TastyBeats: Designing Palatable Representations of Physical Activity

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Figure 1: TastyBeats is a fountain-based interactive system that creates a fluidic spectacle of mixing sport drinks based on heart rate data of physical activity.

ABSTRACT

In this paper, we introduce palatable representations that besides improving the understanding of physical activity through abstract visualization also provide an appetizing drink to celebrate the experience of being physically active. By designing such palatable representations, our aim is to offer novel opportunities for reflection on one's physical activities. We present TastyBeats, a fountain-based interactive system that creates a fluidic spectacle of mixing sport drinks based on heart rate data of physical activity, which the user can later consume to replenish the loss of body fluids due to the physical activity. We articulate our experiences in designing the system as well as learning gained through field deployments of the system in participants' homes for a period of two weeks. We found that our system increased participants' awareness of physical activity and facilitated a shared social experience, while the prepared drink was treated as a hedonic reward that motivated participants to exercise more. Ultimately, with this work, we aim to inspire and guide design thinking on palatable representations, which we believe opens up new interaction possibilities to support physical activity experience.

CHI 2015, April 18 - 23 2015, Seoul, Republic of Korea.

ACM 978-1-4503-3145-6/15/04…$15.00.
http://dx.doi.org/10.1145/2702123.2702197

Author Keywords

Palatable representation; fluidic interfaces; physical activity; quantified self; personal informatics; Human-Food Interaction (HFI).

ACM Classification Keywords

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

INTRODUCTION

Activity trackers like pedometers and heart rate monitors are becoming increasingly popular to support physical activity experiences [41]. These devices collect personally relevant data such as bodily responses to physical activity and provide opportunities to reflect on the collected data through self-monitoring [22]. For example, pedometers count the number of steps taken in a day, while heart rate monitors inform about exercise intensity. Research suggests that regular use of these devices can increase user motivation for physical activity [35, 43].

One key aspect of tracking physical activity is visualization, which improves understanding of the data [22, 35]. "Seeing" makes knowledge credible [4] and "*greater visibility of information puts an added responsibility to act on*" as pointed out by Viseu and Suchman [45]. For example, by visualizing physical activity data, users can gain a better understanding of their physical activity levels and can make this gained knowledge actionable towards

their health and fitness related aims [22]. However, physical activity data such as heart rate is abstract in nature and does not have a "*natural counterpart that can be graphically reproduced*", as noted by Vande Moere [44]; thus highlighting the role of designers for creating meaningful mappings to communicate this information to the user. In response, previous works in the field of HCI have looked at different on-screen visualization methods [1, 7, 8, 12, 23]. A screen, on one hand, offers the capacity to stimulate visual senses, but on other hand, often reduces the user interaction to just the reading of information due to its flat display surface. We think that there is an opportunity to explore new ways of engaging with physical activity data that should go beyond visualizing data on screens. We believe that physical activity data is not just a number, but rather a unique and personal outcome that reflects the amount of energy expended and efforts invested by the user; which we think needs to be emphasized and celebrated.

We, therefore, introduce *palatable representations* that besides improving the understanding of physical activity through fluidic visualization also provide an appetizing drink to celebrate the experience of being physically active. Palatable representation for us involves the use of drinkable fluids such as sports drinks to represent physical activity data. As a proof of concept, we present *TastyBeats*, an interactive system that utilizes heart rate data of physical activity to create a personalized sports drink. *TastyBeats* employs a fountain-based interaction to fashion a fluidic spectacle that can also be tasted, thus offering vivid ways of engagement with the data. Additionally, the prepared drink serves as a refreshment to replenish body fluids that were lost during physical activity. As such, palatable representations contribute to the human energy cycle, where the energy, which is lost during the physical activity, is given back to the body in the form of a drink.

In order to understand how palatable representations can support the everyday physical activity experience, we conducted "in the wild" [34] field deployments of the *TastyBeats* system. We deployed *TastyBeats* in three households for a period of two weeks where six participants, two from each house, interacted with the system on a daily basis. Participants were asked to measure their heart rate data for the entire day and then prepare a drink in the evening. We found that our system increased awareness about physical activity and the experience was rewarding and motivating for the participants. We utilize these findings as well as our experiences of designing the system to articulate interesting aspects of palatable representations, which we believe opens up new interaction possibilities to support the human energy-cycle.

