OneNote Meal: A Photo-Based Diary Study for Reflective Meal Tracking

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Abstract

When a self-monitoring tool is used to enhance behavior awareness, the tool should afford reflection by design. This work examines the "valence of meal" (i.e., healthy versus unhealthy meal) as a means to support reflection on a person's diet in photo-based meal tracking. To study the effect of imposing valence on meal tracking, we designed two conditions—one focusing on capturing healthy meals, the other capturing unhealthy meals—and conducted a between-subjects diary study with 22 college students over four weeks. According to their group assignment, participants tracked only healthy or unhealthy meals by taking photos and rationalizing in texts why their meals were particularly healthy or unhealthy. We found that participants in both groups became more aware of their diet, but the valence of meal influenced them differently regarding their meal assessment, self-reflection, and food choice intention. We discuss ways to leverage valence in designing reflective meal tracking systems.

Introduction

Food tracking has been a prevalent approach for discovering personal dietary insights[16,22,45]. In food tracking, *reflection* is critical for developing and sustaining healthy eating habits, because reflecting on the experience helps people be aware of their diet, think about their food practices, and potentially make better food choices[14,28]. Despite the burden associated with food tracking and reflection, it stands to benefit those who are concerned with their eating habits. In this work, we aim to make food tracking a reflective practice by having people pass judgment on their meals and capture their reasoning, rather than logging the breakdown of food components, as in traditional food tracking.

In supporting reflective food tracking experience, we are inspired by prior work on the framing effects generated by valence manipulation. Tversky and Kahneman introduced the "decision frame," a decision maker's conception of acts, the outcomes, and the contingencies of a certain decision[49]. *Valence*, a type of frame manipulation[34], is recognized as a way to differently shape people's perceptions on the same information. An example of valence manipulation is highlighting either a positive or negative aspect of individual performance[18,33] or information being conveyed[17,31]. Choosing more powerful valence has shown to effectively influence people's decision making[31], improve self-efficacy[18], and induce behavior change[33]. In this work, we examine how the valence of tracking condition (i.e., tracking healthy meals versus unhealthy meals) affects people's daily meal tracking experience, including how they assess the healthiness of meal, reflect on their food practice, and intend to make food choice.

We also leverage photo-based tracking in our study. Echoed by the phrase, "a picture is worth a thousand words," food images can serve as visual prompts for reflection. Photo-based tracking has been recognized for its potential to mitigate challenges in traditional tracking methods[20,22,37,45] such as by lowering tracking burden[23,29,51], enabling photo sharing[20], providing contextual information[23], and enhancing self-awareness[24,40]. In this work, we adopt photo-based tracking to examine how people reflect on meal healthiness *in-situ* using Microsoft's OneNote mobile app[6].

We conducted a between-subjects diary study with 22 college students over four weeks. According to their group assignment, participants were asked to track only healthy or unhealthy meals by taking photos and rationalizing in texts why their meals were healthy or unhealthy. During the study, we collected a rich collection of *situated data* including meal photos, assessment on meal healthiness, reflection texts, and usage logs. Although the goal of this study is not to change people's eating behavior, people could become more aware of their habits through self-monitoring[41]. In fact, we design the study to promote active reflection by way of taking photos and assessing their meals, which could affect their eating intentions. In the following, we summarize related work, and describe our research question and study method. Then, we report the results from the diary study followed by discussion on ways to design reflective food tracking systems.

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Related Work

In this section, we cover related work in the areas of reflective tracking, food tracking, and framing research. Built upon previous research, we highlight theoretical and empirical implications that motivate our work.

