

Data as Delight:

Eating data

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The HCI community has a rich history of finding new ways to engage people with data beyond the screen. With our work, we aim to expand the scope of how interaction design can engage people, arguing that “eating data” has the potential to allow people to experience “data as delight”. With reference to prior work and our design research findings, we discuss the

advantages and the challenges of this approach to integrating data and food. We then identify four themes to guide the design of engagements with data through food: food form, food commensality, food ephemerality, and emotional response to food. Within these design themes, we articulate twelve insights for interaction designers to use when working on serving data as delight.

CCS CONCEPTS • Human-centered computing → Interaction design

Additional Keywords and Phrases: Food, Data Representation, Human-Food Interaction

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1 INTRODUCTION

The HCI community has a rich history of finding new ways to engage people with data, particularly through screen-based representations. While we acknowledge the value of this approach to engagement, we argue that it has limitations, particularly for reaching non-experts, because it takes a narrow, “analyst” perspective: that the value of data representation is based upon the time it takes to glean “essential insight” [111] and “facts” about data sets, such as trends, clusters, and outliers. We note that there are emerging, alternative forms of data representation (e.g. [17, 122]) that consider broader emotional and multisensorial aspects of data engagement [120]. The physical representations of data [108] – “physicalizations” [71] (made famous by the “dangling string” that hung from a ceiling visualizing network traffic [121]) – is one notable example. As another new area of physicalization work, the use of food as a material to convey data holds the potential to engage a broad lay audience. However, while the incidence of research into data experiences with food is increasing [119, 120], recent work offers very limited insight into, and guidance on, the design themes that will support success.

Cyber Wagashi



Figure 1: “Cyber Wagashi”: Experiencing weather data as delight in the form of Japanese confectionery. © Open-meals [68].

We aim to extend knowledge in the fields of data representation and human-food interaction, focusing on multisensorial experiences that we playfully name “data as delight”. By “data as delight” we mean representing data (usually numerical information) through edible material to engage in particular non-experts with the data by having them consume it. As non-experts can find it difficult to make sense of complex data, alternative representations beyond screens have been called for [71]. With “data as delight”, we aim to respond to this call.

First, we contend that “data as delight” experiences offer opportunities to explore the roles of affect and emotion [120] as both alternatives, and complements, to engagement via the visual senses. It is precisely because food can stimulate the senses, facilitate pleasure [45] and better health [104], enhance social interactions [8, 31], and improve wellbeing [96], that we believe that the ability to “eat” data can draw people into an enjoyable, more-than-visual engagement with data. Second, and building on prior work and the practical craft knowledge we have gained from designing systems that combine data and food, we propose a set of design themes and supporting insights that will guide future food and data design work. Specifically, we explore three “data as delight” systems that employ a diverse range of implementation technologies, data approaches, and food ingredients. These three systems give an indication of the size of the design space. The first system, Cyber Wagashi, uses 3D food printing to create Japanese confectionery from weather data; varying the confections’ shapes, sizes and colors to facilitate the eaters’ “contemplation of [Japan’s] transient seasons” [68].

Second, TastyBeats is an installation that creates a personalized sports drink using a liquid jets system. TastyBeats is inspired by bartenders' performative displays of drink mixing. Third, the "EdiPulse" [48] system turns physical activity data into chocolate treats to playfully provoke critical discourse about the quantified self and calorie intake. These systems inform our articulation of four design themes for engaging with data through food: food form, food commensality, food ephemerality, and emotional response to food. From these themes we articulate twelve insights to offer guidance for designers who want to serve data as delight (table 1).

Table 1: The four design themes and associated insights

Design theme	Insight
Food form for data as delight	Location of food to represent data
	Shape and color of food to entice data engagement
	Food's smell to draw attention to data
Food commensality for data as delight	Cooking as shared wrangling with data
	Spectating food preparation as data communication
	Food sharing to facilitate discussions around ownership of data
Food ephemerality for data as delight	Food temperature to time engagement with data
	Impermanence of food to convey time in data
	Satiation and satiety to indicate the conclusion of data engagement
Emotional response to food for data as delight	Food predilection as personalization to facilitate emotional affinity with data
	Eating's intimacy to facilitate engagement with personal data
	Playing with food to facilitate data exploration

In offering these design themes and insights, we also acknowledge, and consider, the challenges for future "data as delight" systems work. Specifically, we note that poor eating can result in adverse health outcomes and be detrimental to wellbeing [21, 38], and that representing data through food poses hygiene-related, cultural and technical challenges, especially in comparison with traditional screen-based data representations.

Wang et al. [119] have explored data as delight via a salad that encodes the employment prospects of STEM degree holders. The salad ingredients are stacked, with breadcrumbs representing available jobs, salty ham representing associate degree holders, sweet corns representing bachelor's degree holders, diced sour tomatoes representing master's degree holders, and bitter arugula representing PhD degree holders. Interviews with diners revealed that the salad engaged them with the data, aroused emotions, and deepened their understanding of the data, for example: "*I was puzzled about how the ingredients were chosen for the different degrees. When I took a bite of the (arugula) leaf – the representation of Ph.D. – and tasted the bitterness, I said to myself, this is why.*" This vignette highlights that data can be represented via taste, extending the designer's possibilities compared to screen-based representations. This approach seems to be the first that comes to mind (e.g. [106, 119]) and we also see the value, however, in our design practice, we found it not only incredibly challenging to implement, but also not making full use of the richness that food can offer to represent data. In consequence, we wrote this article to highlight those rather underexplored opportunities when it comes to serving data as delight.

We acknowledge that the design themes and insights we propose are not yet exhaustive and face some challenges. As such, we do not claim an exhaustive theory, but rather, that further research is needed to extend our preliminary initial work. We therefore frame our work as a starting point into this interesting new area. Such a framing has advantages (relevance, practicality, first-person account), but also disadvantages (requiring

further empirical research to be conclusive). However, we contend that our work, in particular the design themes and the insights provide an initial foundation for research: for HCI researchers, interaction designers, food designers, and chefs who want to pursue the value in “data as delight” systems, and address the challenges they face; and for data experts who wish to analyze, study and examine those systems.