RELATED WORK

Commercial physical activity sensor systems often support visualizations of physical activity data through an accompanying website or a smartphone app, where physical activity data is analyzed through numbers, bar charts and graphs. Studies, however, show that many people have low graph literacy skills and, therefore, do not easily grasp statistical data [15]. As a result, much of the health and physical activity related smartphone apps could fall short in engaging people. In response, prior works have looked at other ways of representing physical activity data.

Visualization through digital metaphors

Consolvo et al. [7] redesigned mobile phone screens in the form of a virtual garden where the flowers grow in size as the user performs physical activity; This method of visualization motivated participants in maintaining their physical activity as participants wanted to make the virtual flowers grow. In another system called Fish'n'Steps [23], user's step count was mapped to an animated fish, which became happy or sad based upon how many steps the user had taken in a day. However, authors found that participants were not interested to look at the fish when they were inactive because they knew that their sedentary activity would make the fish sad [23]. In other works, Anderson et al. [1] developed a system called Shakra where physical activity of the user was monitored using mobile cell signal information; they found that increasing awareness about physical activity encouraged reflection upon one's physical activity. These works suggest that digital metaphors to visualize physical activity data have the potential to motivate users to achieve health goals.

Visualization through physical metaphors

Along with digital metaphors, researchers have also explored physical metaphors for representing physical activity data. For example, Jafarinaimi et al. [18] created a physical sculpture that provides feedback on sitting in a proper posture. Recently, Khot et al. [19] and Stusak et al. [40] designed 3D printed physical metaphors to represent physical activity data in a material form; their accompanying studies reveal that user relationship with physical activity gets positively influenced with physical metaphors. These works suggest that physical medium has great potential to support the physical activity experience.

Visualization through informative art

Fan et al. [12] explored the feasibility of informative art by designing and studying various abstract visualizations of physical activity. They found that people have different tastes when it comes to appreciating and relating to abstract visualizations of their physical activity data. This work suggests us to consider varied preferences of the users, while designing visualization schemes.

Visualization through playful systems

Prior works have also utilized physical activity data to enhance gameplay experiences and thereby, creating opportunities for physical activities around playful systems. For example, the Run Zombie Run [36] mobile app harnesses an engaging game-based narrative to make users

jog more. Berkovsky et al. [3] have looked at virtual game rewards in exchange of physical activity while Nenonen et al. [28] utilized heart rate data as a game input. In other works, TripleBeat system [29] allows runners to stay in their target heart rate zones through virtual competition. These works suggest the potential of a playful interface to support the physical activity experience.

Rethinking physical activity representation

Review of the existing literature suggests that there is an emphasis on using the digital medium to represent physical activity, which not only limits the interaction opportunities to visualization but also overlooks the multi-sensory aspect of experiencing the physical activity data. Since physical activity data can approximately reflect the amount of energy invested by the user in a physical activity, we believe there is an opportunity to harness this information to contribute to the human energy cycle by "*giving back to the body what it has lost during physical activity*".

Supporting this, we introduce palatable representations that turn physical activity data into an appetizing sports drink. Since intense physical activity sessions can cause loss of body fluids; sports drinks can help in the recovery of such body fluids [37]. However, we are also aware that the human energy-cycle is much more complex as the literature on exercise and nutrition suggests [37]: We, therefore, do not portray that a created sports drink exactly matches with an hourly exercise, for instance. However, considering the trends in quantified self [41] and food printing [38, 47], we see an opportunity to combine the two. For example, quantified self focuses on sensing energy expenditure, whereas food printing focuses on new ways of producing energy that can be consumed. We find this an intriguing combination that we believe holds an exciting premise for HCI.

