Children's Media Use Study. Report. Centers for Disease Control and Prevention. http://www.cdc.gov/obesity/downloads/TV Time Highligts.pdf

37. Amy Huggard, Anushka De Mel, Jayden Garner, Cagdas 'Chad' Toprak, Alan Chatham, and Florian Mueller. 2013. Musical embrace: exploring social awkwardness in digital games. In *Proceedings of the 2013 ACM international joint conference on Pervasive and ubiquitous computing* (UbiComp '13). ACM, New York, NY, USA, 725-728. DOI=http://dx.doi.org/10.1145/2493432.2493518

38. Annika Hupfeld and Tom Rodden. 2012. Laying the table for HCI: uncovering ecologies of domestic food consumption. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '12). ACM, New York, NY, USA, 119-128. DOI: http://dx.doi.org/10.1145/2207676.2207694

39. Inamo restaurant http://www.inamo-restaurant.com/promos/tablecloths/

40. Interactive Restaurant Technology http://itrestaurant.net/

41. Rohit Ashok Khot, Jeewon Lee, Deepti Aggarwal, Larissa Hjorth, and Florian Mueller. 2015. TastyBeats: Designing Palatable Representations of Physical Activity. In Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems (CHI '15). ACM, New York, NY, USA, 2933-2942. DOI: https://doi.org/10.1145/2702123.2702197

42. Rohit Ashok Khot, Deepti Aggarwal, Ryan Pennings, Larissa Hjorth, and Florian Mueller. 2017. EdiPulse: Investigating a Playful Approach to Self-monitoring Through 3D Printed Chocolate Treats. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17), 6593–6607. https://doi.org/10.1145/3025453.3025980

43. Hiroshi Kobayashi and Fumio Hara. 1997. Facial interaction between animated 3D face robot and human beings. In 1997 IEEE International Conference on Systems, Man, and Cybernetics. Computational Cybernetics and Simulation, 3732–3737 vol.4. https://doi.org/10.1109/ICSMC.1997.633250

44. Naoya Koizumi, Hidekazu Tanaka, Yuji Uema, and Masahiko Inami. 2011. Chewing jockey: augmented food texture by using sound based on the cross-modal effect. In Proceedings of the 8th International Conference on Advances in Computer Entertainment Technology (ACE '11). ACM, New York, NY, USA, Article 21, 4 pages. DOI: https://doi.org/10.1145/2071423.2071449

45. Hiroshi Kousaka, Hiroshi Mizoguchi, Masahiro Yoshikawa, Hideyuki Tanaka, and Yoshio Matsumoto. "Role analysis of dominant and non-dominant hand in daily life." In *Systems, Man, and Cybernetics (SMC), 2013 IEEE International Conference on*, pp. 3972-3977. IEEE, 2013. https://doi.org/10.1109/SMC.2013.678

46. Vudattu Sachin Kumar, S. Aswath, Tellakula Sai Shashidhar, and Rajesh Kumar Choudhary. 2017. A Novel Design of a Full Length Prosthetic Robotic Arm for the Disabled. In Robot Intelligence Technology and Applications 4. Springer, Cham, 271–287. https://doi.org/10.1007/978-3-319-31293-4_22.

47. Sang-Won Leigh, Harpreet Sareen, Hsin-Liu (cindy) Kao, Xin Liu, and Pattie Maes. 2017. Body-Borne

Computers as Extensions of Self. Computers 6, 1: 12. https://doi.org/10.3390/computers6010012

