“A Postcard from Your Food Journey in the Past”: Promoting Self-Reflection on Social Food Posting

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ABSTRACT

Food-posting, a pervasive practice on social media platforms, opens a window for introspection on personal food intake, physical health, and mental well-being. Existing self-reflection tools on food intake usually require manual logging of dietary information and inadequately support retrospective reviews beyond the data. To facilitate in-depth, non-judgmental self-reflection on information hidden in food-posting, we propose a design to transform general food posts into “a postcard from a past food journey”. The postcards are procedurally created from food posts, and encode nutritional values together with the user’s emotional status extracted from photos and texts. After validating the visual design, we evaluate the auto-generated postcards with 20 participants to explore how they reflect on the data, context, action, and value subjects. Qualitative feedback indicates that our designs encourage users to review their physical and mental well-being differently from conventional visualization. We conclude by discussing issues identified with the non-judgmental postcard design.

Author Keywords

Social food posting; Self-reflection; Postcard; Visual design

CCS Concepts

•**Human-centered computing** → **Empirical studies in visualization;** *Visualization design and evaluation methods;*

INTRODUCTION

Social media has become a prevalent way for people to communicate mundane details of their daily lives [41, 70]. Posts on dining experiences (*i.e.,* posts with photos of food with or without text descriptions) in particular constitute a formidable part of such communications [60]. “Camera Eats First” [73] and “Foodstagramming” [4] are terms created to describe the world-wide behavioral phenomenon of people archiving personal dining experiences in online social communities. To many people who frequently publish food posts online, social food posting is not only a means of self-representation – showing who they are from what they have posted [4, 41, 54], but also a way to implicitly track and communicate their health conditions [13], associated emotional experiences such as happiness [3] and daily well-being [74]. In other words, food posting can extend beyond experience sharing around food and serves as a lens through which social media users can review their nutritional intake and emotional status in context [59].

Despite the richness of information and data embedded in food posts, existing social media platforms do not sufficiently support users in directly using original food posts for retrospective reflection of their physical and mental statuses. First, users take food posting as a diary of highly experiential moments rather than a systematic food logging procedure that tends to be repetitive and tedious [4]. As a result, unlike conventional dietary tracking methods, food posting – being a social sensor [70] – does not conveniently provide nutrition information of given food entries [15, 22]. Second, existing statistical design in self-tracking tools for dining experiences may evoke negative feelings, judgment, or obsession [15, 22]. As food posting was originally intended to capture an experience, conventional statistical design may miss the cues for reflection on experiential aspects during the translation of original posts into quantitative measurements. Third, food posts may not be published regularly and are usually not systematically organized. Although social media platforms usually allow users to revisit historic posts, it is still burdensome for them to search through all the accumulated records, identify and retrieve food-related posts, and then initiate reflections themselves [35].

To address the first challenge mentioned above, we explore an auto-transcription method. Our methods extract nutritional information from food pictures leveraging a food ingredients recognition model and existing nutritional datasets, and emotional status from textual messages through a meta-learning approach. Then we propose a cartoonish landscape design, which encodes the nutrition and emotion details into the visual elements. This assists people in reflecting on their physical health and mental well-being in a non-judgmental way. Adapting the definition from [8], we regard “non-judgmental” as the experience between users and their data in which users do not over-identify themselves and subsequently infer negative stereotypes. Next, to engage users in revisiting their past dining experiences, we present a unique design to the data owners in the form of a postcard from the past. We demonstrate the postcard auto-generation pipeline that can extract the nutritional, emotional, and contextual information from users’ multimedia food posts, and compose the postcards based on

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existing templates. We evaluate the intuitiveness of the proposed visual encoding and the interpretability of our visual design with 10 participants based on food posting data crawled from Instagram. Lastly, we conduct a qualitative study with 20 university students, who often post their dining experience on social media, to investigate how users would reflect on their three-week food posts from four aspects: data, context, action, and value [67]. Feedback from the participants shows that our proposed method could facilitate users' recall of their past experience and awareness of their physical and mental status.

The overarching goal of this research is to examine our auto-generated postcard design for self-reflection purposes, and explore how individuals would reflect on their food intake and emotional status through our proposed design. The main contributions of this work are threefold. First, this work designs and validates a non-judgmental casual visualization based on food posting data, which showcases how to facilitate users' reflection of online multimedia data from an experiential perspective. Second, this work describes an auto-generation pipeline to extract nutritional and emotional information from food postings, which suggests how to process image and textual data provided in online social media posts. Third, this work demonstrates how food posts can appropriately support people to reflect on their past experiences with a postcard design, so that users can create a non-judgmental sense of their nutritional intake, emotional fluctuations, and personal values towards the reflection cues. We also identify potential issues when developing design probes for reflection with a non-judgmental mindset. This work shows that a design with social media content can play a vital role in fostering people's reflections on their physical and mental health, which is valuable for developing self-awareness and motivating users to improve personal well-being.