Reflective Tracking

According to Moon, reflection is a purposeful analysis of a person's own knowledge and experience as a means of achieving deeper meaning and understanding[39]. In Li's stage-based model of personal informatics, reflection is the stage where people have finished integrating their data and are about to take corresponding action[35]. Schön further describes reflection as occurring in two processes: reflection-in-action and reflection-on-action. Reflection-in-action is seen as thinking about an event in-situ (i.e., at the time it occurs). Whereas, reflection-on-action refers to learning from thoughts and experiences after the event[46]. In the context of self-tracking, Ploderer and colleagues further specify how these two modes of reflection can be supported by providing different types of feedback: reflection-in-action through real-time feedback and reflection-on-action through aggregated feedback[43]. While reflection-on-action supports learning from past choices retroactively, reflection-in-action can benefit situations as they are occurring, which can lead to more responsive decisions[46]. Applying this concept to meal tracking, we see two opportune moments to encourage reflective meal tracking: (1) the time of capturing a meal and (2) the time of reviewing meal records. In our study, we designed the meal tracking regimen with an aim to support both reflection-in-action (by asking people to capture specific valence of meal and rationalize in text) and reflection-on-action (by providing weekly feedback).

One of the leading reasons for personal data tracking is to change or maintain his or her behavior through self-reflection[36]. As such, supporting technology mediated reflection is often considered an important goal in designing self-tracking tools[12,19,32,36]. For example, Choe and colleagues leveraged visual data exploration in facilitating self-reflection and found that visual data exploration enables people to identify numerous personal data insights[19]. Isaacs and colleagues designed a reflection tool that supports capturing personal experience and emotional state. They learned that recording and reflecting on the captured data could enhance personal well-being[32]. In light of this prior work, we aim to study the effect of valence on people's reflection in the context of meal tracking.

Food Tracking

As food choices play an important role in an individual's everyday life, many commercial applications (e.g., Make My Plate[3], MyFitnessPal[4], MyFoodDiary[5], Bitesnap[1], YouAte[8]) are marketed to support people track their daily meals. Most of the application designs are driven by consumer demands such as losing weight or watching calories. Meanwhile, research studies have focused on supporting people's healthy eating goals[42], enhancing self awareness[13], and promoting positive behavior change[20] through food tracking. Additionally, researchers have employed different strategies to nudge healthy food choices and enhance user engagement by showing visual feedback[14], applying photo-based tracking[23,29,51], providing nutrition knowledge[25,27], and enabling social sharing[16]. As food tracking typically imposes high capture burden, researchers developed automatic food tracking mechanisms[11,47]. However, the automated approach often limits opportunities for self-reflection. In this work, we adopt photo-based food tracking to alleviate the tracking burden while engaging people in the data capture process to provide opportunities for self-reflection. Note that we use food tracking as a way to understand people's reasoning and reflection on the healthiness of meals, rather than to collect food items per se. Although prior works have examined people's healthiness decisions, relying on surveys and interviews[10,21,26], our study goes further by collecting contextualized responses in a diary study.

Framing Research

Researchers have examined the effect of valence manipulation on self-efficacy and behavior in different contexts[18,31,33]. To test performance under different framing, Hwang and colleagues represented food choices using different monster avatars, which led participants to pay more attention to nutrient information: When positive messages were paired with negative visuals, participants exhibited healthier choices[31]. To investigate which framing of individuals' performance leads to higher self-efficacy in achieving health activity goals, Choe and colleagues compared *remaining framing* (i.e., amount left to achieve the goal) and *achieved framing* (i.e., amount achieved toward the goal), and found that achieved framing leads to an increased self-efficacy[18]. Similarly, Kim and colleagues designed *TimeAware*, a desktop-based system with productivity feedback on positive framing (i.e., productivity level) and negative framing (i.e., distraction level). They found that negative framing leads to better work productivity, but caused more stress[33].