2 RELATED WORK

In this section, we discuss what we have learned from key prior works in our quest to serve data as delight, we identify gaps in design knowledge, and we establish the rationale for this article and its contribution to closing these gaps.

2.1 Multisensory Data Perception

In traditional data visualization, the visual channels - such as position, size, shape and color - for perception of data are reasonably well understood thanks to established taxonomies for the design of visual data communication [86]. However, it is less well understood how non-visual senses can be drawn upon to support data engagement. Recent research has begun to explore the broader sensory and experiential channels along which people can engage with data. For example, McCormack et al. offer a framework for multisensory “immersive analytics” encompassing sight, hearing, touch, muscles, nose, and mouth [67], and more recent efforts seek to formally map the design spaces of olfaction [98] and edibilization [119]. As such, serving data as food can advance the field of data engagement generally and, more specifically, subareas such as embedded and situated representations [109, 122]. In this respect, our work makes use of the physical world along with digitally infused multisensory experiences [22]. However, we contend that food’s value to data engagement goes beyond the physical senses, and should be considered a part of a holistic eating experience, encompassing additional aspects such as socializing and sheer pleasure.

2.2 Combining data and food

Combining data and food is not a new idea. Data already informs many of today’s food production, preparation, and consumption experiences [24], and food and data combinations have produced novel food-technology interactions [97], technology-supported healthy eating approaches [62, 89, 95], and sustainable food practices [25]. Prior work has also explored systems that *use* data to enrich the eating experience. A famous example is the “Sound of the Sea” dish that transforms the seafood dining experience by delivering an ocean soundscape through headphones [105]. Furthermore, the decoration of cakes with digital prints (conveying information such as “Peter turns 18!”) indicates that food decoration holds great potential to support data representation. Our work goes beyond using digital data that delivers additional auditory or visual information to augment the diner’s eating experience. Drawing upon the field of human-food interaction (HFI) [2, 6, 7, 15, 16, 23, 28, 42, 49-57, 65, 70, 112-118], we stress that research into food as part of interactions with technology must consider food’s rich cultural and social history, and not see it solely as a source of energy. We should see food as a “celebratory technology” [36].

2.3 Embedding data into food

Embedding data into food is also not new. For example, “Qkies” [1] embed QR codes into cookies and access the data via a smartphone. In contrast, we extend work on the coming together of data and food by investigating opportunities to engage people *with data through food*.

We also acknowledge that several individual exemplar dishes have already demonstrated how data can be visualized through food. For example, the dish “eating the distance” [99] presents a sequence of fruit crudités: three dishes that represent the distance the food ingredients have traveled to reach the diner. The dishes include: a locally sourced Gin Rickey (only 130 km of travel distance); a Skyr yoghurt with honey, strawberry, and mint (640 km); and a coconut tapioca pudding with pineapple chunks and coconut cream, wrapped in a banana leaf cone (34,000 km). The dishes are spread out at a distance proportionate to the “food miles” travelled [99]. Similarly, designer Martí Guixé has embedded data into several food items as part of exhibitions, including cakes that display their ingredients as a pie-chart [63], and drinks “Atomic Shots” [102], similar to InfoCocktails (in [71]), represent data relating to nuclear power plants accidents and the human populations living within the 30 kilometer surrounding zone. Each gram of gel globules in the shots corresponds to 100,000 people living in these zones.

Furthermore, we acknowledge previous approaches such as “edibilization” [119, 120] and build on their work by including considerations such as automatically turning data into dishes that contrasts this prior work’s mostly manual representation constructions, making our approach more scalable.

2.4 Interweaving data into food with advanced technologies

We note that the creators of the examples above used traditional culinary methods, and we agree with other researchers in this area that technological advances, particularly in food preparation and presentation, offer new opportunities to complement what human chefs can achieve [34, 120]. For example, computational machines, such as food 3D-printers [3], enable us to produce data as delight controlled by software.

We also note that prior works mostly demonstrate individual examples that focus on individual data sets or specific eating experiences. In contrast, we aim to engage with a more holistic approach, reflect upon multiple systems and what they mean for a broader vision, and introduce “data as delight”. Our primary interest is in using food eating experiences to facilitate engagements with data. Consequently, we do not focus on the decorative, disposable “data pieces” of a dish, which often produce food waste. And, while we note that prior work advocates against the use of technology when it comes to eating, because it can be distracting and negatively affect the eating experience [103], we stand with other prior HFI work which contends that technology is only distracting if it is poorly designed. We concur that better design can mean a better eating experience [84].

In contrast with most traditional HFI research [34, 53], “data as delight” aims to find the balance between having too much focus on the food, which diminishes opportunities to engage with the data, and having too much focus on the data, which hinders the food experience. We do not wish to become so entranced by the data that we forget to eat! Negotiating this balance is probably the most challenging aspect of delivering data as delight, although the challenge is not entirely new. We note that similar challenges exist for work on physical representations [120]. If we find this balance, data as delight can offer significant opportunities to engage people with data.

In summary, prior work has explored the coming together of technology and food, and has challenged the common misconception that interactive eating experiences are diminished by the combination of data and food. Systems have emerged that embed data into food, and aim to support eaters in experiencing data as delight. However, we still need a structured understanding of how to design data as delight experiences. To begin the construction of this understanding, we present a set of themes and associated insights based on existing systems.

3 DATA AS DELIGHT SYSTEMS

In this section, we present three data as delight systems. We designed, developed, and exhibited two of these examples ourselves, and can report first-hand experiences, and detail the associated tacit craft knowledge we gained via our research-through-design approach [32, 33, 124]. We also draw on associated studies to explore the user experiences that inform our design insights. These insights are intended to function as intermediate design knowledge, situated between low-level development details and abstract theory [41].