48. Brad Lemley. Really Special Forces. *Discover* 23, no. 2 (2002): 25-26. Retrieved from https://elibrary.ru/item.asp?id=4387582
49. Jason P. Leboe and Tamara L. Ansons. 2006. On misattributing good remembering to a happy past: An investigation into the cognitive roots of nostalgia. *Emotion* 6, 4: 596–610. https://doi.org/10.1037/1528-3542.6.4.596
50. Le Petit Chef http://lepetitchef.com/
51. Chyi-Yeu Lin, Li-Wen Chuang, Li-Chieh Cheng, and Ke-Jeng Lin. 2015. An interactive finger-gaming robot with real-time emotion feedback. In 2015 6th International Conference on Automation, Robotics and Applications (ICARA), 513–518. https://doi.org/10.1109/ICARA.2015.7081201
52. Lian Loke. "Moving and making strange: A design methodology for movement-based interactive technologies." PhD diss., 2009.
53. Pedro Lopes, Sijing You, Lung-Pan Cheng, Sebastian Marwecki, and Patrick Baudisch. 2017. Providing Haptics to Walls & Heavy Objects in Virtual Reality by Means of Electrical Muscle Stimulation. In Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems (CHI '17), 1471–1482. https://doi.org/10.1145/3025453.3025600
54. Andrés Lucero, Evangelos Karapanos, Juha Arrasvuori, and Hannu Korhonen. 2014. Playful or Gameful?: creating delightful user experiences. interactions 21, 3 (May 2014), 34-39. DOI: https://doi.org/10.1145/2590973
55. Deborah Lupton, "Food, the body and the self" SAGE Publications (1996). DOI**:** http://dx.doi.org/10.4135/9781446221761
56. Joe Marshall, Duncan Rowland, Stefan Rennick Egglestone, Steve Benford, Brendan Walker, and Derek McAuley. 2011. Breath control of amusement rides. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '11). ACM, New York, NY, USA, 73-82. DOI: https://doi.org/10.1145/1978942.1978955
57. Dan Maynes-Aminzade. 2005. Edible bits: Seamless interfaces between people, data and food. In Conference on Human Factors in Computing Systems (CHI'05)-Extended Abstracts, 2207–2210. Retrieved from http://www.monzy.org/eui/edible-bits.pdf
58. Derek McColl and Goldie Nejat. 2013. Meal-time with a socially assistive robot and older adults at a long-term care facility. J. Hum.-Robot Interact.2, 1 (February 2013), 152-171. DOI: https://doi.org/10.5898/JHRI.2.1.McColl
59. Mealtime Partners, "Mealtime Partners," Mealtime Partners, Inc, September 2014. [Online]. Available :http://www.mealtimepartners.com/ [Accessed September 2015]
60. Sidney W. Mintz and Christine M. Du Bois. 2002. The Anthropology of Food and Eating. Annual review of anthropology 31, 1: 99–119. https://doi.org/10.1146/annurev.anthro.32.032702.131011
61. Robb Mitchell, Alexandra Papadimitriou, Youran You, and Laurens Boer. 2015. Really eating together: a kinetic table to synchronise social dining experiences. In Proceedings of the 6th Augmented Human International Conference (AH '15). ACM, New York, NY, USA, 173-174. DOI: http://dx.doi.org/10.1145/2735711.2735822
62. Florian Mueller, Stefan Agamanolis, Frank Vetere, and Martin R. Gibbs. 2008. Remote impact: shadowboxing over a distance. In *ACM SIGGRAPH 2008 posters* (SIGGRAPH '08). ACM, New York, NY, USA, Article 94, 1 pages. DOI=http://dx.doi.org/10.1145/1400885.1400985
63. Florian Mueller, Darren Edge, Frank Vetere, Martin R. Gibbs, Stefan Agamanolis, Bert Bongers, and Jennifer G. Sheridan. 2011. Designing Sports: A Framework for Exertion Games. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems* (CHI '11), 2651–2660. https://doi.org/10.1145/1978942.1979330
64. Martin Murer, Ilhan Aslan, and Manfred Tscheligi. 2013. LOLL io: exploring taste as playful modality. In Proceedings of the 7th International Conference on Tangible, Embedded and Embodied Interaction, 299–302. Retrieved from http://dl.acm.org/citation.cfm?id=2460675
65. Isira Naotunna, Chamika Janith Perera, Chameera Sandaruwan, R. A. R. C. Gopura, and Thilina Dulantha Lalitharatne. "Meal assistance robots: A review on current status, challenges and future directions." In *System Integration (SII), 2015 IEEE/SICE International Symposium on*, pp. 211-216. IEEE, 2015. https://doi.org/10.1109/SII.2015.7404980
66. Takuji Narumi, Shinya Nishizaka, Takashi Kajinami, Tomohiro Tanikawa, and Michitaka Hirose. 2011. Meta Cookie+: An Illusion-Based Gustatory Display. In Virtual and Mixed Reality - New Trends (Lecture Notes in Computer Science), 260–269. https://doi.org/10.1007/978-3-642-22021-0_29
67. Marianna Obrist, Rob Comber, Sriram Subramanian, Betina Piqueras-Fiszman, Carlos Velasco, and Charles Spence. 2014. Temporal, affective, and embodied characteristics of taste experiences: a framework for design. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14). ACM, New York, NY, USA, 2853-2862. DOI: https://doi.org/10.1145/2556288.2557007
68. Kenton O'Hara, John Helmes, Abigail Sellen, Richard Harper, Martijn ten Bhömer, and Elise van den Hoven.