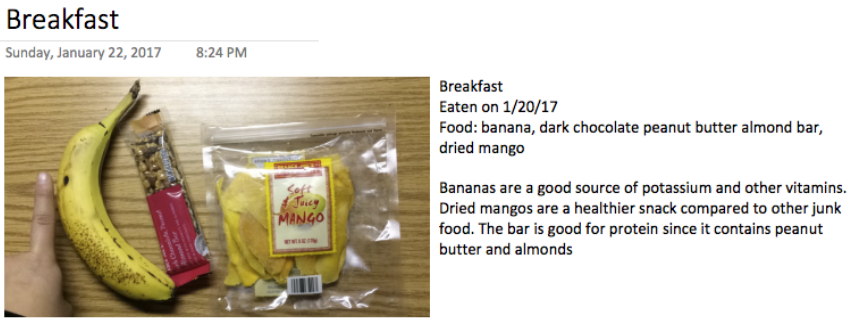


Figure 1: An example of OneNote Meal entry submitted by HG-3 (healthy meal tracking group).

In the context of food research, although not directly referring to meal valence, studies have examined people's perception on healthy versus unhealthy meals in different ways. For example, Calitri and colleagues conducted a one-year longitudinal study to investigate people's cognitive bias towards healthy or unhealthy food, and the effects of bias on their eating behaviors. They found that the bias to unhealthy foods could predict an increase in Body Mass Index (BMI), whereas bias to healthy foods could predict a decrease in BMI[15]. In another study, researchers adopted the strategy of implementation intention to ask people to replace unhealthy snacks with healthy snacks and specify when, where, and why they did so. They found that *motivational cues* to inquire why foods were consumed decreased unhealthy snack consumption more than *situational cues* asking where and when[9]. Similar to this work, we ask participants to rationalize "why" they think a particular meal item is healthy or unhealthy as a prompting cue.

Research Questions and Study Instruments

We postulate that the valence of meals could shape people's food tracking experiences. Thus, we aim to answer the following research question (RQ):

> *How does the valence of meals people capture affect their food tracking experience, including their assessment on meal healthiness, self-reflection, and food choice intention?*

To examine this RQ, we designed a between-subjects diary study with two meal tracking conditions—*healthy meal tracking group* (HG) and *unhealthy meal tracking group* (UG)[1]. Depending on the group assignment, we asked participants to track the meals they considered healthy (HG) or unhealthy (UG) by taking meal photos, and to rationalize in texts their reasons for considering each meal as healthy or unhealthy.

For data capturing, we used Microsoft's OneNote mobile app[6], which is a flexible note taking app that supports capturing texts and photos. OneNote also supports sharing notes, allowing each participant to share their meal tracking entries with the research team in real time. For each meal entry, we asked participants to include the following information as comments: meal type (i.e., breakfast, lunch, dinner, snack), meal name (e.g., salad), key items (e.g., salad with tomato and lettuce), preparation method (i.e., homemade, pre-packaged, or restaurant), and the reason why the participant considered it healthy (or unhealthy). Participants were instructed to include their index finger next to the meal, within the the photo, as a reference of portion size. An example of a complete entry is shown in (Figure 1). In this paper, we use "OneNote Meal" to denote this meal tracking regimen facilitated by the OneNote mobile app.

To support reflection on aggregated data, we sent out weekly summary through emails at the end of each week (Figure 2). We provided the top 6 nutritional facts commonly considered: calorie, protein, total carbohydrate, sugar, dietary fiber, fat (total fat and saturated fat), and sodium[2]. Our primary source of nutritional information was Supertracker[7], a resource approved by United States Department of Agriculture (USDA). If the meal information was not on Supertracker, we turned to MyFitnessPal, and the websites of relevant restaurants or recipes, if any. The weekly summary was designed to promote participant interpretation, rather than directly indicating the healthiness of their meals.

[1] We use "HG-#" to denote participants in the *healthy meal tracking group.*, and "UG-#" to denote those in the *unhealthy meal tracking group.*

Figure 2: An example of weekly summary provided for one of the meals captured by UG-3 (background color was applied to distinguish different food items in the same photo).

Method

We conducted a between-subjects diary study for four weeks. To recruit participants, we distributed the recruitment material through the university research volunteer website. The study occurred at a U.S. Mid-Atlantic state university.