We chose two of these examples because of the intimate knowledge we gained through our design process, particularly with respect to hard- and software design, and because we conducted the studies ourselves. This knowledge gives us a unique insight from the perspective of working with food in a design research lab. To complement our work, we also include an external commercial system to highlight the size of the design space directly applicable to practitioners. We selected this system because it received media attention and is often referred to in our HFI workshops, which indicates reader familiarity [52, 101]. Although we have not tried this system, we believe it complements our experiences. We hope that our discussion of this system gives readers greater confidence that our insights hold both for our practice and the practice of others, and that these insights will be useful for future design work.

Portfolio design researchers argue that presenting and discussing a set of examples can be useful when aiming to present a design space [32]. Furthermore, prior work has also used a similar number of examples when discussing food systems in HCI [84]. In this respect, we hope to employ a similar approach to articulating a space of design possibilities. We begin with the external commercial system called “Cyber Wagashi”.

3.1 Cyber Wagashi

Wagashi are traditional Japanese confections. “Cyber Wagashi” (Figure 1) is a system that uses this food to represent weather data [68] to facilitate the “contemplation of transient seasons” [68]. The goal of the system experience is to make diners “intuitively feel” [68] the climate of the day through the wagashi. Weather data for a specific location on a particular day (wind speed, atmospheric pressure, and temperature) is captured from a satellite data platform and converted through custom-made algorithms into 3D printed “wagashi” forms. Wind speed and system pressure (high or low) are mapped to the food’s form, in particular, size and shape; the atmospheric pressure is mapped to food height; and temperature is mapped to food color. The wagashi can also use weather predictions to make people aware of future conditions; for instance showing how the hottest day of a particular season will become even hotter due to climate change [68].

We note that this project represents an industry-focused approach to facilitating experiences of “data as delight” because the work uses a 3D food printer, and 3D printers have advanced [3] to the point where professional kitchens use them [43, 58].

3.2 TastyBeats



Figure 2: “TastyBeats”: Data as delight in the form of a personalized replenishing drink after physical activity.

Data can be a delight in the form of a drink. The system “TasyBeats” [49] is inspired by sports drinks that aim to provide the right amount of ingredients to replenish people during and after exercise, and by the bartenders’ performative drink mixing displays.

In this system, a heart rate sensor captures physical activities, and once the participant wants to quench their thirst, the system (Figure 2) uses up to four ingredients to mix a personalized drink (for technical details, see [49]). Depending upon how long the participant’s heart rate sat between 60 and 95 beats per minute, the system drives the liquid pump which “spurts” ingredients into the glass. The system design is inspired by the exaggerated movements bartenders make when serving from a bottle (for example, pouring from a height). If the participant’s heart rate sat between 96 and 130 beats per minute, the system adds lightly flavored water. If the heart rate sat between 131 and 165, the system adds liquid containing electrolytes. And, finally, if the heart rate sat between 166 and 195, the system adds richly flavored water. All these responses produce personalized drinks with taste and recovery benefits informed by data. The associated study [49] revealed that participants found the “performance” of the system contributed to the delightful experience of engaging with their physical activity data.

3.3 EdiPulse

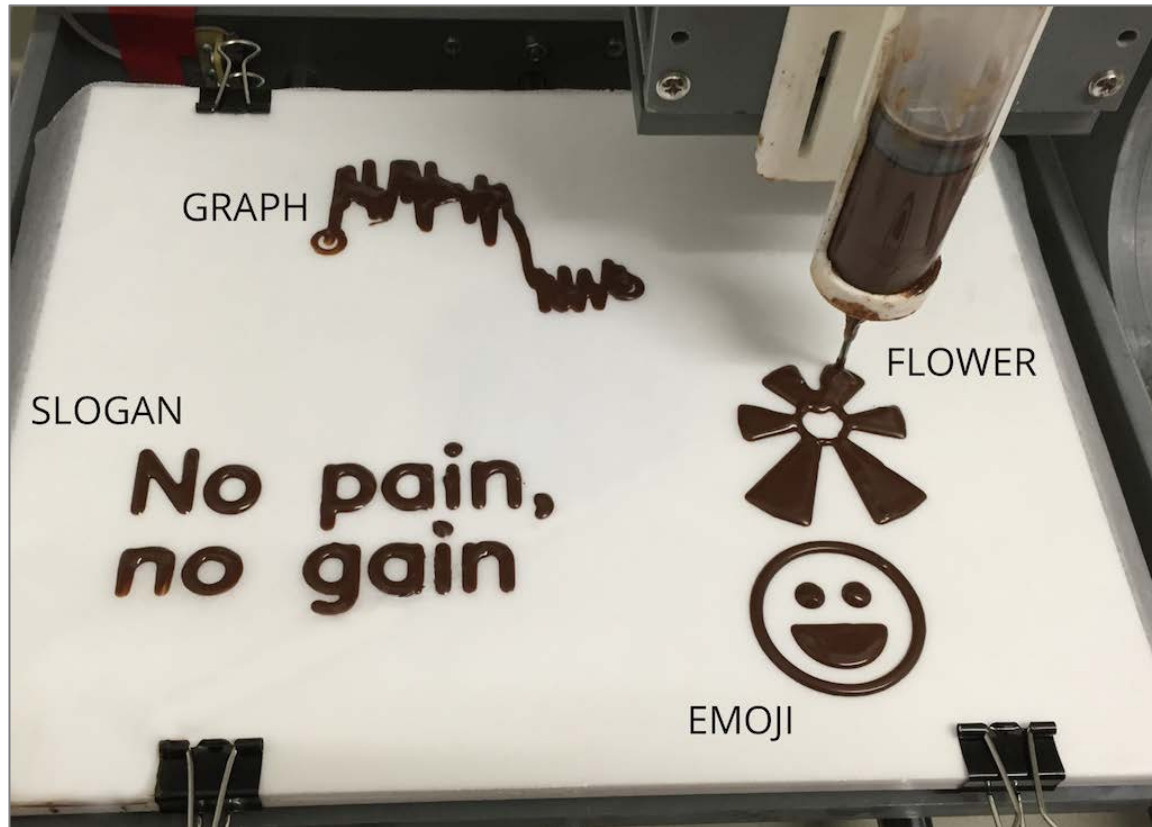


Figure 3: “EdiPulse”: Physical activity data as delight in the form of 3D-printed chocolate treats.