RELATED WORK

Social Media and Self-Reflection

"Self-Reflection" is a widely used term that has many meanings [55]. We adopt the definition where self-reflection is a review and analysis of one's past, present and future experiences to develop a deeper level of self-understanding of the perceptions, beliefs, feelings, and actions regarding everyday life [9, 47]. Researchers have recognized that the process of self-reflection can be supported by social media data [13]. User-generated content (*e.g.,* text, image, video) plays a role as "social sensors" – implicit trackers of individual silos [18, 70]. While social media accumulates data that helps us understand users [6], we also witness new services and applications that curate user's posts which support self-reflection. For example, Facebook offers *Look Back*[1] and *Memories*[2] services to let users review and recall their past experiences. Instead of passively recording the posts along the timeline, such services actively send triggers to users after a certain time to catalyze their reminiscences. Another application, *Timehop*[3], collects old photos and posts from mainstream social media (*e.g.,* Facebook, Instagram, Twitter) and delivers them to the end-users.

Recent studies also propose the means to facilitate self-reflection based on social media data. *Pensieve* [51] offers users memory cues, which include their posts (including photos, text, and music) on social media and prompts feedback about life experiences. The system triggers self-reflection about the identities, the relationships and the traces of life-based on these cues. *Postulater* [29] is a time-delay media sharing system that supports multimedia message exchange between friends and family at any point in the future. These system designs affect future reflection via a message which was compiled and sent from the past. Other systems like *Ripening Room* [6] support reflection based on digital traces of communication details. Using ripening time and ripen score, the system encourages users to reflect on their expressions of emotion and thoughts on social media. Schwanda Sosik *et al.* [58] also examined people's reflections on friendships by accessing participants' "See Friendship" page on Facebook. Our paper builds on this growing body of work by focusing on the self-reflection of personal nutrition and emotion mined from food posts. Leveraging social media data, we investigate how to shed light on personal physical health and mental well-being as well as how to better facilitate self-reflection.

Furthermore, to understand the personal usage of social media to track and share food for reflection purposes, Chung *et al.* [13] interviewed 16 women, who consistently posted about food on Instagram to support themselves and others in the pursuit of personal health goals. The authors identified the tracking motivations and procedures of these Instagram users who often reflected on their old posts without providing additional information. Inspired by this work, we focus on how to foster self-reflection based on original food posts augmented with mined nutritional and emotional information. We aim to investigate an unsupervised method to process the multimedia data provided on social media to obtain an in-depth understanding of personal health and well-being.

Analyzing Food Posts from Social Media

Online food posting has become a prevalent way to share a daily dining experience and many social networking sites host plenty of multimedia data. As such, various researchers have tapped into these data to analyze patterns of nutritional habit and emotion. For example, Phan and Gatica-Perez [52] leveraged Instagram posts with the most frequent hashtags and studied the food and drink consumption patterns. Adopting different hashtags on Instagram data, Mejova *et al.* [46] presented a large-scale analysis of obesity patterns. Culotta [16] and Abbar *et al.* [1] modeled health-related statistics through the tweeted dining experiences based on Twitter data. Moreover, Dixon *et al.* [19] studied global food consumption patterns and their impact on users' daily emotional well-being. While these works aim to understand food and drink consumption patterns or food-related emotional expressions, their results have been restricted to the group level. As such they do not guarantee individuals a means for self-reflection.

Besides the demographic patterns, previous research also investigated computational techniques to extract valuable information from the food posts. Towards this end, some researchers extracted the keywords of ingredients from the textual messages. Abbar *et al.* [1] estimated the calories for each food-related topic by searching the identified food keyword from a nutritional information website and checked the validity manually. Sharma and De Choudhury [60] referred to the official USDA National Nutrient Database [2] for nutritional information from the post hashtags and validated it through a crowd-sourcing procedure. Such methods have limited im-

[1] https://www.facebook.com/lookback
[2] https://www.facebook.com/memories
[3] https://www.timehop.com/

pact, as they rely heavily on the textual data provided in the food posts. To overcome this limitation, Rich *et al.* [54] utilized posted images to understand food-related content. This inspired us to leverage computer vision techniques to recognize a dish's name and the ingredients from posted food images [57]. While limited research has studied specifically how to extract emotional information from food posts, we draw inspiration from a more generic field – text-based emotion detection [7, 12, 75] – to leverage the textual data provided in food posts to computationally extract emotion details.