To the best of our knowledge, there has not been any exploration on using fluids to represent physical activity. However, past works in HCI have explored fluids for creating novel interactive experiences. For example, the Currency Fountain [9] shows the currency rates using a water fountain based display while Geurts et al. [17] designed a Splash Controller for interactive play experiences with water. Similarly, Steve Mann designed various fluidic musical instruments such as the Water Hammer Piano [25]. The Student Innovation Contest at UIST 2013 featured various fluidic interaction possibilities developed using the PumpSpark water fountain kit [11]. A few other works explored the use of soap bubbles [42] as well as water jets [33] for tangible interactions with computer systems. These works illustrate the potential of fluids in representing information and creating engaging experiences. However, there has not been much exploration on drinkable fluids except a system by Daisuke that transforms backend web processing data into a drink [10]. In response, we propose *TastyBeats* as the first exploration of using drinkable fluids to represent physical activity data.

WHAT IS TASTYBEATS?

TastyBeats is an interactive system that transforms heart rate data of a physical activity into a personalized drink. We employ a fountain-based interaction in the preparation of the drink, which not only provides visualization of the performed physical activity but also turns this event into a spectacular and celebratory event.

The *TastyBeats* setup includes a central glass and four containers as shown in Figure 1. Each container has a food graded water pump [14] fitted at the bottom. These pumps shoot drinks from the containers into the central glass (Refer Figure 2) and are driven by Arduino [2]. Working of the system is explained below.

Figure 2: TastyBeats in action.

Mapping heart rate data to different drinks

TastyBeats divides heart rate values into four zones following Fletcher's classification of physical activity levels based on heart rate [13], however, the range of values were slightly adjusted to suit the current interaction. Each zone has a characteristic drink as explained below. In the current prototype, we have used Mio liquid enhancers [26] for preparing the drinks because they came in a variety of flavors and they had zero sugar and zero calories. We want to highlight that the use of sports drinks was mainly driven from the interaction angle; we did not intend to advocate sports drinks or the usefulness of them in relation to physical activity.

1) Low activity zone: Water

The first zone is a low activity zone where the user is mostly sedentary or doing light physical activities such as standing and walking. This zone corresponds to a range of heart rate values varying from 60 to 95 beats per minute (bpm). Since there is not much physical activity happening in this zone, we choose water to represent this zone.

2) Moderate activity zone: Light flavored water

The second zone describes aerobic activities corresponding to a range of heart rate values from 96 to 130 bpm. We choose light flavored water such as mango-peach flavor of Mio liquid water enhancers to represent this zone.

3) High activity zone: Electrolytes
Third zone describes aerobic activities with high intensity and corresponds to a range of heart rate values lying in between 131 to 165 bpm. Such activities if done for a longer duration may require electrolyte supplements [37]. We therefore choose Mio liquid enhancer containing electrolytes to represent this zone.

4) Intense activity zone: Rich flavored water
The fourth zone corresponds to intense physical activities with heart rate values between 166 to 195 bpm that usually do not last more than 10 minutes [37]. We choose a dark red and rich flavored (Mio fruit punch flavor) drink to describe its occurrence in a physical activity session.

Dynamics of the fluid spectacle
We use Polar H7 heart rate monitor [30] and its accompanying smartphone app, Polar Beat to record the heart rate data of a physical activity session. The Polar Beat app saves the heart rate data on Polar website, from where we download the heart rate data in XML format. *TastyBeats* application written in Processing [31] then identifies the pattern of heart rate zones from the XML file and sends this pattern to the *TastyBeats* system via serial communication. This pattern enumerates identified heart rate zones along with their frequency. For example, for a set of heart rate values: (69,75,83,102,150), the heart rate pattern would be [(zone: 1, freq.: 3), (zone: 2, freq.: 1), (zone: 3, freq.: 1)].

The *TastyBeats* system reads the pattern sequentially and accordingly drives the pumps from the corresponding containers. The pumps shoot the drink into the central glass for 2 seconds, so that the central glass can accommodate multiple shoots from every container. The central glass gets full by 30 shoots with 400ml of drinks. Now, for a longer physical activity session, 7-8 hours in our case, we optimized our system so that it shoots drink only when the pattern moves to a different zone. For example, if the heart rate data stayed in the same zone, shooting happens only once. The system stops when the pattern gets finished or the glass gets filled with 30 shoots.