The “EdiPulse” system transforms physical activity data into chocolate treats [48]. The aim of this work – highlighted by the choice of chocolate as food material – is to playfully provoke critical discourse about the quantified self (as promoted by, for example, activity trackers) and calorie intake. During the day, participants wear a heart rate monitor which senses physical activity data. At the day’s end, a modified 3D printer installed in the participants’ homes transforms the data into chocolate (Figure 3) (for technical details, see [48]). The chocolate representations are in the form of emoticons, graphs, or slogans such as “no pain, no gain”, with the form and thickness reflecting the duration and intensity of the physical activity. The amount of chocolate being used is the same for each day, only the forms of each representation change. Participants in an in-the-wild [100] study described the experience of eating data as “delight” and observed that the data served as food functioned as a lubricant for social interactions amongst the household’s members around the topic of being physically active and eating as a family. Our volunteers also expressed that the system could support them in reaching their health-related goals or facilitate behavior change. For example, 38% of EdiPulse users did not eat their chocolate if they did not reach their exercise goal. One participant said: *“It is hard to guess correctly if you have*

done enough exercise to get a smiling Emoji, so you often do more exercise than what you normally do". Participants also reported that the data representations inspired them to reach their fitness-related goals.

4 KEY THEMES AND INSIGHTS

We now articulate a set of key themes for data as delight systems. Each theme comprises three design insights. We present the key themes and insights that we believe could be both interesting and practically useful for interaction designers. We derived these themes from our analysis of previous work, both in academia and in kitchens worldwide, from craft knowledge gleaned through our design work on two of the systems mentioned above, and from our countless prior design iterations, including the consideration of design alternatives. These themes and insights have been refined based on participant and exhibition attendee feedback on our work.

We acknowledge that themes could also be derived through a literature review alone instead of along a set of systems. However, we argue that our focus on experience with systems is a major strength of our work, compared to past work that favored literature reviews, theoretical arguments, etc. over designing novel systems (e.g. [13, 14]). Therefore, past work can fall short in fully incorporating the multisensorial appeal of food as the authors have to rely on food pictures in the articles rather than their "first-person account" [107] of having eaten the food. Having tasted many "prototypes", we can offer such a first-person account; this is essential for fully understanding bodily experiences, according to phenomenology [107]. Solely reading about food can only offer a "third-person account".

Furthermore, we believe that "food design insights" coming from "food designers" will be more likely to be embraced by designers compared to coming from pure theorists. In addition, we believe that a literature review might have resulted in some of our themes, but not in all of our 12 insights, making our work more attractive for the future of HCI research as it is more complete.

4.1 Method: How we arrived at the themes

We arrived at the four themes by drawing from autoethnography (based on our prior experience with it [81, 85]) and combining it with annotated portfolio research (based on our prior experience with it [72, 74-80, 83, 84]). Our process involved a lot of eating inside and outside the lab, including in the restaurants that evolved some of the commercial examples. We began by writing down all findings from our prior work and discussed them in online meetings with all authors (who have expertise in human-food interaction, information visualization or both). We then grouped them resulting in a shared document, before distilling the resulting insights down to the most prominent. We then grouped these into four themes, refining their wording through collaborative writing in an online document. Furthermore, we used whiteboards, post-it notes, affinity diagrams and "thinking through writing", while also looking back at our original findings and early system prototypes to derive the themes and insights.

We note that we did not start our system design work with the aim of developing design themes. Instead, and characteristic of the practice in a design research lab, the themes emerged from practice, informed by theoretical thinking. In hindsight, we believe that starting with the goal of developing design themes might have made the process easier for us, however, we personally needed the process to arrive at our final contribution. Nevertheless, we acknowledge other approaches are certainly possible, for example "interaction criticism" [9].

This approach to deriving knowledge of a novel design space has been used previously [11, 73, 74, 82, 84], and we believe it is applicable to our work on data as delight. Such an approach has practical strengths,

generating vivid descriptions that practitioners can readily grasp, and also weaknesses, such as providing limited opportunities to articulate how strategies emerged [11, 76, 82].

We did not intend for the themes and insights in this work to represent a complete understanding of data as delight, and we acknowledge that they do not. Rather, our work offers a foundation for a more comprehensive and structured understanding that will emerge as research labs and kitchens develop more systems. Furthermore, we acknowledge that through our approach we developed a rather positive attitude towards data as delight, which possibly tints the articulation of the themes. We point out that as we are enthusiastic about the field, we hope that others can also get excited about the opportunities while we acknowledge the challenges, which we discuss later in the article.

We structure our themes using phenomenological perspectives of bodily experiences [110], as previously suggested in interaction design around the human body [73]: these perspectives are broadly concerned with the spatial, social, temporal, and corporeal. Our respective themes are: food form for data as delight; food commensality for data as delight; food ephemerality for data as delight; and emotional response to food for data as delight. We believe this multifaceted approach allows us to highlight interaction design opportunities that lie beyond the obvious and that, hopefully, will inspire practitioners to venture down underexplored paths.

