EdiPulse: Investigating a Playful Approach to Self-monitoring through 3D Printed Chocolate Treats

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ABSTRACT

Self-monitoring offers benefits in facilitating awareness about physical exercise, but such data-centric activity may not always lead to an enjoyable experience. We introduce *EdiPulse* a novel system that creates *activity treats* to offer playful reflections on everyday physical activity through the appealing medium of chocolate. *EdiPulse* translates self-monitored data from physical activity into small 3D printed chocolate treats. These treats (< 20 grams of chocolate in total) embody four forms: *Graph*, *Flower*, *Slogan* and *Emoji*. We deployed our system across 7 households and studied its use with 13 participants for 2 weeks per household. The field study revealed positive aspects of our approach along with some open challenges, which we disseminate across five themes: *Reflection*, *Positivity*, *Determination*, *Affection*, and *Co-experience*. We conclude by highlighting key implications of our work for future playful food-based technology design in supporting the experience of being physically active.

Author Keywords

Physical activity; chocolate printing; self-monitoring; food printing; quantified self; human food interactions.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

The growing popularity of self-monitoring devices [56,62] is contributing to a wider availability of previously inaccessible physical activity data, such as an individual's heart rate, but we know only little about how, and for what purposes, this data could and should be used. Currently, this data is mainly used to increase awareness about an individual's physical activity levels and to support motivation for increasing physical activity. Moreover, numbers and graphs are predominantly used to visualize this data [18]. To this end, an active lifestyle is perceived as a eudaimonic pursuit [63] where the emphasis is on improving athletic performance through rational self-analysis. However, multiple recent studies [23,24,73,85] report that the use of numbers and graphs might only offer a limited view on the rich experience of being physically active. Quantification might be useful in bringing awareness to exercise, but this "*number crunching*" activity may not always lead to an enjoyable experience [23,25]. Hassenzahl et al. [37] raise concern that in the long run, numbers could make exercise feel like work, and we need better, richer ways to represent this data. We agree with these notions and wonder if we could make self-monitoring a more playful experience that embraces the rich qualities of living an active lifestyle. For instance, instead of "*boring users to death with numbers*" [36], we ask, what if we turn this data into something more delightful like chocolate?

We present *EdiPulse* that translates physical activity data into 3D printed *activity treats* (Figure 1). These treats are created from 20 grams of dark chocolate and embody four forms: *Graph*, *Flower*, *Slogan* and *Emoji*. This quantity remains the same irrespective of the amount of physical activity done by the user. Instead, their representations become more gratifying with more physical activity.

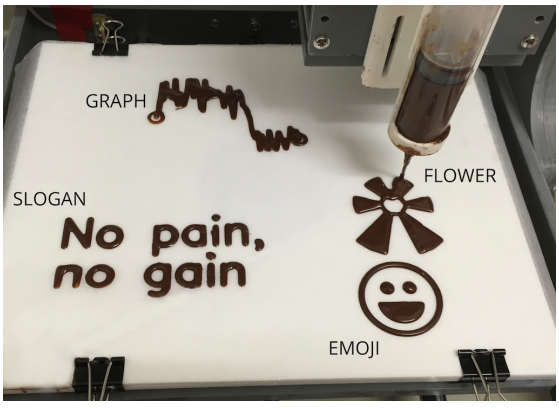

Figure 1: ***Activity treats come in*** **four different forms:** ***Graph, Flower, Slogan*** **and** ***Emoji.***

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Our interest in chocolate stems from its rich multisensorial appeal and ability to bring sheer pleasure from its moderate consumption [15,55]. Besides, studies also report that eating moderate amounts of dark chocolate daily is good for cardiovascular health [1], for improving cognitive abilities [21] and helping in post-exercise recovery [2]. We aim to capitalize on these aspects to offer vivid ways of engaging with one's data. We also choose emerging 3D food printing technology [84] to alter the shape of chocolate in unique and creative ways based on digital data. Printing chocolate also creates a sweet aroma of warm chocolate that further adds to the evocative experience. However, we are also aware that chocolate is a calorie laden food and its over consumption could cause weight gain, although research findings on this topic are inconclusive [27]. As such, we do not advocate eating chocolate or its usefulness to health, but rather use it to unfold a playful approach to self-monitoring.

We conducted in-the-wild field deployments [72] of the *EdiPulse* system across 7 households and studied its use with 13 participants for 2 weeks per household. We found that despite any negative connotations that chocolate might carry in relation to physical activity, participants did not find *activity treats* as counterproductive to their fitness goals. Rather, these treats brought positivity and determination towards leading an active lifestyle.

This research makes the following contributions: 1) By presenting *EdiPulse*, we introduce HCI to the opportunity of combining self-monitoring with playful food based technology design to embrace the rich qualities of living an active lifestyle. 2) We contribute first conceptual design understanding of the interrelationship between physical activity and chocolate by presenting a descriptive account on the design and adaptation of the *EdiPulse* system. 3) Finally, we offer 4 key implications of our work to guide future explorations in creating playful self-monitoring systems with food.

RELATED WORK

Identifying different ways to represent data has always been an area of interest within HCI. The majority of the existing works however is centered on on-screen visualization techniques. Few works have looked into abstract form of visualizations using metaphors of a garden [19], informative art [26] and aquatic ecosystem [51]. For example, in the *Fish'n'Steps* system [51], an individual's step count is mapped to an animated fish, which becomes happy or sad based on the number of steps taken by the user. Systems like *Health Mashup* [8] and *Habito* [32] provide textual feedback on self-monitored data, whereas prior works have also explored gamification techniques [9, 90] to make physical activity playful. For example, *Heart Burn* [91] is a digital car racing game where the real-time heart rate data influence the car's speed in the game, while Walsh and Golback [87] have converted user's steps to a currency that can be spent within an online explorer game.