Design process and considerations
We have taken an incremental and exploratory approach for designing the TastyBeats system where the data gathered from one trial informed the system design for the next trial. As such the design inquiry for TastyBeats was carried out in three phases as explained below.

In the first phase, regular focus group discussions were held with participants from the community surrounding our research lab. The participants came from varied academic backgrounds such as industrial design, computer science, and HCI, which helped us to draw from their experience and discuss advanced topics such as engaging aspects of a palatable interface. Several design ideas were proposed for the possible interface demonstrating the diversity in user expectations as well as choices for an interactive setup (Figure 3). Below we mention the key topics we discussed and how we came up with the final design of the system.

Figure 3: Other design options for TastyBeats were discussed but not considered due to a) less interaction possibility with equidistant pumps, b) self-priming issue with the pumps.

Arranging the containers (setup)
Initially, there were ideas about keeping all four containers at equal distance from the central glass such as in a semi-circular or square fashion (Figure 3a). However, we decided to put the containers in a straight line around the central glass (as shown in Figure 1) that offered us more interaction flexibility. For example, containers that are further apart from the central glass give higher elevation for the water shoot than the ones that are closer to the central glass; making it easier to see the differences in the heart rate while witnessing the system interaction.

Choosing the physical activity data
We chose heart rate as opposed to other physiological measures such as METs and steps because heart rate is more personal as well as dynamic. As a result, the chances that the system would produce distinctly flavored drinks are high. For example, an activity comprising of transitions between low and moderate activity zones will add water and light flavored water respectively into the central glass, while an activity causing rapid transitions between different zones will add more flavors as well as electrolytes to the drink. From our study, we also found that using heart rate enabled tracking of other psychological factors such as stress, which we believe are also essential while considering the overall well being of a person.

Creating the personalized drink
To create a personalized drink, different parameters such as smell, texture, viscosity, and flavor were considered. However, our design choices were limited due to the hardware (pumps) available with us. As a result, we had to discard some of the drink parameters. For example, the pumps did not work with carbonated water, thus giving texture to the drink was not feasible; Additionally, since the pumps were not self-primed, they needed to be immersed in liquid for pumping (Figure 3b). As a result, we looked only at such parameters with which the pumps could work successfully. We therefore utilized three parameters: flavor, volume and color of the drink to create a meaningful mapping between the physical activity data and created drink. Flavor of the drink is based on the identified heart

rate zones in the data, while the recurring occurrence of these zones within the data contributes to the volume of the drink (which increases with the activity duration) thus describing both quality as well as the quantity of the activity. Finally, color is used to signify the highest reached heart rate zone in the data, besides it also creates a visual appeal to understand the data even from a distance.

In the second phase, we exhibited early versions of the TastyBeats systems at three different academic venues where more than 400 participants interacted with the system. Each of these exhibitions helped us to refine our design further by resolving issues such as food safety (using materials that are food safe). Other findings from the exhibitions are explained in [20]. In the final phase, we field deployed the system in various houses to study its use in everyday context, which we discuss in the next section.

TASTYBEATS IN ACTION (FIELD STUDY)

We conducted an exploratory "in the wild" study [34] to understand how *TastyBeats* will integrate into everyday physical activity experiences and what effect it can have on everyday physical activity. Given the exploratory nature of this work, we focused on gathering a rich set of opinions that illustrate reflective thinking about a system rather than a majority.

Recruitment

The study took place in three households across a large metropolitan city for a period of two weeks. In total, we had six participants: 1 couple in mid thirties (Chad: 37 yrs., Male; Sarah: 34 yrs., Female), 1 couple in mid twenties (Dave: 28 yrs., Male; Sarah: 26 yrs.) and two housemates (Adam: 26 yrs. Male; Rahim: 29 yrs., Male). Our intention behind using more than one participant from the same house was to investigate the affect of palatable representations on social dynamics as explored in previous works on material representations [19, 40]. Figure 4 provides demographic details of the participants along with their level of physical activity every week (low: 1-2 days, moderate: 3-4 days, high: more than 4 days). All participants had tried electrolytes-based sports drinks before, but their main source of rehydration was water.