4.2 Theme 1: Food form for data as delight

This theme is concerned with the spatial aspects of data as delight. We identify the following key insights for designers:

4.2.1 Location of food to represent data

Designers can use the location of food to represent data. This location can refer to the position of the food on the plate or on the table itself (as made famous by restaurant Alinea [44]). We also point to the opportunity to “deconstruct” an individual dish and lay out the individual ingredients as a way to represent data. For example, with the “Deconstructed Food Miles Smoothie” [26], each fruit puree of the smoothie is served in a separate glass, and their location away from the drinker represents the distance the ingredients had to travel to reach the bar. Because the blueberries are imported from Canada, they are positioned 19 cm away from the drinker in Boston; the strawberries from Peru are 68 cm away; the pineapple from Costa Rica is 78 cm away; and the Chilean Blackberries are 94 cm away. The drinker decides whether to consume the ingredients, one at a time, or all at once (having access to several straws with multiple lengths). Hopefully, the drinker learns from the data that some of the long-distance items are not necessary for a delightful experience, and that they could avoid the pollution associated with those items in the future, or at least appreciate the effort it took to get them to the drinker.

The VR game by Arnold et al. [6] provides another example, in which food is placed around a room. To succeed in the game, players must align their virtual and physical actions across the physical and virtual space. These examples suggest that, by considering the location of food, designers can also influence which ingredients are eaten together and possibly even their order, thereby facilitating particular types of data engagement.

The location of the liquid containers of TastyBeats played an important role in the way that the mixing action unfolded: by placing them in a square, they all had an equal distance to travel, resulting in a performative spectacle, where the end result, the drink, is in the middle where “everything comes together”. Our initial

prototypes had the containers in a row, which allowed for larger fountain actions to occur for the outside containers, and hence emphasize any high heart rate data. However, the pumps would in the start-up phase not produce enough power for this to be viable.

In hindsight, we could have done more in terms of location with EdiPulse. However, as the chocolate needed to be printed at just the right temperature (we experimented with fans and thermoelectric cooling), we found it to be preferable to print the different representations as close together as possible. This also minimized “smearing” of the chocolate.

4.2.2 *Shape and color of food to entice data engagement*

Designers can choose to represent data via the shape and the color of the food. These characteristics contribute to the appeal of a dish and can encourage data engagement [105]. For example, the colors used in the TastyBeats work played a key role in not only communicating the different heart rate data ranges, but also in enticing people to engage with the data in the first place.

EdiPulse participants could choose between four different data representations, all delivering the same amount of chocolate. In interviews, participants expressed how much this feature contributed to their desire to engage with the data, as each representation allowed them to learn about the data in different ways.

Cyber Wagashi used shape and color quite extensively. For example, increased height represented increased atmospheric pressure. Assuming that weather data is never the same, Cyber Wagashi also ensures that each confection is unique, further contributing to its appeal.

We note that shape can also influence the size of a dish. However, unlike with virtual representations, where, for example, a designer can very easily change the size of a virtual pie chart on a webpage, food size is more difficult to manage. Furthermore, when considering shape, as it relates to size, designers should consider a diner’s satiety level (which we discuss below) and also the value of avoiding food waste.

4.2.3 *Food’s smell to draw attention to data*

Food smells can attract eaters and bystanders to data. Most foods emit a unique, pleasant smell, especially when cooked, and we highlight that designers can utilize this feature as an (often underused) way to draw attention to data. Prior work has already investigated the use of smell in interaction design [47, 91, 92], including the use of artificial smell [123] for information visualization [98]. Here, we extend this prior work, which focused more on conveying information *through* smell, and propose that designers can use the resulting smell as a way to *draw attention to the data*. Smell has the advantage that it can travel beyond the line of sight of the food to reach bystanders while being strongly associated with emotional responses, including memory recall [19, 35, 91]. As such, a smell might help make data more memorable [18, 59].

While EdiPulse study participants commented on the smell released when the drink liquids jetted into the air, the smell was not considered pleasant. If the smell could be improved, we could, for example, place the system in a public area near gym exits. The smell of data being produced could inform people who are not watching the performance or exercising nearby. The smell could entice these bystanders to engage and possibly discuss the data, making the data as delight experience a social one.

TastyBeats study participants applauded how the melting chocolate emitted a “*wonderful*” smell that permeated their entire house. Other inhabitants, regardless of their room, could also smell the melting chocolate. This realization compelled the house members to leave their rooms and join the delight “party” to view the

chocolate data; demonstrating how smell (unlike most visual displays) can reach people, even if they do not have line-of-sight to the data representation.

Furthermore, we point out that smell can attract people whose locus of attention is not on the food. They might, for example, be engaging in conversation or looking at a mobile phone while eating the Cyber Wagashi at a restaurant. However, smell generally has a low fidelity when it comes to its potential of conveying complex information [98]. Hence, we point out that designers might want to consider smell in combination with other data representations, like the size of the dish in our Cyber Wagashi example.

4.3 Theme 2: Food commensality for data as delight

While we can eat alone, eating is often a social endeavor, and the word “commensality” captures the essence of this experience: it is the “practice of sharing food and eating together in a social group such as a family” [93]. Of course, shared experience with data has been considered by the visual data analytics community already, however, generally in a very traditional visual analysis setting, i.e. multiple people looking at a visualization together [39].

4.3.1 Cooking as shared wrangling with data

Cooking together can be a very social activity. Shared preparation steps, such as melting the chocolate and filling the 3D printer (EdiPulse), or filling of the ingredient containers (TastyBeats), offer opportunities to engage eaters with the data well before they eat. Indeed, cooking is a process that often requires a particular set of ingredients, all of which have to be obtained, measured and assembled in a particular order. We believe that this part of the preparation process lends itself to communicating data, and can support learning about relationships between individual data points and their dependencies. As most people are already familiar with the basics of cooking, there is no need to learn additional skills before they can engage with data “wrangling” [46]. This “wrangling” might be an intriguing way to engage people who might be unfamiliar with, even “fearful” of, data and its associated analysis, or who think they might not be “good with mathematics”. The experience could be a particularly useful way to engage children with data; especially those who are too young to engage with screen representations. Furthermore, because ingredients are readily available in most kitchens, data engagement can be spontaneous. Just as cooking is a life skill, engagement with data is a (modern) life skill, and we contend that the opportunity exists to use one skill to teach and facilitate engagement with the other.