Design for Self-Reflection

Self-reflection does not come naturally to most people and they usually need a reason or some encouragement to do so [23]. Previous research has offered descriptions and frameworks for designers to deliver elements that trigger behaviors associated with self-reflection. Cuttone *et al.* [17] proposed heuristics for the design and evaluation of interactive data visualizations that serve as personal tracking systems. Extended with the design heuristics, Slovák *et al.* [61] proposed a framework that scaffolds the transformative reflection process. These descriptions provide guidelines for developing systems that promote self-reflection and suggest that visualization can be utilized as a powerful method towards this end [68]. As Choe *et al.* defined in [10], visual evidence is an important component for inducing a data-driven reflection. Mathur and Karahalios [44] also claimed that visualization brought the technically available information to light. On the industrial side, many commercial self-tracking tools have provided visualizations in the dashboard form for an overview of the data, but they still fall short of delivering a means for self-reflection [11].

Various visualization techniques have been explored to facilitate users' reflection and understanding of their tracking data [30, 56]. Unlike traditional task-focused information visualization systems, casual visualization is designed for everyday use [53, 63]. The data in the casual visualization is usually encoded aesthetically to foster non-judgmental awareness and long-term behavioral changes [39, 76]. For example, *UbiFit Garden* [14] uses the metaphor of a blooming garden to represent the users' physical activities. Similarly, *Fish'n'Steps* [39] builds the link between the user's daily step count and the activity of a fish in a virtual setting. More artistically expressive forms such as Chinese ink painting [77] are also applied to help users reflect on their health conditions. As for the gist of sustainability, natural objects such as a coral reef [34], a fish [25] and a tree [24] are among common choices as iconic representations of users' environment-related behaviors. These systems generate positive reinforcement signals as users interact with them. Results show that such systems trigger more emotional attachment compared to those who rely purely on statistical representation [34].

Previous research also explored different representation forms and media to facilitate self-reflection. Epstein *et al.* [21] summarized that visualization forms (*e.g.,* maps, one-sentence summaries, graphs, abstract pictures) are being utilized as visual cues of the gathered data. Thomas *et al.* [66] remediated social media data into a physical book, a photographic triptych and a film in support of personal reflection. Ayobi *et al.* [5] examined paper bullet journaling for logging and reflecting on everyday life. Besides those, postcard, a combination of text expressions and graphical demonstrations, has been adopted for data representation in previous research. For example, *Landscape* [37] is an energy consumption digital postcard designed to provide a friendly and aesthetic experience of understanding users' electricity consumption behavior. Also, Gerritsen *et al.* [28] designed a technology probe that selected snippets from archived emails and mailed them with physical postcards; Lupi and Posavec [42] collected and visualized their weekly data and shared them through postcards in the *Dear Data* project. By representing cues from past memories, postcards are able to remind people of past experiences and trigger meaningful reflections, and are often used to share information about a particular memory or experience [28]. Based on these facts, in this paper we propose a postcard with a non-judgmental visual design on its front. We aim to investigate the feasibility and obtain users' feedback on the new media and visual design in supporting self-reflection.

PIPELINE

Previous works have demonstrated how to automatically compose visual design summaries based on raw data [26, 62, 71], but they do not yet fully support the multimedia data. Besides, the generated visualization results are in a conventional statistical style. When composing visual summaries for users' reflections on food posts, it is critical to support multimedia data analysis and experience-oriented visual representation in an automated generation process. Inspired by previous designs for data remediation [28, 37, 66], we propose a pipeline to automatically compose a postcard-design visual summarization (output) based on food post data (input), by following the common practice of generating visual representations [45, p.18]. Our proposed pipeline consists of two modules (Figure 1), *i.e.,* Information Extraction and Postcard Composition.

Information Extraction. This module first collects the image, text, and metadata from the original input, then transforms the raw food posts into related nutrition, emotion, and contextual information. During the data processing procedure, this module (1) extracts the nutrition information from the related datasets based on the recognized dish name and the ingredients learned from the posted image; (2) obtains the emotional information through the meta-learning approach; and (3) retrieves the posting time and address from the metadata. This module produces the nutrition, emotion, and context information as output to the next module.