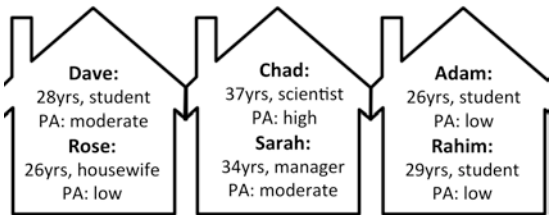

Figure 4: Demographic details of our study participants along with their level of physical activity (PA).

Setup

Each house received a kit containing the TastyBeats system, two Polar H7 heart rate monitors, two iPods and a poster explaining the study's procedure (Figure 5). We also provided sanitizers and napkins to clean the glasses and accidental spilling of drinks. We also provided users with a MacBook Air to run the *TastyBeats* system. Participants were not compensated to participate and the system was taken back at the end of the study. Following the cultural probing practice [16], we also supplied diaries and asked participants to reflect upon their experiences with the system.

Figure 5: Each house received a kit containing the TastyBeats system and a poster explaining the study's procedure.

Procedure

We installed the *TastyBeats* system in every household at a location of the participants' choice (which we noted). We first gave a demo on how the system works with dummy data and explained the study procedure. We also printed an A3 poster detailing the study steps (Figure 5), asking the participants to perform the following tasks:

Tasks in the morning:

We asked the participants to wear the heart rate monitor and start the recording of the heart rate data through the Polar Beat application installed on the iPod. Usually the recording started around 7-8 am when participants began their day. We asked participants to continue their day as usual which may or may not involve physical activity.

Tasks in the evening:

In the evening, usually around 5-6 pm, when participants returned home from work, we told them to stop the Polar Beat application on the iPod and take off the heart rate monitor. Once the recording was stopped, the heart rate data from the day was synced to the Polar website. Participants then prepared the *TastyBeats* setup, which involved pouring water into the four containers and adding the liquid enhancers (two pinches) into three of them. We then asked the participants to press a button that downloaded the data and started the *TastyBeats* program on the provided laptop. The program then started the *TastyBeats* interaction, which involved shooting drinks into the central glass based on the heart rate data. The interaction lasted around 3-4 minutes. Finally, the participant was free to taste the prepared drink.

Data source

The main source of data was the interview conducted at the end of the study in participants' home, which went for about 45 to 60 minutes per participant. The post interviews focused on participants' experiences with the *TastyBeats* system. We also utilized the diaries given to the participants as well as photos and videos taken by the participants to further support the interviews. We visited each household two times (first and last day) and spent around 4 hours in total with participants at each house. We also maintained contact with everyone through emails and phone calls in case they needed any technical support. We took notes and recorded interviews, which were later coded and analyzed for common themes using a grounded theory approach.

FINDINGS

Given the long time frame necessary to achieving health benefits as a result of physical activity, it is often difficult to judge the efficacy of short design-led study interventions [5, 21]. Instead, it has been suggested that such interventions should be judged based on their impact on practices [5] and how they brought about changes in people's attitudes (rather than behaviors), fostering mindfulness and leaving room for stories [32]. We describe below key insights gained from the deployments.

Accommodating TastyBeats

All participants welcomed the system with curiosity and considered it a part of their kitchen ambience. The system occupied a space on the kitchen slab in both couples' home (Figure 6). Adam and Rahim, however, placed the system in a private room as one of their other roommates had a cat and they thought she might mess with the system.

Figure 6: The TastyBeats system was placed on the kitchen slab in Dave and Rose's house.

Experiencing TastyBeats

All participants tracked their data for around 7-8 hours every day. The couples preferred to have their drink after dinner usually around 9 pm. Dave mentioned that the drink was like a personalized dessert or pleasurable treat for the tiring day activity, while referring to the sweet taste of the drink, Sarah said: "*it is like having a grape juice before going to bed*". Adam and Rahim did not have a preferred time for the drink; sometimes they had it just after coming back from work and some other times a little later.