2012. Food for Talk: Phototalk in the Context of Sharing a Meal. Human–Computer Interaction 27, 1-2: 124–150. https://doi.org/10.1080/07370024.2012.656069

69. Elinor Ochs and Merav Shohet. 2006. The cultural structuring of mealtime socialization. New directions for child and adolescent development, 111: 35–49. Retrieved from https://www.ncbi.nlm.nih.gov/pubmed/16646498

70. Kyohei Ogawa, Yukari Hori, Toshiki Takeuchi, Takuji Narumi, Tomohiro Tanikawa, and Michitaka Hirose. 2012. Table Talk Enhancer: A Tabletop System for Enhancing and Balancing Mealtime Conversations Using Utterance Rates. In Proceedings of the ACM Multimedia 2012 Workshop on Multimedia for Cooking and Eating Activities (CEA '12), 25–30. https://doi.org/10.1145/2390776.2390783

71. Natalie Pearson, Paula Griffiths, Stuart J. H. Biddle, Julie P. Johnston, and Emma Haycraft. 2017. Individual, behavioural and home environmental factors associated with eating behaviours in young adolescents. Appetite 112: 35–43.

72. Mirjana B. Popović, Dejan B. Popović, and Rajko Tomović. 2002. Control of arm movement: reaching synergies for neuroprosthesis with life-like control. Automatica: the journal of IFAC, the International Federation of Automatic Control 12, 1: 9–15. Retrieved from http://www.doiserbia.nb.rs/Article.aspx?id=1450-99030201009P

73. PowerSkip. Available online: http://www.powerskip.de (accessed on 7 March 2017).

74. Jerry E. Pratt, Benjamin T. Krupp, Christopher J. Morse, and Steven H. Collins. "The RoboKnee: an exoskeleton for enhancing strength and endurance during walking." In *Robotics and Automation, 2004. Proceedings. ICRA'04. 2004 IEEE International Conference on*, vol. 3, pp. 2430-2435. IEEE, 2004. https://doi.org/10.1109/ROBOT.2004.1307425

75. Nimesha Ranasinghe, Adrian David Cheok, and Ryohei Nakatsu. 2012. Taste/IP: The Sensation of Taste for Digital Communication. In Proceedings of the 14th ACM International Conference on Multimodal Interaction (ICMI '12), 409–416. https://doi.org/10.1145/2388676.2388768

76. Nimesha Ranasinghe, Kasun Karunanayaka, Adrian David Cheok, Owen Noel Newton Fernando, Hideaki Nii, and Ponnampalam Gopalakrishnakone. 2011. Digital Taste and Smell Communication. In Proceedings of the 6th International Conference on Body Area Networks (BodyNets '11), 78–84. Retrieved from http://dl.acm.org/citation.cfm?id=2318776.2318795

77. Nimesha Ranasinghe, Kuan-Yi Lee, Gajan Suthokumar, and Ellen Yi-Luen Do. 2016. Virtual ingredients for food and beverages to create immersive taste experiences. Multimedia tools and applications 75, 20: 12291–12309. https://doi.org/10.1007/s11042-015-3162-8

78. Nimesha Ranasinghe, Gajan Suthokumar, Kuan-Yi Lee, and Ellen Yi-Luen Do. 2015. Digital Flavor: Towards Digitally Simulating Virtual Flavors. In Proceedings of the 2015 ACM on International Conference on Multimodal Interaction (ICMI '15), 139–146. https://doi.org/10.1145/2818346.2820761

79. Mauricio Reyes, Ivan Meza, and Luis A. Pineda. 2015. The Positive Effect of Negative Feedback in HRI Using a Facial Expression Robot. In Cultural Robotics (Lecture Notes in Computer Science), 44–54. https://doi.org/10.1007/978-3-319-42945-8_4

80. Helen C. Roberts, Anna L. Pilgrim, Marinos Elia, Alan A. Jackson, Cyrus Cooper, Avan Aihie Sayer, and Sian M. Robinson. "Southampton mealtime assistance study: design and methods." *BMC geriatrics* 13, no. 1 (2013): 5.

81. RobotWorx: Packaging Robots https://www.robots.com/applications/packaging

82. Tomoya Sasaki, Mhd Yamen Saraiji, Charith Lasantha Fernando, Kouta Minamizawa, and Masahiko Inami. 2017. MetaLimbs: Metamorphosis for Multiple Arms Interaction Using Artificial Limbs. In ACM SIGGRAPH 2017 Posters(SIGGRAPH '17), 55:1–55:2. https://doi.org/10.1145/3102163.3102166

83. Johann Sebastian. Joust. http://www.jsjoust.com/presskit/#awards

84. Grace Tan Hui Shan. 2009. Facially expressed emotions. In response to basic taste solutions differing in concentration. Retrieved September 19, 2017 from http://www.diva-portal.org/smash/record.jsf?pid=diva2:959256

85. Jane Shi, Glenn Jimmerson, Tom Pearson, and Roland Menassa. 2012. Levels of Human and Robot Collaboration for Automotive Manufacturing. In Proceedings of the Workshop on Performance Metrics for Intelligent Systems (PerMIS '12), 95–100. https://doi.org/10.1145/2393091.2393111