However, we also note that, unlike most screen-based data systems, cooking does not often offer an “undo” button [66]. When we mix two ingredients, they can rarely be separated, and our data engagement carries with it a certain irreversibility. Consequently, we believe designers should take into consideration that cooking-related data as delight experiences could require a stronger commitment to actions.

4.3.2 Spectating food preparation as data communication

We often learn how to cook by watching others. Consider how appealing it is to watch others prepare a dish or drink. We noted earlier the entertaining similarities between TastyBeats and the performance of a bartender mixing cocktails, and, of course, many restaurants feature open kitchens that allow diners to watch the performative spectacle. Designers would be well advised to use the appeal of watching food preparation as a way to facilitate data engagement. For example, designers could draw on the appeal of televised and streamed kitchen shows to engage a wide audience with data through the cooking process. Moreover, technology offers

novel opportunities to communicate data to spectators of food preparation. For example, robots could participate and perform, in ways akin to the computational machine performing the drink mixing in Tastybeats, and the ice-cream serving robot, which is a children's favorite [88]. Also, robots can tirelessly repeat the same data/cooking action, which allows for the repeated representation of complex data relationships. Furthermore, we point to the opportunity to use networking advances to support spectating. Examples include the live internet cooking streams on Twitch and Mukbang, which involves watching other people eat [4].

4.3.3 Food sharing to facilitate discussions around ownership of data

Sharing (or declining to share) food can be used by designers to facilitate discussions around the ownership of data. While digital content can be kept and shared easily after use, food can no longer be shared once it has been consumed. Sharing food means giving something (data) that we cannot retain to someone else, which puts a heightened focus on data ownership [66].

The number of people drawn to the TastyBeats exhibition showed the appeal of getting a drink, especially on a hot day. Interestingly, participants reported that they did not wish to share their drink as much as expected, and not just because it was a drink, given that drinks are shared less often than food. Participants said that they were hesitant to share due to a perception that their drink “was theirs”, as they had “made it”.

EdiPulse study participants reported that their entire households participated enthusiastically in the chocolate preparation, printing, and consumption because the chocolate was appealing. This experience was quite different from participants' experiences with using physical activity tracking systems in the past, including step counters and mobile tracking apps. Their family members did not “flock” to the screen in the same way that they flocked to the chocolate system. EdiPulse participants' unwillingness to share data representations was even greater than in the TastyBeats study. Participants were reluctant to share their chocolate delight – even with their children – because they had invested physical effort and “earned it”. The families discussed where the data came from, who “produced” it, and consequently, who owned it.

The Cyber Wagashi work used weather rather than personal data. The fact that the weather data comes from Tokyo will make eating the wagashi in Tokyo a more personal experience than eating it in, for example, New York (acknowledging that the appeal of many “foreign” restaurants is the diversity in food they offer, for example outside Japan: “Let's go to a Japanese restaurant as I feel like eating Japanese”). However, as the experience does not appear to facilitate the same appealing personal loop between data production and consumption (compared with TastyBeats and EdiPulse), the result might not be the same kind of discussions around ownership of data.

4.4 Theme 3: Food ephemerality for data as delight

This theme highlights the temporality aspects of data as delight.

4.4.1 Food temperature to time engagement with data

Knowing that many dishes are most delightful when eaten at a certain temperature, designers can enhance experiences by timing engagements with data. This capacity to time engagements differentiates data as delight from traditional digital data representations, which often involve more sporadic engagement. For example, we could represent data by modifying the interactive ice cream that plays sound with each bite or lick [115]: sound clips could represent the volume of glaciers melting due to global warming. Because ice cream melts over time,

designers can ensure that eaters engage with the data immediately when served, and continue their engagement until complete (not taking breaks, as participants can with digital representations).

The TastyBeats drinks lend themselves to drinking immediately after the mixing action, while the drink is still cold. The study participants did not want to drink a warm drink, especially after exercise, and although we did not use carbonated water, the mixing action probably added air to the resulting drink that, over time, would have dissipated, resulting in a flat drink. Adding carbonated water could have strengthened this effect further. These features complemented the intention of the system: to engage people with the physical activity data from their performances on that particular day (rather than, for example, a month earlier).

The EdiPulse system also engaged with the ephemerality of food, however, here, participants had to wait for the chocolate to cool before eating it. The wait afforded them moments of “idle” time, during which they could engage with the data as a way to “kill” time. As such, we highlight that the ephemerality of food can be used to time the engagement with the data, both to drive engagement, but also use data engagement as idle time killer.

In hindsight, we believe that our designs could have made even more use of the ephemerality of food to support data engagement, however, we leave this for future work.

4.4.2 Impermanence of food to convey time in data

Designers can use the impermanence of food to convey temporality in data. Most foods have a limited shelf life, and packaged food often has a “best before” date. After a while, food goes bad and can begin to change color and shape. Designers can use these temporal/physical qualities to communicate how data changes over time, without the need for complex interactivity. For example, bread could communicate how social media posts can become quickly “stale” or unimpactful (inspired by the QR code on cookies [1, 103]). Furthermore, we could use old food to elicit strong visceral reactions to data, complementing prior work in this area [12]. As such, we highlight that our approach can be seen as an ephemeral interface [27]. We note that the EdiPulse chocolate exposed to the air after 3D printing developed “bloom”, i.e. crystalline fats that melted and rose to the top. Although safe to eat, our participants felt uncomfortable doing so, hindering full data engagement.