Postcard Composition. After collecting all the retrieved data, this module aims to compose the postcard with a non-judgmental design (front side) and contextual information with a legend (backside) based on the input. Through matching for the encoding scheme and computing the layout based on pictures with segmentation information, the module generates a cartoon style landscape for the front side of the postcard. Based on the original food posting data, this module produces the backside of the postcard with a paragraph of the rephrased message using predefined templates, a stamp redesigned with the original image post, a postmark with the timestamp, a tagged address, and a legend scheme. The pipeline takes the final postcard design as the output.

INFORMATION EXTRACTION

Previous large-scale dietary studies on food choices and nutritional patterns employed questionnaires, surveys, or other forms of self-reported information (*e.g.,* food diaries) to track daily activities of food consumption [48]. However, with the popularity of social media platforms, we can also discover human behaviors from their online activities. Collecting food

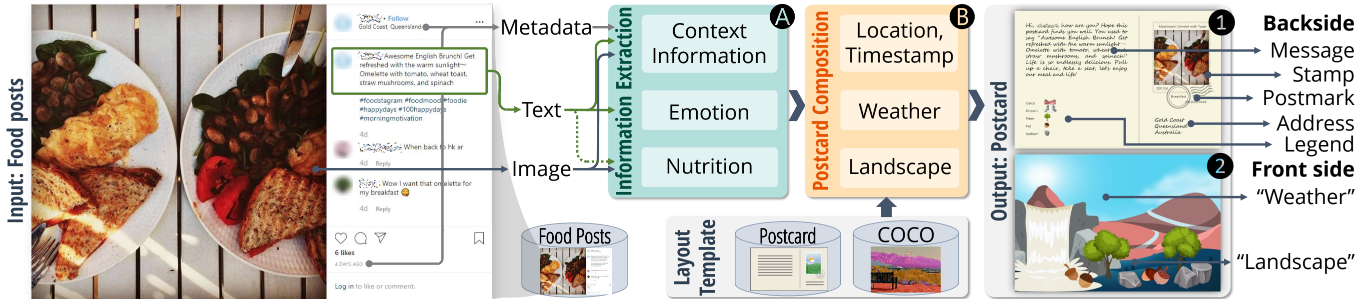

Figure 1. The overview of the proposed pipeline to automatically generate postcards based on food posts data. The pipeline consists of two core modules, *i.e.,* (A) information extraction, and (B) postcard composition. We demonstrate the pipeline with the food post on Instagram as an example. The dotted line indicates that the textual data could be used to validate the nutrition information if they contain related information. The final output includes a postcard's (1) backside and (2) front side designs based on the layout templates.

posts from social media grants us quick access to the integrality of behavior patterns [1] in the context of food: we not only retrieve people's eating habits, but we also observe their emotional experience, the time of the post, the place where they tagged, and so forth.

We validated the proposed pipeline by utilizing data obtained from Instagram. Previous research on food related posts [13, 18, 46, 52, 60] has demonstrated that Instagram is a popular social media platform which supports photo-sharing with an underlying social network. For data collection purposes, we crawled public food posts through Instagram's official API[4]. Adopting the methods from [13, 60], we collected data using specific food tracking hashtags (#foodmood and #moodfood) as a raw dataset. Then, we filtered those posts related to food through image detection and keyword comparison. In addition, we performed manual filtering to remove advertisements and spamming posts. Our final dataset consisted of 101,762 posts with images and textual data. Nevertheless, the data collected from social media still requires us to do additional processing to mine its rich information. We collected the context information from the original posts directly (if the posting time and address were tagged), and further retrieved nutritional and emotional information.

Nutritional Information

To get the nutrition information, we borrowed the method from Facebook's Inverse Cooking [57] to extract the name and the ingredients of the dish based on the input image. The ingredient prediction model accepts 224×224 pixels of food images. Through processing the images with neural network architecture, the model first extracts the 512-dimensional image and ingredient embedding based on the ResNet-50 encoder. Then the model decodes the embedding to the closest ingredients via a transformer with 4 blocks and two 256-dimensional multi-head attentions. The model can achieve a recall of 75.47% and a precision of 77.13% on the Recipe1M test set. After finding a dish's name and ingredients' list, we searched and crawled the nutrition details from the official USDA National Nutrient Database [2], We first applied the food name from the nutrition dataset to retrieve the reported nutrient information. For posts which matched more than one food descriptor, we calculated the average value across all the matched records as the aggregate for such posts. For posts without matching descriptors, we leveraged the ingredients to find a similar one by string matching. We used five major nutrition details for visualization, *i.e.,* carbohydrate (g), protein (g), fat (g), fiber (g), and sodium (mg), and total calories (KCal) for stamp design.