Study Procedure

Participants were randomly assigned to one of the two groups (HG or UG). Before the four-week diary study, we led one-on-one pre-study sessions. During the 30-minute pre-study session, we described the study procedure and obtained participant consent. We helped them install Microsoft's OneNote app on their mobile phone, created a OneNote notebook for them to track meals, and provided detailed instructions and examples of meal entries. Right after the pre-study session, we asked participants to complete a short pre-study survey, which included a demographic inquiry, a self-reported healthy eating level (i.e., from 1 for far below the average to 5 for far above the average), and a dietary quality questionnaire. We designed this questionnaire through a modified survey extracted from valid Food Frequency Questionnaires (FFQ)[30,38,48,50]. The modification of this survey was advised by a registered dietitian as to ensure its accuracy and relevance to the college-age population and their most commonly faced dietary decisions.

If participants believed they did not have anything healthy (or unhealthy) for a particular day, we asked them to submit a short comment indicating that they did not have anything to capture. We asked participants to submit at least one entry per day. They could submit multiple entries if they considered more than one of their meals to be healthy (or unhealthy) in a day. If a participant did not submit any entries for a day, we sent them an email reminder. If a participant missed entries for 3 consecutive days or more, they were dropped from the study.

At the end of each week, we sent participants in both groups a weekly summary of the meals they had captured, with the nutritional information of each food item (Figure 2) over the past week. After four weeks, participants took a post-study survey, which included the same dietary quality questionnaire used in the pre-study survey. We then conducted a 30-minute post-study interview with each participant to understand their meal tracking experiences, particularly their assessment on meal healthiness, self-reflection, and food choice intention. We audio-recorded and transcribed all of the interviews. After the study, each participant received a $20 gift card or cash based on their preference.

Data Analysis

From the pre- and post-study survey data, we calculated participants' pre- and post-study dietary quality scores and their self-reported healthy eating levels. We also analyzed the descriptive data on entry types (e.g., entries with photos and comments, entries with comment-only) and frequencies of each type (see Table 1). For qualitative data from written comments and interview transcripts, we used bottom-up thematic analysis; three researchers, together, iteratively coded interview transcripts to identify emerging patterns and discussed when there were any discrepancies.

Results

We recruited 29 participants, and all of them were individuals who (1) were at least 18 years old; (2) had a smart phone that could install the OneNote app; (3) had data plan or WiFi access; and (4) had no history of eating disorders. At the end of the study, 22 (13 in HG, 9 in UG; 16 female, 6 male) out of 29 (75.9%) participants completed all the study activities. These participants' ages ranged from 18 to 29 (M = 21.64, SD = 2.56). We note that our participants were limited to healthy college students in the U.S. and were predominantly women (72.7%). Thus, our results may not generalize beyond this group. Participants came from diverse backgrounds; nine of them were international students (4 Chinese, 3 Korean, and 2 Indian), and thirteen were domestic U.S. students. Participants were 1 freshman, 3

Group	Usage	Sum	M (Mean)	SD (Standard Deviation)	Minimum	Maximum
HG (N = 13)	Total Entries	405	31.15	9.44	15	48
	Photo + Comment Entries	332	25.54	11.18	12	44
	Photo-only Entries	5	0.38	0.77	0	2
	Comment-only Entries	13	1	1.35	0	5
	Nothing to Capture	55	4.23	4.49	0	12
	Photos Without Index Finger	19	1.42	3.38	0	12
	Missing days	48	3.69	4.60	0	14
UG (N = 9)	Total Entries	237	26.33	5.71	19	37
	Photo + Comments Entries	170	18.89	7.95	6	33
	Photo-only Entries	0	0	0	0	0
	Comment-only Entries	12	1.33	2.91	0	9
	Nothing to Capture	55	6.11	5.73	1	19
	Photos Without Index Finger	11	1.22	1.64	0	5
	Missing days	36	4	3.80	0	11

Table 1: General usage of OneNote Meal. There was no significant difference between groups regarding the variables reported above. "Missing days" is the number of days that participants did not submit any entries. "Nothing to capture" is the number of days when participants noted that they did not have anything to capture for their tracking condition.

sophomores, 8 juniors, 5 seniors, and 5 graduate students (2 M.S. students and 3 Ph.D. students). Seven participants dropped out of the study—6 participants who did not meet the minimum data tracking requirement (4 HG, 2 UG) and 1 HG participant for personal reasons. Among the seven participants who dropped out of the study, five of them participated in part over the winter and spring break, which could have led to low adherence to the study regimen.