Recently there has also been an interest in incorporating other senses such as touch, sound and taste to increase the effectiveness of feedback [66]. To this end, areas like data physicalization [40], data sonification [6,65] and data edibilization [88] have emerged. We previously designed and studied 3D printed representations of physical activity data [45,83] while Lee et al. [49] created a *Patina Engraving System* that represents physical activity data through engraved patina like patterns on a wristband. We situate our work in the area of *data edibilization* [88], which considers the positive psychological effects of food to offer rich multisensory experiences of narrating an interesting story with edible data.

Food has a rich cultural and social history. Its preparation and consumption provides opportunities for bonding and interaction among individuals [15,55]. French gastronome Brillat-Savarin [12] notes that pleasures associated with eating and drinking constitute some of the life's most enjoyable experiences. Drawing on this, several works within HCI have started exploring food as a celebratory technology [33]. Resner introduced the concept of Edible User Interface (EUI) that utilize the multi-sensory experience of food to create novel interfaces such as *TasteScreen*, where users interact with a system by licking liquid residue of different flavors that driped onto the LCD screen [57]. Murer et al. [59] designed *LOLLio*, a gustatory interface for playing games. *Qkies* [71] is a system that embeds QR codes on cookies, while *Meta Cookie* [64] is an augmented reality based system that controls nutritional intake by changing the perceived size of the food through a head-mounted display. *Chocolate Machine* [43] is another interesting system that dispenses a chocolate at scheduled intervals to improve user's self-control. These works have explored the playful side of food based interactions [17,81], but not necessarily in relationship with an active lifestyle, which we consider as a missed opportunity.

Food shares an interesting relationship with physical activity. We exercise to expend energy and we need food to replenish the loss of energy. The relation also works the other way around where we exercise to burn the calories gained from consuming too much food. With today's sensing technologies, if we can now measure how much exercise we have done, then what would happen if we relate this to the kind of food we eat? Khot et al. [46] worked on this idea to design *TastyBeats* that provides users with personalized sports drinks, where the quantity and flavor is based on the amount of exercise a user has done in a day. The accompanying study highlighted that having an engaging process and consumable material contributed a playful experience while offering benefits in terms of facilitating social interactions and self-expression. We take this concept forward and look beyond liquids to translate data into food. However, instead of making direct mappings between energy spent and food [47], we chose to use a more artistic rendering of the data in a food material with which most share an affective relationship: *chocolate!*

EDIPULSE

EdiPulse stands for Edible Pulse. *EdiPulse* translates heart rate data into 3D printed chocolate treats (Figure 2). We refer to these 3D printed chocolates as *activity treats*, as they come in a moderate amount and offer a unique playful representation of one's physical activity data.

EdiPulse uses a Polar heart rate monitor [69] and its accompanying smartphone app to record heart rate data. The *EdiPulse* application downloads heart rate data from the Polar web site and then parses this XML data to identify heart rate zones within the recorded data. The application takes an average of every 10 minutes of recorded heart rate data. If this value is above 65% percent of the maximum heart rate, the application considers those 10 minutes as active time, in accordance with The American College of Sports Medicine [3] guidelines. The system then uses this information to algorithmically construct the four *activity treats* using *OpenJSCAD* [68] software. We discuss the rationale behind these choices in the next section.

***Flower*:** (Max. size (mm): 60 × 60 × 2. Avg. print time: 3 min.) *Flower* provides a summary of physical activity across each hour of recording. Each petal of the *Flower* corresponds to an hour and its length denotes the amount of physical activity in that particular hour. The *Flower* does not explicitly indicate the starting hour, as we wanted the *Flower* to be ambiguous [31], allowing participants to identify the starting hour on their own.

***Slogan*:** (Max. size (mm): 160 × 120 × 2. Avg. print time: 5 min.) *Slogan* makes a cheerful comment about physical activity done by the user in a day. For example, if the user has been inactive during the day, then the *Slogan* will contain motivating words that communicate the benefits of an active lifestyle as shown in Figure 2.c and 2.d. On the other hand, if the user has been active, then the *Slogan* will offer praise through gratifying words; an example can be seen in Figure 2.a and 2.b.

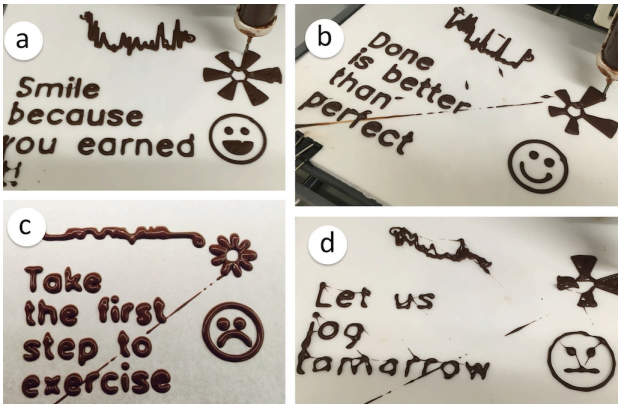

Figure 2: Participants received a different *Slogan* each day based on their activity.

***Emoji*:** (Max. size (mm): 40 × 40 × 2. Avg. print time: 2 min.) *Emoji* communicates an individual's progress towards a self-selected activity goal through an emoticon.

At the start of the day, users can enter their physical activity goal for the day into the *EdiPulse* application. This goal is a chosen duration for doing moderate to high level of physical activity and it could span over the day. The *Emoji* bears one of four faces: *sad face*, *straight face*, *happy face* and *super happy face* based on how close one gets to the set goal. For example, achieving and exceeding the goal respectively results in a *happy* and *super happy Emoji*, while failing to meet the goal results in a *sad* or *straight face Emoji* as shown in Table 1.

Time spent exercising (in relation to the set activity goal)	0 – 50 %	51 – 99%	100%	>100%
Received *Emoji*	☹	😐	☺	😀

Table 1: In *Emoji*, an individual's progress towards their activity goal is communicated through different emoticons.