86. Iris Soute, Panos Markopoulos, and Remco Magielse. 2010. Head Up Games: combining the best of both worlds by merging traditional and digital play. Personal and Ubiquitous Computing 14, 5: 435–444. https://doi.org/10.1007/s00779-009-0265-0

87. Ryoji Soyama, Sumio Ishii, and Azuma Fukase. 2003. The Development of Meal-Assistance Robot "My Spoon"-Selectable Operation Interfaces. In Proc. of the 8th International Conference on Rehabilitation Robotics, 88–91. Retrieved from http://dev02.dbpia.co.kr/1/05/35/1053571.pdf?article=887582

88. Charles Spence. 2017. Breakfast: The most important meal of the day? *International Journal of Gastronomy and Food Science* 8, Supplement C: 1–6. Retrieved from http://www.sciencedirect.com/science/article/pii/S1878450X17300045

89. Charles Spence, M. U. Shankar, and Heston Blumenthal. 2011. Sound bites': Auditory contributions to the perception and consumption of food and drink. Art and the senses: 207–238.

90. Charles Spence and Betina Piqueras-Fiszman. 2014. The Perfect Meal: The Multisensory Science of Food and Dining. John Wiley & Sons. Retrieved from https://market.android.com/details?id=book--5gCBAAAQBAJ

91. Charles Spence and Betina Piqueras-Fiszman. 2013. Technology at the dining table. Flavour 2, 1: 16. https://doi.org/10.1186/2044-7248-2-16

92. Yu Suzuki, Haruka Shinkou, and Hirotada Ueda. 2012. Influences of a Robot's Presence and Speeches in a Cooking Support System. In Proceedings of the ACM Multimedia 2012 Workshop on Multimedia for Cooking and Eating Activities (CEA '12), 31–36. https://doi.org/10.1145/2390776.2390784

93. Taekwondo vest https://mmafightstore.com.au/shop/adidas-wtf-approved-body-protector/

94. The Relationship Between Food and Mood. Food & Nutrition. https://foodandnutrition.org/blogs/stone-soup/relationship-food-mood\

95. Tinkerkit Braccio Robotic Arm https://store.arduino.cc/usa/tinkerkit-braccio

96. U Arm Pro http://www.ufactory.cc/#/en/

97. Uber eats https://www.ubereats.com/

98. Chi Thanh Vi, Asier Marzo, Damien Ablart, Gianluca Memoli, Sriram Subramanian, Bruce Drinkwater, and Marianna Obrist. 2017. TastyFloats: A Contactless Food Delivery System. In *Proceedings of the 2017 ACM International Conference on Interactive Surfaces and Spaces* (ISS '17). ACM, New York, NY, USA, 161-170. DOI: https://doi.org/10.1145/3132272.3134123

99. Wen Wang, Lining Yao, Teng Zhang, Chin-Yi Cheng, Daniel Levine, and Hiroshi Ishii. 2017. Transformative Appetite: Shape-Changing Food Transforms from 2D to 3D by Water Interaction through Cooking. In *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems* (CHI '17). ACM, New York, NY, USA, 6123-6132. DOI: https://doi.org/10.1145/3025453.3026019

100. Jun Wei, Xuan Wang, Roshan Lalintha Peiris, Yongsoon Choi, Xavier Roman Martinez, Remi Tache, Jeffrey Tzu Kwan Valino Koh, Veronica Halupka, and Adrian David Cheok. 2011. CoDine: An Interactive Multi-sensory System for Remote Dining. In Proceedings of the 13th International Conference on Ubiquitous Computing (UbiComp '11), 21–30. https://doi.org/10.1145/2030112.2030116

101. What is savoring. The positive psychlopedia. https://positivepsychlopedia.com/year-of-happy/what-is-savoring/

102. Takashi Yamada and Tomio Watanabe. 2011. An arm wrestling robot system for human upper extremity wear. In *Proceedings of the 2nd Augmented Human International Conference* (AH '11). ACM, New York, NY, USA, Article 38, 2 pages. DOI=http://dx.doi.org/10.1145/1959826.1959864

103. Toshitaka Yasuda, Midori Fukiwake, Kenji Shimokasa, and Yasuhiro Mine. "Investigation of Food Characteristics Modulating Spoon Motions in Skilled Spoon Users: Proposal of a Control Target for the Active Self-feeding Spoon." *Advanced Biomedical Engineering* 6 (2017): 110-121.

104. John Zimmerman, Jodi Forlizzi, and Shelley Evenson. 2007. Research Through Design As a Method for Interaction Design Research in HCI. In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '07), 493–502. https://doi.org/10.1145/1240624.1240704

105. Zomato https://www.zomato.com/