In the following, we report our findings in four categories: general usage, effect of valence on participants' assessment of meal, effect of valence on participants' self-reflection, and effect of valence on participants' food choice intention.

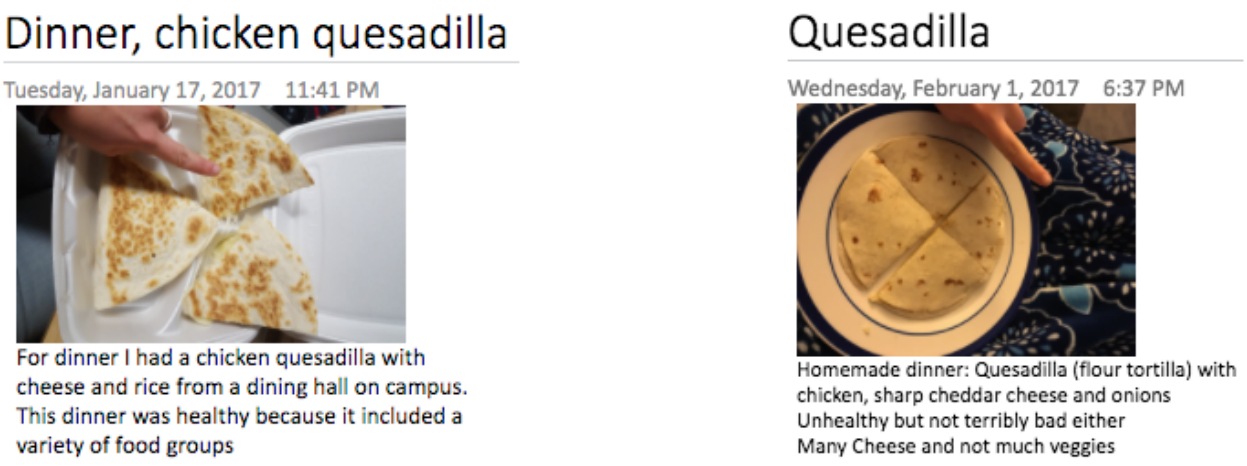
General Usage

Over the course of four-week study, 22 participants logged 642 entries (M = 29.18, SD = 8.32) in total. On average, HG participants missed 3.69 days and UG participants missed 4 days of logging. Although HG participants submitted more entries (M = 31.1, SD = 9.44) than UG participants (M = 26.3, SD = 5.70), we found no significant difference between the two groups. Details of OneNote Meal entries are shown in Table 1. Regarding dietary quality scores collected via pre and post study survey, participants in both groups showed a slight increase in their dietary quality, but the change was not significant. For self-reported healthy eating level, five participants (H1, H2, H11, U3, U8) reported an increase in their healthy eating level, and five (H3, H5, H7, U2, U4) reported a decrease in their healthy eating level. In what follows, we describe the results according to our research question.

Effect on Assessing the Healthiness of Meals

When participants assessed their meal, they used heuristics such as nutrition components, meal composition, preparation methods, food items, brand stereotypes, and social influences. It is worth noting that, although participants in both groups used these heuristics, how they applied them differed by their tracking condition.

It came prominently that participants assigned to the healthy meal tracking group tended to focus on the healthy side of their meals, whereas those in the unhealthy meal tracking group tended to focus on the unhealthy side of their meals. When referring to the meal composition, HG participants tended to consider a meal healthy if *"the majority of the items on the plate were considered healthy"* (HG-1). In some occasions, the addition of one more healthy item could make an entire meal healthy despite other unhealthy items: *"adding an egg to a noodle dish makes for a healthy meal because of added protein"* (HG-12). Other times, HG participants also used the overall food variety to signify that they had a healthy meal: *"I like to have the whole meal with mixed colors"* (HG-4). In contrast to HG participants, UG participants tended to consider a meal unhealthy even when there was only a few unhealthy components, such as



(a) A healthy meal entry submitted by HG-7.