Graph: (Max. size (mm): 180 × 60 × 2. Avg. print time: 3 min.) *Graph* shows recorded heart rate values over time. We map the recorded heartbeat per minute to a point in XY space and then extrude the resultant 2D shape along the z-axis to achieve a suitable thickness of 2 mm.

DESIGN PROCESS

The final designs of the *activity treats* were the results of many explorations, developments and printing trials that spanned over a year. We held five focus group discussions with experts of different academic backgrounds from a local research community to help us in refining our design choices and to gather diverse perspectives on the relationship between food and physical activity. Due to the space limitation, we only discuss the key design decisions.

Choosing the process (Why food printing?)

When we started this work, the first thing we explored was the process to create *activity treats*. Wang et al. [88] suggested that there are three ways to encode data in food: 1) *Food based approach*, where the existing process of creating food is slightly altered but keeping the recipes and the look of the food intact. For example, artworks like data-cuisine [41] fall into this category, where different foods are arranged in a particular manner to signify a certain data insight. 2) *Data-driven approach*, which takes the liberty of experimenting with the recipes and allows new forms of food to emerge as a result. Here, the focus is on the data and no so much on the food. 3) *Hybrid approach* where both approaches are combined to reinvent traditional dishes with new ingredients or methods. We follow the third approach to create *activity treats* using food printing.

We choose food *printing* [84] (instead of any traditional methods of cooking) because it offers a way to connect digital information with food relatively easy. Food printing follows an additive manufacturing process where an object is created by placing the edible material (currently in the form of a paste, extruded using a syringe) layer by layer until the object, based on a 3D model, is fully formed.

Food printing has been used to create smooth easy-to-eat food for the elderly who have difficulty swallowing food [78] and also as a social food-based messaging system [89]. However, to the best of our knowledge, there has not been any exploration on using food printing to support the physical activity experience.

Choosing the material (Why chocolate?)

From the start, we were quite keen on using chocolate as a material to create *activity treats*, despite the negative connotation it can carry with it. We wanted a material that could add playfulness and intrigue to this idea of 'self-monitoring and then eating the data based on the sensed activity', hence chocolate was a suitable choice.

Choosing the amount (How much chocolate?)

We carefully choose not to map the exact amount of calories burnt during an exercise to the amount of printed chocolate, acknowledging the issues related with overconsumption of chocolate. We rather focused on making the treats more beautiful with an increase in the amount of physical activity. We also used dark chocolate and kept its quantity to a maximum of 20 grams a day.

Choosing the representations

We started by exploring the literature [18,20,30,52,63,90] and took into account findings from earlier studies [8,9,32,45,46,48,73] to identify possible representations for *activity treats*. The technical capabilities of current food printers [16] also influenced the selection. For example, current food printers cannot print tall structures easily. As a result, we restricted our design explorations to rather flat models. We also considered the printing time, chocolate amount, and the size of the print bed (20cm × 22cm) for print efficiency. We drew on Nicolson's [63] suggestion to provide a variety of representations to raise the chances that each participant can find something meaningful in the data. Drawing on goal-setting theory [52], we also allowed individuals to set their activity goals and used *activity treats* to display progress towards it.

The final selection was based on the design strategies suggested by Mols et al. [60] as follows: 1) *Information driven reflection:* This form of reflection represents data without any prescribed interpretation. We chose *Graph* and *Flower* to help people understand how their activities change over time and how they progressed towards their goals. Representations of this form have been studied in earlier works [19,45]. *2) Expression driven reflection:* This form of reflection adds a subtle interpretation of data using familiar metaphors and expressions. Metaphors are believed to be more engaging, motivating and easy to interpret [51]. Drawing inspiration from this, we chose *Emoji* to give users the ability to reflect and identify themselves in alter egos. *Emojis* have been previously studied in the literature [39,42,77]. *3) Dialogue driven reflection:* This form of reflection offers textual feedback on data. Textual feedback often comes in the form of a praise or positive encouragement. It is also less ambiguous and directs attention to important information [32]. Textual feedback has been explored in earlier research [8,32]. We chose *Slogan* to explicitly acknowledge an individual's exercise efforts and to cheer them towards their fitness goals. However, we kept *Slogan* short in length considering the size of the print bed (20cm × 22cm) and the amount of chocolate (20 grams) required to print.

Managing the printing process

We used a *ChocEdge* [16] 3D printer to print the *activity treats*. During the exploration, we found that chocolate, as a print material, requires care and attention in terms of printing. For a good quality print, the temperature of the tempered chocolate and room should be in the range of 25-32°C [50]. Extensive tempering of the chocolate results in watery prints (Figure 3.c), whereas air bubbles in the syringe also affect the quality of the print (Figure 3.d). We also explored different ways to simplify the printing process for our study participants. We tried attaching custom fans and cold plates to the printer so that the chocolate hardens quickly after printing. However, these alterations did not give consistent results. As a remedy, we gave participants a food thermometer for an accurate tempering of the chocolate and asked them to maintain the temperature of the room in the range of 25-32°C during printing.

Another challenge was the removal of the printed chocolate from the print bed. We tried printing chocolate onto different food materials such as bread and biscuits but the printing results were inconsistent. Hence, we used a flat acrylic sheet with a baking paper attached with bulldog clips as a print surface. The baking paper allowed easy removal of the cooled chocolate. Figure 3 provides the three-step preparation before printing *activity treats*.

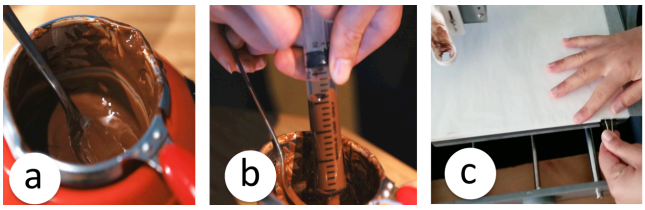

Figure 3: The chocolate printing preparation process: a) tempering b) filling syringe c) setting up the print bed.