Enjoying the interaction

All participants actively took part in making the drink everyday and keenly observed how the drink was being made through the fountain-based interaction. As such, the system became a part of their daily routine. According to Adam, the system was "*something you always want to see, once you come home*", to which Rose added, "*its nice to see the machine making a drink and the taste of the drink is also very good, but it is also very healthy, that way you feel good about it*." Along with the drink, the participants also appreciated the interactive quality of the system: "*the best part of it is watching the interaction, shooting into the cup*", Dave commented. Rose was delighted to see her heart rate transformed into a drink, she mentioned, "*compared to regular apps with only show the data, this prepares the drink, and that way its kind of special, it feels that you are getting energy back*."

Taste as a surprise

Sarah mentioned, "*Seeing the drink is one thing, but if it's the same color everyday, then there is no surprise. Surprise is the taste, which is different on daily basis*."

Taste as a satisfaction

Chad also commented, "*Tasting it [drink] adds an element of satisfaction. It would have been less engaging if I was not allowed to drink it*." Adam felt, "*it is like drinking your own progress, literally*."

Witnessing the interaction

Chad mentioned, "*This (TastyBeats) is kind of neat where I can see the different levels mixing in. You actually get to interpret how active your day was based upon the drink being mixed. So, I think its more of incentive to see it mixed because you get a better understanding of why the drink is the way it is*."

Relating TastyBeats to physical activity

Participants mentioned that the presented data in its fluid form offered new insights into their physical activity routines. As a result, they became more attentive to their bodily responses and everyday activities.

Correlating activities to drink

Participants were able to correlate different days' activities with the drink that was created in the evening, which in turn encourage them to try new physical activities. Rose tried different physical activities such as running, cycling and household cleaning on different days. She was able to differentiate how her heart rate data in these activities was reflected in the drink. Rahim confirmed this by saying: "*I did see the differences [in the drink], when I had a more active day, there were subtle changes in the taste.*"

Identifying bodily warning signals

The dark rich flavored drink that Sarah received on three consecutive sedentary days made her realize that she had very high heart rates. She told her husband about it and consequently they looked up the Internet to learn about "normal" heart rate values and possible reasons for higher values. They then tried to swap around the heart rate monitors on the next day to see if there was a fault with it. Sarah said: "*What it [TastyBeats] made me aware of was my heart rate. It is not something that I think of. When I saw my high heart rate [through the dark red colored drink], I felt my pulse for the first time. It made me think about the reasons and found that medication is one of the factors [she was on a medication for a while during the study period]*."

Motivating to exercise

A recurrent theme was the motivating quality of the system, linking to the theme of fulfilling the energy-cycle. Participants reported that the system encouraged them to not miss their daily workouts. Rose said: "*Just to see what drinks you get and how much, you feel like going out and running, sometimes it's like an inspiration*." Adam responded similarly, "*it motivated me to exercise more*".

On a sedentary day, Chad received a drink containing mostly water, to which he replied, "*It was little bit frustrating to get watery drink, but it was not unexpected. That kind of motivated me for more physical exercise the next day to get drinks from level 3 and 4*."

Taking health more seriously

Dave spoke extensively about how *TastyBeats* made him be more serious about his as well as his wife's health. He said, "*I will continue cycling to work from now onwards*". Other participants also reported that the system encouraged them to not miss their daily workouts. Dave, Rose and Chad started walking or cycling to the work instead of driving.

Social dynamics around TastyBeats

Participants said that they often prepared their drinks together, laughing and discussing their activities with each other. Usually participants saw each other only in the evening. As such they did not know precisely how active the other person was during the day: The understanding came by watching the interaction when other person's drink was being made. Chad said in the interview, "*it's good that me and Sarah doing it [the study] together, as we get to see each other's heart rate from the drinks being made*" [with a smile], "*in that way, Sarah now knows much more about me and my activities*."