(b) An unhealthy meal entry submitted by UG-8.

Figure 3: An example of similar meal entries submitted by participants in both groups.

dessert (UG-1,3,4,7,8), or unhealthy ingredients such as sugar (UG-3,7,8,9) and preservatives (UG-6). For example, UG-3 noted in their OneNote that *"this meal was unhealthy because of the icecream,"* and UG-6 explained that *"the sauce is from a jar, it has preservatives and unnatural ingredients that would be better off left out of my diet."*

This finding was further exemplified by our observations where participants in both groups captured similar food items, but perceived the healthiness of the meal differently. For example, HG-7 thought that quesadilla was healthy due to its variety of food groups (Figure 3-a), whereas UG-8 thought the opposite because of an unbalanced ratio between healthy (i.e., veggie) and unhealthy (i.e., cheese) components (Figure 3-b). Other types of meals, such as an omelette and pasta, were also frequently captured by both groups, with opposite reasoning.

Effect on Self-Reflection

Participants in both groups acknowledged that they had gained awareness of their diet—especially whether they were eating healthy or unhealthy: *"I think it was helpful to keep track of foods and I realized what I was eating, especially when I had to take pictures of what I thought was healthy..."* (HG-3). UG participants also expressed that tracking unhealthy meals helped them find patterns in their daily meals (UG-2). For HG participants, tracking healthy food painted a brighter picture of their diet, and therefore helped them with their self esteem. This was echoed in a statement from HG-4: *"If you only track healthy parts [of your meals,] you probably feel a lot better about yourself rather than [tracking] everything"*. For participants who had a wide range of healthy and unhealthy meals, tracking healthy meals made them pay more attention to their healthy meals and feel positive about themselves. Notably, some HG participants expressed a sense of guilt when there was nothing healthy to capture (HG-3, HG-5, HG-11). For example, HG-5 considered eating healthy meals as a daily task; on the days when there was nothing to capture, they felt *"a little frustrated, a little mad because I didn't accomplish the task [...] it became a task for myself."*

Compared with HG participants, UG participants were more surprised to realize that their meals were quite unhealthy (UG-6, UG-7). For example, UG-7 noted, *"I like to think of myself as a healthy eater [...] but I realize that a lot of things that I thought I have every now and then are a lot more unhealthy than I thought they were. I guess consciously thinking about [them], and having to document everything really made me realize."* UG-6 also expressed: *"I think I never realized how much cheese I eat. I noticed that I'm putting a lot of extra fat on everything I eat."* UG participants (UG-3, UG-5, UG-7) also expressed a sense of guilt, but in a way opposite from HG participants; they felt guilty when they captured unhealthy meals and felt good when there was nothing to capture. Leveraging the self-revealing experience, UG-4 improved their meal decisions: *"if I logged something that seemed unhealthy then I would try to balance that out."*

Participants in both groups found the weekly summary helpful, especially for reflecting on what they had eaten over the previous weeks and the nutritional facts. With the weekly summary, participants gained nutrition knowledge: *" I could definitely predict what nutrition facts within a food after the study."* (UG-10), and became more informed

about what to eat: *"I am more aware what I should be or should not be eating every day."* (H-8). But many were not sure how to interpret and make use of this information: *"whats the difference between calorie and carbohydrate?"* (HG-13), *" I dont know what to do with it"* (HG-3). Two participants (HG-5, HG-10) indicated their doubt on the accuracy of the nutrition facts: *"but you don't have the size [of food]. The only thing you have is my finger"* (HG-5).