Concealing digital display and ad-hoc printing method

We used *Printrun* [70] program, to drive the printer. Under normal settings, this program displays a 3D replica of the object currently being printed on the screen. However, we altered the program settings to conceal the digital display of the *activity treats*. Our intention was to keep the treats as a surprise so that they are revealed directly on the print bed in edible form.

We also orchestrated the printing to keep users engaged in the printing process. For example, *Slogan* was printed in an ad-hoc manner, where letters from different words (within a *Slogan*) were printed randomly. To elaborate, a word 'Sweat' would be printed progressively as: *_ _ _ _t → _ _e_t → _ _ eat → _weat → Sweat*.

EDIPULSE IN ACTION (FIELD STUDY)

We conducted an in-the-wild [72] study to understand the role of *activity treats* in supporting everyday physical activity. The study took place in 7 households across Melbourne, Australia. The recruitment followed a snowballing method. There was no financial compensation. Table 2 provides the demographic details of each household (H) of 13 participants (gender, age) along with their physical activity goal for each day of the study.

H1	Harry (M, 31, 30 min.)	Fiona (F, 27, 30 min.)
H2	Josh (M, 44, 30 min.)	Karen (F, 45, 45 min.)
H3	Adam (M, 27, 30 min.)	Helena (F, 28, 1 hour)
H4	Rohan (M, 32, 45 min.)	Diya (F, 28, 45 min.)
H5	Gavin (M, 27, 1 hour)	Daisy (F, 26, 45 min.)
H6	Jayden (M, 24, 45 min.)	Sarah (F, 28, 1 hour)
H7	Frank (M, 52, 45 min.)	

Table 2: Participants' details (names changed) along with their activity goal.

We decided to engage more than one person from the same household to understand social dynamics around the use of *EdiPulse*. Frank's roommate Kelly also wanted to participate in the study, but she had to cancel last minute. Since Frank was very enthusiastic about the study, we allowed him to be a solo participant. As we only had access to one printer, we proceeded with a sequential order of installing the *EdiPulse* system in different households. Overall, the deployments took more than 4 months.

The lead author visited each household on the first and last day of the study and spent around 4 hours in total in each household. On the first day, he explained the study procedure with a demonstration of how to use the system. He provided each participant with the necessary supplies along with an instructional manual. The initial meeting with participants was also used to gain an understanding of their active lifestyle. Study participants self-rated themselves as moderately active doing physical activity at least 2-3 times a week. None of the participants were obese and neither had a desire to change their behavior. However, they wanted to add consistency to their exercise routine. Ten participants had used self-monitoring devices but not for a long time. Nine participants were fond of chocolate.

Participants performed the following tasks on each day: **1) Morning Tasks:** Participants put on the heart rate monitor and started recording data using the Polar Beat app, installed on the iPod Touch. Once the recording started, participants continued their day as usual while carrying the iPod. **2) Evening Tasks:** Participants stopped the recording around 6pm. Their heart rate data then automatically synced to the Polar website. We downloaded the data from the website and prepared the 3D models of *activity treats* using the *EdiPulse* application. We then emailed the 3D models as a single print file (.gcode) to the participants. We kept the task of 3D modeling on our side to reduce participants' workload and to keep the *activity treats* as a surprise. After receiving the files, participants followed the steps outlined in Figure 3 to print their treats. The preparation took around 15 minutes while the printing took an average of 13 minutes.

Data source and analysis

Interviews were conducted at the participant's home on the last day of study and took about 45 minutes per participant. We kept the nature of the interviews semi-structured in order to leave sufficient room for topics to emerge, and to support a deeper elucidation of participants' responses and thinking processes. During each interview, we carried a list of questions (topic guide) related to the research aims that helped us to remain on track, while leaving sufficient flexibility in the discourse. The questions revolved around the motivations, expectations, utility and experiences of using *EdiPulse*. We also gathered participants' feedback on system design, use of chocolate and food printing to represent data. Additionally, we welcomed opportunities to discuss any photographs and recordings of their interactions with *EdiPulse* that participants voluntarily captured during the course of study. This additional data helped us to investigate how people reacted and integrated the *EdiPulse* into their everyday life.

All interviews were audio recorded. During the study, we also maintained contact with all study participants via email and phone, to provide technical support whenever needed. We utilized inductive thematic analysis [11] to analyze the collected data. We examined the interview notes to get an initial sense of recurring themes and then inductively coded the interview data by developing labels to describe the phenomena. After deriving the set of codes, we iteratively clustered related codes into higher-level groupings, representing the major themes as findings.

FINDINGS

The study identified five overarching themes: *Reflection, Positivity, Self-determination, Affection and Co-experience*.

Edible component of *activity treats* (chocolate) was a standout element across all themes and the majority of the findings. However, we also narrate findings related to the choice of representations as well as printing process, as they played an influential role in making *EdiPulse* a pleasurable experience. We use participants' quotes to exemplify the collected their experiences with *EdiPulse*.

T1: Reflection

Following reflective informatics [7], this theme describes how *activity treats* allowed participants to step back and think about their everyday life experiences. In particular, the use of chocolate, serendipity of representations and delayed feedback not only challenged individual's perception of their active life but also made the experience enjoyable.

EdiPulse facilitated reflection on physical activities

Participants used the *EdiPulse* system to reflect on their daily routines. For most participants, the study was an "eye-opener" of their level of physical fitness. Rohan reflected: "*It was a clash of realities, when I saw a sad Emoji, I felt, 'God dammit, is this me?' I have to do more exercise*." Adam similarly was sad to realize the kind of sedentary life he is living. He said with a sigh: "*When I was younger I had a very active lifestyle, these days I am more sedentary in comparison. I need to kick off my activities a bit more*."