4.4.3 Satiation and satiety to indicate the conclusion of data engagement

Satiation is the process that causes one to stop eating while satiety is the feeling of fullness that persists after eating, suppressing further consumption [10]. We believe that designers can use satiation and satiety to indicate the conclusion of data engagement. Furthermore, food intake usually occurs at specific mealtimes; commonly, three times a day. These characteristics pose challenges but also offer opportunities for designers creating data as delight experiences. For example, designers cannot “overfeed” people with data (while virtual data can lead to mental “overload”, food leads to physical fullness) but they can ensure that users will engage with the data at least three times a day, at regular intervals (assuming a regular meal day).

For example, once TastyBeats participants had quenched their thirst, they reached a natural conclusion to their engagement with the data. Any future desire to engage with the data and drink more would call for additional physical activity.

While the EdiPulse chocolate and the Cyber Wagashi were small confectionaries and probably did not satiate eaters, they might still satiate between mealtimes. EdiPulse participants appeared to regard the final eating of the data as an endpoint to their discussion and reflection, readying themselves for the next interval of effort and activity tracking. This response aligns with prior work, which highlighted that participants viewed eating as a

sign that they could “let go” of their data. Wang et al. reported one participant saying: *“Eating my academic record [the data represented] means that I have accepted, understood, and digested the results. I have turned the past into nutrition for the future, and now I can let it go”* [119].

Again, we compare this experience to traditional data representation experiences on screens, which generally do not indicate to users how and when to conclude any data engagement.

4.5 Theme 4: Emotional response to food for data as delight

This theme is concerned with the emotional aspects of data as delight, highlighting food’s strong affective affinity. Eating is much more than just the consumption of calories; it “constitutes some of life’s most enjoyable experiences” [20]. In consequence, we argue that designers can make use of the “pure pleasure” eating brings and tap into the emotional aspects of the eating experience.

Prior interaction design investigations have already suggested that we pay greater attention to how people “feel” about bodily experiences [90]. Research points to the “1st person” [40, 72] perspective as an approach to the “felt” human body that complements the material perspective (which regards food as calorie carrier) [107]. Engaging with data through food helps us to consider the 1st person perspective, and to facilitate a more personal, affective “felt” experience with the data (emphasizing objective, rational, and material perspectives). We believe that designers are well-advised to consider data as delight as a way to engage people with data in a personal, “felt” way.

4.5.1 Food predilection as personalization to facilitate emotional affinity with data

Food preference predates language and our food predilections become a significant part of our persona: “who we are is what we eat”. We are only just beginning to understand what factors - such as genes, and culture - influence our food predilections. However, we do know that our predilections are associated with strong emotional responses [30]. We, therefore, highlight that designers can personalize food based on a user’s food predilection to facilitate strong emotional responses to data.

For example, because all of our EdiPulse participants liked chocolate, it was easy to engage them with the data. Participants expressed enthusiastically how they liked the chocolate representations better than most of their prior activity tracker representations on screens because the chocolate provided emotional pleasure. By personalizing the chocolate taste, we could have targeted specific members of a household. Engagement with the physical activity data in a family household could focus on the adults, rather than the children, if, for example, we used chili chocolate (we assumed that children do not like chili chocolate). Indeed, we selected chocolate over other food (marzipan is equally suitable for 3D-printing) precisely because we wanted to elicit a strong emotional response to the notion of “energy-in, energy-out” in regard to physical activity tracking and personalized food consumption. Here, we offer an anecdote. A national TV news program decided to record a segment about our research. The use of chocolate seemed to become a central feature of the segment. While the reporter became excited about the chocolate, an external nutritionist suggested that a virtual reward should replace the chocolate as a reward for exercise. In this way, our work seemed to have achieved its goal: to spark a discussion about quantified self’s tracking agenda and what this means for personalized food.

We also acknowledge that personalization for data as delight is critical to avoid allergic reactions. To keep eaters safe, designers should consider participants’ food predilections and their food allergies. Designers can

learn from chefs how to communicate allergen information. For our studies, we provided participants with a printed “menu” that listed all ingredients.

4.5.2 Eating's intimacy to facilitate engagement with personal data

Eating is an intimate experience, and not just because we have predilections for certain foods. Before we put something in our mouth, we need to trust that the items will not, for example (and as a minimum), be dangerous or poisonous. We contend that the intimacy of eating experiences indicates the potential value to be gained from engagement with personal data.

The “Death by Chocolate” example [5] does this work chillingly well. “Death by Chocolate” represents the most common causes of death (such as cancer and cardiovascular disease) using miniature chocolate caskets that come with five different fillings. The diner is encouraged to “choose a praline and find out which type of death you picked!” [5].

With TastyBeats, we initially discussed using alternative data from external, non-personal sources; for example, representing data from the stock market. This alternative would allow participants to experience what the stock market “tastes” like. However, participants’ extent of control over the data is very limited if non-existent in this context. In contrast, being able to “taste” the result of their physical activity appeared to help facilitate a deeper understanding and appreciation of participants’ ability to influence the next day’s data: participants said that it motivated them to exercise more.

The use of personal physical activity data in EdiPulse appeared to align well with the intimate eating action of chocolate. Participants applauded how the personal character of eating matched the personal data, where the calories-out from the physical activity closed a loop with the calories-in from the eating.

Cyber Wagashi does not use personal physical activity data. However, as wagashi is culturally deeply related to the four seasons in Japan, Cyber Wagashi aims to connect with the eater’s personal experience of the seasons in Tokyo (assuming the eater has been to Tokyo).

4.5.3 Playing with food to facilitate data exploration

The ability to play with data can facilitate engagement [37]; in particular, playing with data can support data exploration [69]. Prior work has already highlighted the potential of food to support playful experiences [15, 16], for example, by making eating challenging and reducing autonomy over the eating process [84]. We contrast this feature with screen-based data visualizations, which can too easily “feel like work”. In contrast, prior work notes that consuming data in the form of food often feels more “like play” [23] as the notion of how people “feel” about the data plays a much more heightened role. We extend this prior work by proposing that designers can use food’s playful potential to facilitate data exploration. Playful food might be particularly appealing to children, facilitating a pathway to get them excited about data exploration.