Facilitating competition

Adam felt the system was highly competitive: he competed with Rahim in terms of who will burn more calories and get a better drink. He narrated to us a funny incident that happened during the study. "*On Saturday, I stayed at home reading and watching TV, I did not go anywhere, but my friend Rahim went and played some sport [football with friends] and did some jogging and stuff like that, so it was physically very active day for him and for me it was very very inactive, just the opposite. When he came back, we did our drinks [together]. We started with him and his drink was pretty amazing and very concentrated, using lot of drink from [container] 3 and 4 and almost nothing from 1. After that it was my turn, since there was no activity by me, I did not get anything, just a little bit of water [from container 1] and nothing from the other. It was just funny. It was so obvious that he did lot of activities and I got what I deserved. So we started laughing, it was so fun!*"

Cheating felt bad (tasteless)

Adam further added, "*later on the same day, when we were having dinner, I felt like having a drink. So what I did, I cheated the system. I uploaded Rahim's data and got the same drink that he got. Kind of funny that he did the activities and I got the drink. But actually to be honest, it didn't feel good at all, I felt that what I told Rahim too, you know what, this drink is personal, I feel like it is yours and I am drinking it. It feels like drinking something that does not belong to me. So it did not taste good, really honestly*."

Creating personal affection with drinks

Participants from the other houses also felt that the drink was personal to them and is not something to be shared: Rose said, "*sharing my drink with others is a bit weird, I will tell others about it [my drink], but I will not share the drink, definitely*." Additionally, Chad was interested to store the drink from his intense workouts so that he can cherish those activities for a longer time.

Appreciating TastyBeats

Most participants spoke enthusiastically about the system as well as about their participation in the study with their friends. To our surprise, Adam maintained voice memos to log his as well as Rahim's interactions with the system.

Appreciating the palatability

During the follow-up interviews, we discussed various possible scenarios in which part of the interaction was missing. We asked what if we take away the palatable aspect by just mixing colorful water based on heart rate data. To which, all participants responded negatively. Chad said, "*It would probably be less of incentive especially when you are wearing the heart rate monitor for exercise and at last you can't drink it. It is like producing something but you won't get a reward out of it, other than some water which you can't keep with you*" Dave worried that, "*Having a drink is something like a reward for what you have done. But if it was just water, which you have to throw away, the beauty of interaction would have disappeared*."

Waiting for the rewards

Rahim narrated us the following story, "*one day I came home running from my office, I was exhausted and needed*

something to drink, I could have picked something from the fridge, but instead I poured the drink into the glasses and then drank it once the interaction was over, that way I knew what my heart rate was." Chad further added, "*If I was thirsty, it's a little bit frustrating that you have to set it up and then you have to wait. But seeing the interaction is also rewarding*."

Welcoming the abstract visualizations

Dave appreciated the abstract nature of *TastyBeats* and mentioned, "*for a non athlete like me, detailed data does not make much sense, once in a while you may want to know what your heart rate details are, but on a daily basis abstract interpretation of data is good enough*".

Issues with TastyBeats

Along with the positives, participants also mentioned a few issues with the system that needs to be addressed.

Cumbersome heart rate monitoring

Rose and Sarah found wearing the heart rate monitor for the whole day as cumbersome. Sarah said, "*You need a little bit of discipline for putting it on everyday during the rush hours in the morning.*" To which, Adam proposed a solution: "*Eventually I will come to know what drink I get for what activity. So next time when I had a similar activity, I can just look back in history and plug in the data to get a similar drink, that way I do not need to wear the heart rate monitor or the similar activities.*"

Irregular size drinks

In our system, volume of the drink was based on the duration of physical activity and its type. As participants' activities varied during the study period, they received drinks of different volume. However, Dave did not like getting drinks of different volumes, and wished for a standard size drink irrespective of the duration of his physical activity.

The leftovers

Participants did not like the fact that containers were open from the top, which led to the wastage of the leftover drinks. Dave and Adam asked if the system could be sealed from the top so that they can reuse the remaining drinks rather than throwing them out.

The spilling

The system occasionally spilled drink on nearby surfaces, which was not appreciated by participants, as it required cleaning and led to wasting of food. Rose said, "*Little droplets are okay. But not too much."*

DISCUSSIONS

We discuss below the experiences that the palatable representations of physical activity elicited for our participants.

Rewarding aspects of palatable representations

According to the Goal Setting Theory [24], incentives are important to sustain a user's interest in an activity. Previous works in HCI have looked on virtual rewards and incentives to support physical activity among people [3]. However, according to the study by Munson and Consolvo [27], virtual points and rewards do not have a lasting impact because system assigned rewards are found to support motivation only in the early stages of usage. Therefore, it may be worthwhile to consider a greater scope of reward types. Possibly, rewards that change over time can be a valuable benefit for physical activity.