Edible treats made feedback enjoyable

All participants felt that the edible component enriched the experience of reflecting on one's data. Harry compared his previous experience of a cycling app with *EdiPulse*: "*I used to check the distance and speed using an app. But my interaction with the app stopped there, it did not go any further. Now with EdiPulse, I got a chocolate printed 'Emoji', totally different than the numbers and much more pleasing to the heart. And who would say no to chocolate!*" Daisy added, "*It's unbelievable that EdiPulse not only tells you how much exercise you have done through different shapes, but you get to eat those shapes too.*"

Activity treats offered more time to reflect

Five participants liked the fact that *activity treats* are printed physically and not simply shown on the screen. Samantha pointed out, "*Today, we are bombarded with messages through Twitter and other social feeds and you get very used to not paying attention to them, if they are not meaningful for you. Here there was direct meaning in the writing, so you probably stop and look at them more*." Josh said: "*I like the way it uses the chocolate instead of digital screens to display data. It takes me away from the screens, where I spend most of my time due to work anyway.*"

Slogan added serendipity to the process of reflection

Participants compared the *EdiPulse* system to a *fortune cookie* where one is intrigued to know the message. Karen liked the way the system prints *Slogan*, "*I enjoyed the writing, getting a new motivational Slogan every day meant a lot to me." Josh added: "We kind of knew whether we will get a happy 'Emoji' or what will be the shape of the 'Graph' at the end of the day, but Slogan always offered something new*." Guessing the right *Slogan* was a challenging but exciting activity. Frank mentioned, "*I loved watching the Slogan getting printed. The system keeps on adding alphabets [letters], and like a small child, I keep on guessing it [laughing]*." Most participants found that *Slogan* had more appeal when the message was positive and reflected interesting things about their life.

Activity treats offered summary of the day at a glance

Six participants liked the selection of representations, which offered them a quick summary of their day. For Adam and Daisy, the *Graph* was essential to identify and reflect on their activities. Daisy said: "*I like how it really shows the ups and downs. It is really expressive. You look at it and you can recollect what happened during the day*." *Emoji* on the other hand, was treated like a report card. Helena was happy that "*In the evening, when I see a happy Emoji, I feel that I did a good job*." Gavin and Daisy liked how *Flower* petals effectively communicate sedentary and active hours by varying their length. Frank compared the *Flower* petals to sunrays, "When I do exercise, I feel like the sun is smiling for me and blessing me with longer rays (petals of the '*Flower*')."

T2: Positivity

This theme talks about the positive influence of *activity treats*. *Activity treats* became celebratory rewards to support individual's activity goals and the printing process created avenues for pleasure, creativity and nostalgia [33,35].

At first chocolate felt counterproductive

Six participants felt initially that chocolate can be counterproductive to their exercise efforts but as they used the system on a daily basis, they were surprised to see the positivity and fun that it brought to their exercise. Gavin explained how his perception towards chocolate changed over the course of the study: "*I was initially skeptical over the chocolate, but now I realized that exercise becomes more fun with chocolate and a little bit of chocolate does not harm anyone*". Sarah had similar thoughts: "*You normally think you should not have chocolate if you are doing exercise, but getting a moderate amount of chocolate was kind of good that it broke the barrier*."

Activity treats were considered as celebratory rewards

For nine participants, *activity treats* was a prize that they earned for being physically active. Fiona liked the use of chocolate as a celebratory reward for her efforts, she explained: "*Food is an important part of the celebration. We often reward ourselves by going to restaurants to celebrate, and what can be better than a chocolate to cherish my 40 minutes run*!"

The amount of chocolate felt appropriate

All participants appreciated receiving the same amount of chocolate every day irrespective of how active they were on each day. Helena commented: "*Having an edible reward is good, but you can really get cheeky with it like you burned 2000 calories and here is 2000 calories in return. But I like that the system is not tailored in that way*." Jayden similarly said: "*I kind of liked that it gave me a small reward or energy for the next day's exercise. It was not a lot but just enough to put a smile on my face and to keep me motivated to exercise*."

Thinner forms of chocolate supported guilt-free eating

Three participants found eating *activity treats* quite different to eating a solid block of chocolate because of the thin size (2mm in height). Interestingly, four participants felt that eating this way was more fun because it diminished their guilt of eating chocolate. Daisy said: *"It is because of this arrangement, so when you are eating it, you feel the flavor but you do not feel that you are eating a lot of chocolate, not in the way that will make you guilty or something."* (Figure 4.a)

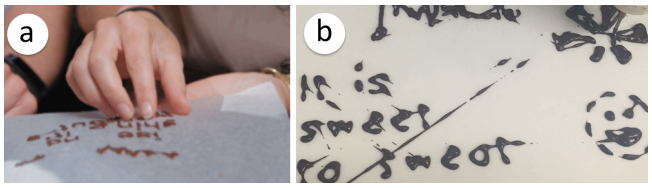

Figure 4: a) Thinner forms of chocolate were fun to eat. b) Participants did another round of print to get perfect treats.

Printer qualities made the experience evocative

Eleven participants found the printing sound quite pleasant. Besides the sound, they also enjoyed the sweet smell of the warm chocolate during the printing process. Frank, who sometimes did the printing during the morning, exemplified this best when he said: "*My roommate Kelly commented that it was the first time ever she woke up with the smell of chocolate, which she liked a lot. It gave both of us the motivation to start an active day with a smile*".

Printing new treats every day was exciting

Adam compared the printing process with chocolate molds and found that printing offers more excitement: "*There is an element of personality that comes through printing, and it is really good. You know that this chocolate is from my data and no one is getting the same data. As a motivational tool, if I had got the same mold as yesterday, I would already know what's coming, it's no longer a mystery*."