We considered the TastyBeats system drink mixing to be playful. Participants laughed a lot at the system’s frequent spilling. We also point to “food fights” that children can have in kitchens. The associated mess and spilling allow for serendipitous playfulness to occur that can support people in getting engaged with the data. Even if such spilling does not occur, participants know that they could, which contributes to the experience’s appeal. Again, we contrast these qualities with digital data representations, which offer no opportunity for spilling. In this regard, we recommend that designers consider exploiting the opportunity to facilitate data exploration through playful engagement with food.

However, when talking about data as delight through play, we also need to point out any negative potential. For example, playing with food is only considered appropriate in particular contexts. Additionally, designers should consider how different utensils might afford different kinds of play with food, and how eating with one's hands might be accepted and very playful in one cultural context but frowned upon in others.

5 LIMITATIONS AND FUTURE WORK

While our work highlights the positive results of experiencing data as delight, we acknowledge that data as delight could also deliver negative outcomes: distracting us from our eating activity (which has been warned against by mindful eating researchers and thinkers [64, 87]); possibly wasting food; leading us to perceive food as less valuable; and encouraging cultural insensitivity (as previously identified [84]). How to design future systems that minimize the potential for such negative outcomes to occur form important parts of future work.

We do not think that data as delight is the ultimate solution to a richer engagement with data and a more refined appreciation of food. However, data as delight makes a contribution to HCI in the form of knowledge that interaction designers and data experts, as well as culinary practitioners, can use to take a fresh approach to food and data and to explore what food and interactive technology can learn from one another. Future work needs to build a deeper understanding of the design space for data as delight, as has been done for the visual channels for data communication by the visualization research community [86].

More broadly, we agree with prior work that we face global issues arising from society's misaligned relationship with food, ranging from obesity to eating disorders [84, 94], and that we need to re-examine our engagement with food "from every angle" [84].

We acknowledge that our work has all the limitations common to design research [32]. We touch only lightly upon long-term engagement, and we have only scratched the surface of data as delight opportunities and issues. For example, we could explore how we might convey data through other food characteristics such as texture and sensation in the mouth, and how our eating behaviors can be shaped by contextual elements [29], such as background music [105]. We also touched only lightly upon the rich cultural aspects of food and how they might relate to data as delight. For example, what are the design considerations when people are fasting for religious reasons and may have less access to data? Also, we have not yet discussed how people with bodies beyond the "norm" can benefit from data as delight, or be disadvantaged. For example, while people with vision impairment might benefit from the tactility of data as delight, people with poor olfactory sense might be limited in their experience. Despite the challenges data as delight research needs to address, the notion of using food to bring data to people holds great potential. Most importantly, we think, data as delight can conceivably reach everyone, because everybody eats.

Furthermore, we also only examined a small set of example systems. Adding additional examples would allow for a wider understanding and designing more systems could facilitate enabling the testing of some of the derived insights. Furthermore, we limited ourselves to eating activities, leaving other food aspects such as "growing" or "cooking" food [24] and their potential to convey data for others to explore in the future.

We also acknowledge that our approach is not the only way to make data delightful. Nevertheless, we believe our approach presents an interesting and intriguing way forward that is easily implementable, allowing for immediate engagement with design explorations.

During our design explorations, we identified opportunities to engage with data as delight beyond the immediate eating action; we consume, digest, and then excrete what we eat. In particular, we point to the

opportunity to engage people with the data in the hours *after* they consume it. Following the work of Li et al. [60, 61], who use ingestible sensors as a way to engage people with their digestive system, we imagine using digestion to facilitate people's engagement with data after it is consumed.

We also acknowledge that we have not yet collected quantitative evidence for health, social interactions and wellbeing benefits nor behavior change in terms of eating. Such evidence could be collected in the future through questionnaires and sensor data. Furthermore, studying if changing eating behavior is easier with our approach than non-food approaches is also an interesting avenue for future work. We also acknowledge that data as delight could also be misleading, for example when it suggests that "enough" physical activity was performed, and the food is perceived as a reward. Designers should be aware of such potential for data as delight to be misleading.

Furthermore, we acknowledge that the data as delight approach comes from a privileged perspective, where eating is much more than preventing starvation. As such, we highlight that our work complements, rather than replaces, existing data representation approaches.

Finally, we acknowledge that our systems do not yet, themselves, sense the food consumed. Hence one can argue that users might not have to eat the food and hence engage with all the data after all. Future systems that sense eating actions (such as previously proposed [115]) might help in this regard. Nevertheless, we believe that with our work from a perspective of design research, we can begin contributing a more structured understanding of the design of data as delight.

6 CONCLUSIONS

Interaction designers have increasingly embraced new forms to engage people with data beyond the screen. As part of the more embodied forms of data representations, we have proposed the use of food as a promising direction as it can facilitate experiencing data as delight. For us, data as delight describes engagement with data as a multisensorial affective experience. However, so far, there is only limited design knowledge available on how to design data as a delight. To change this, in this article, we have presented a set of themes and associated design insights for the design of future data as delight experiences based on designing, exhibiting and studying a set of data as delight examples and related work. With our work, we aim to facilitate the benefits that working with food can bring, including pleasure, health benefits, social interactions and overall wellbeing, while paying more attention to the role of affect and emotion in data engagement. Our goal is that with our work, we are advancing the field by painting a fuller picture of how to design systems that allow experiencing data as delight.

We expect that our work can encourage interaction designers to consider the characteristics of food and eating practices in their understanding of how to engage people with data. Furthermore, we anticipate that interaction designers and data experts consider eating practices as a way to facilitate engagement with data, as well as food designers and chefs offer their skills to the community to help them understand data through food.

Overall, we hope that our research will result in more opportunities to experience data as delight. Ultimately, with our work, we aim to expand the scope of how design can engage people by serving data as delight.

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