In this work, we explore this dimension through an appetizing drink and a visceral spectacle of creating the drink, both of which participants found equally rewarding. In case of Chad, even though he was dehydrated due of cycling, he waited for the interaction to end to get a deserving drink. Participants find watching the interaction as the best part of *TastyBeats*, and were very keen to witness the interaction not only for their own but also for their partner's everyday activity. Furthermore, participants also developed a personal affection with their drink mainly because the drink embodied their personal data. Rose was motivated to perform different physical activities to see how it would reflect in the drink and what it taste like. One participant, Adam, even tried to cheat the system by creating drink from his friend's data, but that drink did not taste good for him. Lastly, there was always a surprise element associated with how the drink will taste. We therefore encourage designers to equally focus on the interaction aspects as well as the palatability of the resultant drink while designing palatable representation.

Shared spectacle of personal data triggers discussions and playful interactions

Most of the existing works in visualizing physical activity is geared towards individual use [41]. Physical activity data is often collected and shown on a private computer or smartphone screen. In this work, we explored public display of data in a private setting like home through a shared system of creating a drink. Often the drink was made together and participants keenly observed the process of making the drink. In that process, they became more aware of each other's physiological state, which in turn triggered discussions and playful social interactions. Participants often competed to get a bigger drink and shared moments of laughter when the prepared drinks were drastically different from each other. Recently, a few other works have also started to explore public consumption of heart rate data. For example, Walmink et al. [46] created an augmented helmet that project heart rate data of the wearer in real time to fellow cyclists while Curmi et al. [8] allowed public display of heart rate data on social networks. These works illustrate potential for social interaction in public sharing of data but with a risk of privacy. However, in our study, participants did not raise privacy concern, as the data was presented in an abstract form. Therefore, one way to address privacy

related issues could be to use such abstract forms of visualizations that provides basic information about the physical activity, but hides intrinsic details from the user.

Finally, making data public with fluids means that there are chances of spillage, which can be fun, but we found that participants did not like wasting food (drinks in our case). Therefore, there is a tradeoff in terms of the spectacle and the palatable quality of the drink.

STUDY LIMITATIONS

Here, we mention the two main limitations of this work. Firstly, *TastyBeats* creates a drink only at the end of the day. There are situations when such a drink might be needed right after a physical activity, which was not supported by the current version of *TastyBeats*. Secondly, our study reports results from a 2 weeks intervention. Longitudinal studies might be needed before drawing conclusions on the motivational aspects of the system. Despite these limitations, we believe our work offers first insights into a palatable representation that could inform the design of future systems aiming to support human energy cycle through palatable representation.

CONCLUSION

Main contribution of this work is the first conceptual understanding of the design of palatable representations. We presented results from an "in the wild" field deployments of the *TastyBeats* system that offers insights into how people understand and react to personal data when presented in a palatable form. *TastyBeats* served as a mediator for reflective thoughts and discussions besides offering a public and vibrant vista of their heart rate.

Recent advancements in food printing have opened up new possibilities for creating engaging interactions and experiences around food [6, 38, 39, 47]. However, existing explorations mainly utilize mechanical and time-consuming techniques to produce food. Through this work, we explore another dimension of producing personalized food using a vibrant, attractive and familiar setting of water fountains, which we think would guide designers towards thinking differently about food printing methods.

Our work also intertwines the two growing fields in HCI, namely, quantified self and food printing, thus it might raise issues on their relationship and relevance. Our work also informs the design of food printing machines, highlighting an opportunity to print things "*we do not currently have*", like heart rate. Our work brings to the fore the idea that one can eat one's own data such as heart rate. This might inspire a discussion of the role of HCI in the human-energy cycle. In future, it would also be interesting to see how *TastyBeats* is applicable in other settings such as in gymnasiums or public events like marathons. Finally, our work has scratched only the surface of palatable representation, and we encourage designers to consider new possibilities afforded by such representations to support user's experience with physical activity.

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