EdiPulse offered a sense of ownership on data

Despite the preprocessing and printing troubles, participants enjoyed printing their *activity treats* at home. Harry said: "*Printing at home is great, since it is edible, I like to eat it fresh at home, just after the printing*." Daisy added, "*When you print at home, you have the freedom of choosing the moment, when you want to print and feel rewarded*". Jayden added, "*The best part is there is no middle man who says here is your print, so I felt some sense of ownership*."

T3: Determination

This theme talks about motivational qualities offered by activity treats towards fulfilling activity goals of an individual. To participants, *activity treats* were not just a hedonistic gloss of chocolate. *Activity treats* also became the motivational anchors and fueled enthusiasm towards an active lifestyle. In pursuit, participants achieved their goals 76% of the time. Interestingly, *activity treats* also made participants more aware about their chocolate eating habits and they consumed activity treats only on active days.

Activity treats became motivational anchors

Besides the "feel-good" factor, nine participants found *activity treats* as a motivational anchor to achieve their desired goals. The *Emoji* was the favorite activity treat for all participants. Gavin emphasized: "*For me the Emoji was the strongest motivator, others were nice too but for me the Emoji was sufficient*." Karen similarly described her affection towards the chocolate-coated *Emoji* by saying: "*Receiving a smiling Emoji feels like someone liking your photo on Instagram. It's a nice encouraging thing for the day*." Frank was happy that he could also eat such *Emoji*.

All participants also wanted to avoid getting a sad face *Emoji*. In consequence, they tried to be more active. For example, Diya received a straight face *Emoji* for two subsequent days, which was disappointing for her. She said, "*Through the study I learned that you have to go an extra mile to get a happy smiling Emoji*."

Contextual Slogan encouraged more activity

When participants fell short of their desired goal, the *EdiPulse* system delivered *Slogan*s like "*The gym is waiting for you*". All participants liked such encouragements and reminders and often did more exercise the next day. Daisy said, "*The EdiPulse system really helped me to create a routine. Now I regularly go to the gym. I think I badly needed that kind of push. I am really happy that I got the kick now*". Josh changed his everyday routine by reflecting on the *activity treats*: "*Now, I walk more during the day. When I go out for lunch, I walk and take stairs.*"

EdiPulse served as an ambient reminder to be active

Participants felt that the presence of the system in their kitchen worked as a constant reminder to remain active. Sarah said: "*It is not easy to turn away from it if it is sitting on the kitchen bench printing delicious chocolate and reminding you to do exercise. A mobile app can be a bit of a fad: you use it for a while and then you don't.*" Diya similarly said, "*I feel like I am answerable to this machine. Even when I am outside, I kind of hear the printing sound and smell of chocolate that reminds me of my activity goal*." To this end, the physical presence of a food-printing system installed in the kitchen facilitated an ambient awareness and a responsibility to become physically active.

Activity treats were consumed only on deserving days

Interestingly, participants' eating behavior was influenced by the content of the treats. For example, five participants did not eat their *activity treats* on days when they received the sad face *Emoji*. Instead, they ate the chocolate only on days when they received happy or super happy *Emoji* to celebrate their success. Diya said, "*It was challenging at first not to eat the chocolate, but I was determined to achieve my goal on the next day, which I did*." It was interesting to see that participants engaged with the data even if they were not happy with their performance.

Activity treats were reprinted to get deserving treats

Print results were not always consistent. Sometimes because of the air bubbles in the syringe (Figure 4.b), the treats did not print as expected, which annoyed most of the participants. Jayden said: "*It was quite disappointing to see the prints becoming messy. If EdiPulse does not print it correctly, you feel like you haven't done the task properly*." Interestingly, most participants did another round of printing to get satisfactory and good looking treats. Diya said: "*Getting perfectly printed activity treats made me happy. Receiving messy prints felt like the system is angry on me and punishing me with bad prints*."

Activity treats reduced consumption of chocolate

All female study participants were fond of chocolate, but *EdiPulse* helped them in controlling their temptation. Daisy said: "*Although chocolate was so accessible, you also knew that every night you would have a bite of chocolate. And when I did not exercise, I knew from the system that my body did not ask me to eat more chocolate. So it really made me eat less chocolate than what I normally do*."

Delayed feedback prompted more activity during the day

The printing schedule was designed to deliver the *activity treats* at the end of the day. Participants appreciated such a delayed but fixed time of feedback to print their *activity treats*: "*The first thing I want to do after I am back from the office is to print my treats. I want to see if I have done enough to get a smiling Emoji, or a long petal Flower*." For Diya, the anticipation of the deserving treat kept her active throughout the day: "*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*."

T4: Affection

This theme describes participants' personal affection with *EdiPulse*, where *activity treats* were considered as objects of self-esteem and pride.

Activity treats were rarely shared but never wasted

Eleven participants never shared the *activity treats* with others. Helena said: "*It was a personal reward for what I have done. I would not give it to others since I did all the hard work. I know, it sounds really bad but I kept these treats to myself*." Jayden similarly commented, "*Food is generally shared, but once it has data elements to it, it becomes more personal*."

Sharing of *activity treats* only happened to prevent any wastage of chocolate. Samantha created chocolate bunnies from the leftover chocolate: "*I love chocolate, and I can not see someone wasting it. I will probably gift these bunnies to my friends*." At Karen and Josh's home their son mostly ate *activity treats* from Josh's data. Josh explained: "*I suppose, I am concerned over the wastage of syringes, plastics, and the paper, but it's good that the chocolate is never wasted. Even if I do not eat it, my son would eat it*."

Participants enjoyed the chocolate printing process

Participants particularly enjoyed standing next to the printer and guessing, "*what the printer is telling tonight*", as explained by Frank (Figure 5). Josh added: "*Because of the nature of the machine, you keep watching it doing the print. It is a much nicer process to see how it reveals my data as opposed to directly knowing what it is going to say*."