Effect on Food Choice Intention

Thinking about whether meals were healthy or unhealthy made some of the participants become more cautious about their food choices. We found that tracking healthy meals created an overt positive influence for most HG participants. Interestingly, having to capture at least one healthy meal was mentioned frequently by HG participants during the interview: *"It kind of helped me target [a healthy meal] for at least one of the meals of my day, [...] It helped me to push myself to eat a little bit healthier"* (HG-4). Particularly, participants who already considered themselves *"healthy eaters"* thought tracking healthy meals was a *"good opportunity to keep up with healthy food"* (HG-12). Participants with diet-related health concerns showed a personal interest in making better meal choices (HG-10). Through tracking healthy meals, HG participants expressed that they wanted to be healthier, and acted on these thoughts by avoiding days with nothing healthy to upload, a way of motivating their healthy eating behaviors (HG-1, HG-13).

On the other hand, for UG participants, tracking unhealthy meals had a cautionary effect *prior* to eating something unhealthy (UG-1,4,5,6,7). It made them judge their food more critically (UG-6); similarly, UG-1 recalled, *"[I] thought, 'is this a healthy meal or unhealthy meal?' And then I actually tried to avoid eating what I considered unhealthy."* The action of logging meals made participants pass pre-judgments on their meal decisions, and once something was recognized as unhealthy, it deterred them from eating it (UG-5).

Discussion

Valence of Meal Tracking

Many existing food tracking tools are similarly designed in terms of target behavior and data type, focusing on capturing food items, calories, and amounts in an exact manner. Also, they expect the users to track as many data as possible, with an assumption that this approach will give a complete understanding of one's diet. However, there are two problems with this approach. First, tracking every food item might not be necessary for everyone, depending on his or her goal of food tracking[23]. Second, existing food tracking tools often lack support for reflection, which is a huge missed opportunity because people learn from reflecting on data, not from the data themselves. Thus, we argue that designers need to attend to ways in which self-monitoring tools can afford self-reflection.

This work sheds light on how "valence of meals" could be used in promoting reflective meal tracking experience. Tracking only healthy or unhealthy meals, as opposed to tracking all food items, could reduce tracking burden and promote people's reflection on their meals and eating habits by having them pay more attention to their own food practice. For example, we observed that participants from two groups could assess a similar meal differently, as a result of focusing on healthy or unhealthy aspects of the meal. Reflecting on the valence of their previous food choices, participants also thought about their food choice for the future (e.g., "What healthy item should I have?")

We found no statistically significant difference between the HG and UG groups in terms of tracking behaviors and changes in dietary quality score, which might be due to our small sample size. However, our qualitative findings from participants' written notes and interviews provided rich insights on how the valence of meal tracking affected participants' assessment on meal healthiness, self-reflection, and food choice intention differently. In our study, tracking healthy meals had many positive outcomes for the HG participants. It strengthened HG participants' intention to maintain their healthy eating habits (e.g., capture at least one healthy item). Tracking healthy meals also provided HG participants with a satisfactory view of their meals, and of themselves in return. However, it may leave less room to be self-critical, taking away opportunities to improve their current behavior. Given that behavior change is one of the important goals of self-monitoring[44], tracking healthy meals only, or more broadly, tracking only the positive side of behaviors could be ineffective for those who want to identify shortcomings and nuanced problems. Our HG participants then turned to the frequency of the healthy meals, or lack thereof, to verify whether they were on the right track. This approach could give some clues about one's dietary problems, but only at a superficial level. On the other hand, tracking unhealthy meals had both positive and negative effects. Although some UG participants were confronted with an unsatisfactory view of themselves, having to capture unhealthy items prompted them to reflect on their meals and

provided opportunities to improve their existing eating habits and mend the negative self-view. Furthermore, tracking unhealthy meals amplified UG participants' self-reflection on their eating habits, and helped deter them from eating unhealthy food. This observation corresponds to prior research suggesting that monitoring undesirable behavior can effectively reduce its occurrence[41]. Tracking negative behaviors therefore could be appropriate when the goal is to identify problems, rather than casual tracking.