Three participants voluntarily took photographs of the printing process and affectionately shared them on different social media. For them, the experience of watching the print and taking photographs was nothing short of a thrill. Karen said with a smile, "*Taking photographs of the print raised my heart rate and in that way I am burning more calories, I wished I had the monitor on*".

Figure 5: Participants enjoyed the printing process.

Enthusiasm for EdiPulse persisted despite the printing labor

All participants found the preparation steps time consuming: "*Loading the syringe and setting up the printer was kind of labor work that one should do to get their activity treats*." Helena echoed similar concerns: "*The preparation needs to be faster and easier*." Harry pointed out that besides being time-consuming the process sometimes also caused a mess: "*Many times when I tempered the chocolate, I got chocolate all over my fingers, which by the way was not a bad thing (laughing)*." As such, eating was a part of engaging with the printing process.

Getting activity treats was dearly missed (post-study)

The first author met Gavin ten days after the end of the study. Gavin said how much he misses the system: "*I was so habitual to the system that gave me sweet rewards for my exercise - now I miss all that. There is no reward waiting for me in the evenings now. The other day I had a very active day and I was really missing my sweet treats, so I created some treats for myself and Fiona from the leftover chocolate*." (Figure 6.a) Adam felt the absence of *EdiPulse* in his home.

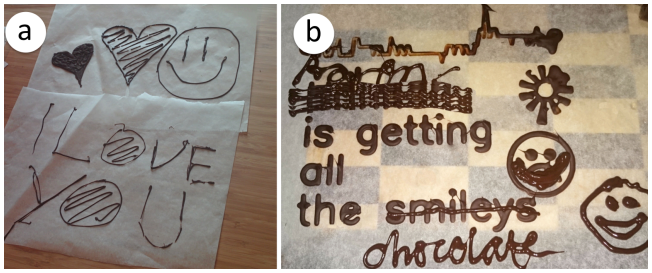

Figure 6: a) Gavin manually created *activity treats* to reward himself, mimicking the *EdiPulse* system. b) Adam altered Helena's *Slogan* to show a playful side.

Diversity in food materials was desired

Although all participants appreciated the use of chocolate to create *activity treats*, they also wished for more food diversity. Fiona said: "*We eat a variety of food on a daily basis. This is a particular device that prints only chocolate. But I am sure in 10-20 years, I could see every food being 3D printed*." Four participants on the other hand wanted to print with healthier foods like protein powder to closely tie *EdiPulse* with their exercise nutrition routine.

T5: Co-experience

The final theme describes the social qualities of *activity treats*, facilitated by the co-experience [29] of printing treats with family members.

Activity treats drove healthy competition

The system also encouraged healthy competition between four couples. Gavin and Daisy competed with each other in terms of who would get a super happy *Emoji*. Helena also mentioned: "*I loved when Adam got the printed 'Slogan' as 'Helena is getting all the happy 'Emoji*'. *I liked how it reflects my competence*". Her partner, Adam, who was less active than Helena took this fact sportingly and manually wrote the following message on top of Helena's *Slogan*: "*Adam is getting all the chocolate*" (Refer to Figure 6.b).

Printing activity treats brought participants together

All participants enjoyed preparing *activity treats* together. Rohan compared printing *activity treats* with cooking and enjoyed doing it together with Diya. He said: "*It was like cooking but with more fun because we also get to talk about what treats we will get and then compare our treats*." Participants also encouraged each other to achieve their fitness goals and showed keen interest in each other's data. Jayden said: "*Normally, I would not have looked at Sarah's data if it was only on a mobile, but now it is printing right in front of me. I felt intrigued to know more about how her day went.*"

Families provided social push to exercise

The public visibility of *EdiPulse* and sweet aroma of hot chocolate being printed grabbed attention of non-participating family members. Frank said, "*As I woke up, the first thing my friend Kelly reminded me was to do exercise and monitor myself. I guess, she just wanted to start her day with the pleasant smell of my activity treats.*" In Karen and Josh's case, the reaction of their son was equally inspiring and acted as a push for them to do more exercise. Karen voiced: "*I knew that our son would certainly look at them (the smiley) and compare why is yours a smiley and why is dad's a sad face. I want daddy to get a happy face, so I think it could be quite persuasive*".

IMPLICATIONS FOR DESIGN

Based on the study insights, we draw designers' attention to following design implications [75] that could help in building playful food based designs for supporting the experience of being physically active.

Delayed Feedback & Anticipatory Savoring

In our study, we found that participants appreciated getting the feedback on their daily activity level at the end of the day. Having to wait for their *activity treats* moderated participants' consumption of chocolate throughout the day. Rather than eating any chocolate at any time, participants valued getting the *activity treats*, which were personalized to their activity levels. Since there was no feedback on whether the participant had achieved their activity goal for the day until evening, the delayed feedback also added a surprise element to what the *activity treats* were going to be. This uncertainty in predicting whether they have done enough activity to get a super happy *Emoji*, fuelled interest in doing *opportunistic* physical activity [18].

The appreciation to delayed feedback can be explained in terms of the *Anticipatory Savoring* [53], where an individual psychologically looks forward to a positive experience. In this case, the positive experience was to enjoy well-deserved chocolate treats. Getting the feedback at the end of the day not only moderated participant's cravings for chocolate but also pushed them to be more active throughout the day. Moderation of chocolate eating habit was a surprise finding to us because unlike a meal, chocolate is usually not eaten in a fixed pattern. Rather it is munched at any time of the day. Similar results were found in earlier studies where anticipatory savoring reduced overall consumption of chocolate [10, 44, 61]. Since in *EdiPulse* chocolate was closely linked to one's active life, it subconsciously affected participants' eating choices. We therefore encourage designers to create opportunities for anticipatory savoring by utilizing appealing materials and keeping them as surprise through the use of delayed feedback. The importance of delayed feedback is also iterated in earlier works on slow design [34,62,67].

Visual Appeal

The study highlighted that the visual aspect of the *activity treats* was very crucial in contributing a positive experience. We found that participants wanted appealing and perfectly printed *activity treats* and in this pursuit, they were happy to perform multiple prints if the initial print was not as good as expected. We also found that irrespective of their activity levels, participants were motivated to print their activity routines daily. To this end, receiving *activity treats* printed in chocolate offered moments of mastery experience supporting individual's self-efficacy [5,86].

Our study also highlights the importance of an appealing medium to represent data, because participants found the sight of a beautifully printed chocolate difficult to ignore [22,80]. As such, we found that the visual aspect of the treats had significant impact on the overall experience to the extent that even negative feedback served as motivation. For example, we found that participants were not discouraged by seeing the *sad Emoji* on sedentary days, rather it served as an inspirational goal to do more exercise to achieve a *super happy Emoji*. This finding contrasts with the findings of prior study on Fish'n'Steps system [51] where the negative framing of the on-screen feedback led to reduced interest in data.

In line with earlier studies [45,48], participants also preferred intuitiveness with a possibility of quickly gaining insights into their activities in comparison to exploring graphical data that require numerical literacy and interpretive abilities. For example, we found that the *Emoji* and *Slogan* had more appeal than the *Graph* and *Flower*. We thus encourage designers to consider the visual appeal of the *activity treats* for both active and sedentary days

while keeping the representations easy to interpret. Finally, in this work, we only looked into altering the visual forms of *activity treats*, but other features such as flavor aroma [22] and texture [79,81] could also be explored to make *activity treats* pleasurable.

Printing process & Savoring

We found that participants cherished the printing process as much as the consumption afterwards, unlike our earlier study, where the process of 3D printing plastic artifacts received lesser appreciation [45]. All participants enjoyed the printing sound of the printer. The sight and smell of the chocolate being slowly overlaid on the print bed further added to the sensorial experience. The ad-hoc printing of the treats also glued participants to the printing site, as they treated it as a game of guessing the right word. Interestingly, this activity also gave participants an opportunity to reflect on each other's activity levels for that day. Although the preparation in terms of getting the chocolate ready for printing was felt to be laborious, participants' interests in printing sustained throughout the study. They felt that the benefits like the excitement of seeing their data in an edible form were bigger than the *duties* they had to perform.

The interplay of different senses, together with slow reveal of data facilitated by ad-hoc printing lends itself to *Savoring* [13]. Savoring aims to prolong and intensify the enjoyment of a consumption experience by drawing attention to sensory aspects of the experience that might otherwise be missed [13]. Wang et al. [88] described five advantages of data edibilization in terms of attractiveness, richness, memorability, affectiveness and sociability, which our study confirmed. Learning from these insights, we encourage designers to accommodate both printer and food characteristics to engage users in the printing process.

The field study also identified some open challenges in the printing process such as the preparation labor and printing troubles, which we believe would resolve as food printing technology advances. We already see efforts in this direction, e.g., printers like Foodini [28] and Bocusini [14] offer much smoother workflows. However, we argue that instead of making food printing efficient, we can harness its slowness to offer playful engagement that capitalizes on savoring. Secondly, multisensorial nature of engagement with the printing process could also potentially increase the value of the provided feedback [38,54]. Earlier work [4] also suggests that involving users in the creation process can make feedback more influential.

Consumption

After making a good quality print of their *activity treats*, participants enjoyed consuming them. As these treats were printed in thin spread-out form, it also prolonged the experience of eating chocolate without the worry or guilt of consuming too much chocolate. We also found that participants enjoyed getting chocolate treats on active days, whereas on sedentary days, they preserved these treats for later consumption. However, the data element of *activity treats* added an interesting twist to the social behavior of the participants. Participants shared the photographs of their treats with their friends and on social networks. But since these representations were carrying the personal data of participants, they rarely shared their treats with anyone. Rather, these treats became objects of self-esteem and pride. Earlier studies [45,73,83,85] also report similar personality traits where individuals took pride in their data.

As participants became more aware of each other's active life, they persuaded each other to complete their activity goals. Interestingly, even the non-study participants were intrigued by the idea of *activity treats*, and their involvement in the process further encouraged participants to persist with their daily goals. These findings correlate with the earlier work on family based reflection [74] where healthy competition in a family setting led to enjoyment and motivation towards physical activity.

Our study identified two contrasting behavior related to the consumption of personal data and food. Physical activity data, which is usually meant for personal consumption became social through the public process of printing, whereas chocolate, which is something people share, was kept for personal consumption. This leads to an interesting question as to whether the designers should focus on personalizing the design of *activity treats* or they should try to focus on nurturing social experiences. In future, it would also be interesting to see how creating *activity treats* from more than one person's data facilitate both social experience and self-esteem.

CONCLUSION

This paper offered the first conceptual understanding of the relationship between appealing foods like chocolate and physical activity through the design and study of *EdiPulse*. Given the exploratory nature of this work, pursuing users to be physically active was not the primary focus of this work. Instead, our intention was to gather a descriptive account on how playful treats in an appealing medium of chocolate can positively influence an individual's behavior and attitude towards physical activity. To this end, we do not position our work as a health promotion tool. However, we acknowledge two main limitations of our work: 1) a short design-led exploratory study, and 2) the novelty of the 3D chocolate printer. We invite further research to understand long-term effects and use of *activity treats*.

We also see our work as a precursor to exciting opportunities that food printing technology [76,84] will afford for playful self-monitoring. This work also opens up opportunities for interdisciplinary collaborations amongst different fields: food sciences, design, sports and nutritional science and HCI. We look forward to exploring and witnessing new ways of connecting the biographies of the material world with the immaterial world.

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