Taken together, we suspect that valence choice should be made depending on people's current states and goals. Tracking healthy meals could be helpful for maintaining healthy eating habits for those who already have healthy diets, while tracking unhealthy meals could be helpful in deterring people from eating unhealthy food, especially when their goal is to change their unhealthy diet. While we do not suggest either one is superior to the other in promoting healthy eating, the results indicate the importance of providing people with a filter—that is, the *valence of behavior* that they can use to judge behaviors when they track data or reflect on the captured data. We encourage other researchers to incorporate and leverage the valence of a tracking item in designing reflective self-tracking systems. For example, we envision a food tracking system that asks people to track either healthy or unhealthy food on alternate weeks, urging participants to reflect on their eating habits from both perspectives. In addition, participants' diverse diet practices, cultures, preferences, and personalities might have influenced their attitudes toward meal healthiness. Therefore, exploring how individual traits affect people's response to the valence of tracking warrants future research.

Supporting Reflection Throughout the Process of Self-tracking

Reflection could happen throughout various steps in self-tracking. One framework we used in designing our study was from Ploderer and colleagues: reflection-in-action through real-time feedback and reflection-on-action through aggregated feedback[43]. This framework helps designers systematically think about ways to support different types of reflection. However, we learned that this dichotomous view of reflection is well-suited for automated tracking, but less so for manual tracking. In automated tracking, where data are being captured at the time of occurrence of an action (e.g., Fitbit, a real-time step count tracker), it is feasible to create and send real-time feedback. However, in manual tracking—such as the photo-based meal tracking combined with written comments, or traditional manual food logging, there is a time gap between when an action occurs and when the data is being captured (usually at the end of the day). Thus, existing food tracking systems, including our own study design, intervene at the time of data capture, rather than during the eating moment. Similarly, YouAte[8] asks people to mark whether a meal is on-path with their eating goals at the moment of tracking, and answer a set of simple questions, such as how they feel about having this meal after tracking. Going forward, we see opportunities in promoting reflection-in-action by encouraging reflective activities right before the eating moment—for example, through an in-situ prompts that ask people to answer health-related questions about their upcoming meal choice. Such prompts can leverage location sensing (e.g., restaurant), wearable devices (e.g., detecting eating gestures[47]), social media activities (e.g., eating-related posts), and personal eating routines (e.g., breakfast, lunch, and dinner time for individuals).

Reflection-on-action happened when participants reviewed the weekly summary, which helped them be aware of their overall eating habits and set goals for upcoming weeks. Although many food tracking systems support reflection-on-action through providing aggregated feedback on food consumption over time (e.g., calorie intake trends), existing feedback (including the feedback we provided in our study) is insufficient due to its interpretation difficulties, missing entries, and limited information for self-discovery. To better support reflection-on-action, we suggest that food tracking systems minimize missing entries by sending in-situ reminders for people to track their meals through detecting eating moments, or by capturing food photos automatically with embedded smart sensors. We also suggest that the aggregated feedback highlight abnormal information such as binge eating to support critical reflection-on-action[19].

Conclusion

To study how the valence of meal tracking affects people's food tracking experiences, we created two conditions–one focusing on capturing healthy meals, the other capturing unhealth meals–and conducted a four-week diary study with 22 college students. We found that participants in both groups became more aware of their diet, but the valence of meal affected the two groups differently on their meal assessment, self-reflection, and food choice intention. Particularly, tracking healthy meals helped participants reflect on their diet positively, and encouraged them to maintain healthy eating habits, although it did not leave enough room for "critical" self-reflection. Tracking unhealthy meals deterred

participants from eating unhealthy foods and nudged them to form an unsatisfactory self-view. Our study showed that implementing a particular valence of a target behavior in designing self-tracking systems could provide opportunities for self-reflections. In closing, we argue that *valence* is an important concept to incorporate in designing reflective self-tracking systems, and call for more work leveraging this concept in the future.

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