[4] https://www.instagram.com/developer/

Emotional Information

We adopted a meta-learning approach in emotion distribution learning [75] to make full use of a small training sample. The method accepts the food post message as input and predicts distributions for Ekman's six basic emotion [20] (*i.e.,* anger, disgust, fear, joy, sadness, and surprise) at each time. Specifically, we first used the method to learn tensor embeddings on the training data and partition the embeddings into clusters via the K-nearest neighbors (KNNs). Afterward, the method trains a meta-learner on the clusters that can adapt to the new data with only a few training samples, and then fits the meta-learner on KNNs of a testing sample to predict its emotion labels. When evaluated with the six distance and similarity metrics [27], the method achieved scores of 0.34 in Euclidean, 0.33 in Sørensen, 0.34 in Squaredχ^2, 0.44 in K-L, 0.85 in Fidelity, and 0.67 in Intersection on SemEval 2007 with 90% training data and 10% testing data. In our case, as sometimes the input sample is small, we can get robust emotion distribution results from limited input data by adopting the meta-learning approach. We applied the most intense and dominant emotion for each food post and left the other detected emotion for further use.

POSTCARD COMPOSITION

After obtaining all the information, we designed the postcard's front side (Figure 1.(2)) with a non-judgmental visual design to encode the nutritional and emotional information and the backside (Figure 1.(1)) to show the contextual information. In this section, we first discuss and design the encoding scheme for front side visualization through a design workshop; then we evaluate the encoding scheme and visualization output with 10 general participants; finally, we describe the backside design in detail.

Front Side Design: Design Encoding Scheme

To find a suitable encoding scheme and design style, we recruited six university students with design backgrounds (4 females; $Mean_{Age} = 24.67$, $SD_{Age} = 1.80$) to brainstorm the encoding details in a one-hour workshop. We aimed to design a casual visual representation that achieves the following goals: **G1**. reveal informative and expressive context with diverse elements; **G2**. enable clear association by leveraging metaphorical encoding; **G3**. reduce visual clutter and balance visual layout; and **G4**. eliminate ambiguity and cultural bias. During the workshop, we organized the first 20-minutes as a warm-up session to make sure all the participants understood the definition, features, and design goals of the postcard's front side representation. Then we presented the participants with a questionnaire of the main categories of emotion and nutrition extracted from the social media data. We encouraged the participants to propose and discuss any possible design templates and encoding combinations for all listed data items within 40 minutes. After collecting and arranging the results, we finalized the data encodings to consider the comparability.

Participants provided interesting design templates during the workshop. There are design choices regarding the natural environment with global circulation patterns (cloud, rain, rivers), ocean ecosystem, flora, and fauna; the physics theory about the state of matter (ice, liquid, vapor), energy/force transfer (conservation of energy); the chemical reaction of neutralization (an acid and a base); and a life scene of passengers with trains, stations, buildings, and scenery along the way. After discussion, participants agreed that a landscape was good for representing one's physical and mental status with metaphors (**G2**) and many related features can be created to present the emotion and nutrition aspects of one's well-being (**G1**). Besides that, natural landscape design was a popular choice in the previous research [14, 24, 34, 39] when promoting self-reflection. As to the design style, participants put forward five proposals: paper cut, water-ink, cartoon, physicalizations, and pointillism style of design. To make the visual representation straightforward, colorful, and relatable to the public, all participants agreed that the postcard should adopt a cartoonish style to make the design more widely-accepted.

At the end of the design workshop, participants arrived at an encoding scheme to represent the emotion and nutrition information. Since weather conditions are widely associated with emotional feelings in daily practice [65, 78], participants suggested to assign the emotional information to different weather conditions in the upper part of the canvas, whereas the rest of the elements "on the ground" (*i.e.,* the lower part) encoded the nutrition data (Figure 1.(2)). Participants defined the encoding by referring to the meaning of the data, as the encoding should make sense to the audience (**G2**). There were five major categories of nutrients, and we listed the metaphorical encoding elements and the reasons for each of them following the design goals **G1-4**: (1) Carbohydrate: participants chose a mountain to represent this nutrient as it makes up a large percentage of our daily calories, and is our main source of energy; (2) Fats: participants used nuts as they are commonly recognized as sources of healthy fats; (3) Fiber: participants applied trees because the fibrous indigestible portion of our diet is mainly from vegetables; (4) Sodium: participants employed stones to represent the inorganic elements based on the immediate association; (5) Protein: to minimize any visual clutter on the lower part of the visual representation and eliminate possible cultural bias, participants designed a waterfall made of milk, which is an idea presented in *Food Landscapes* [72], to infer the meaning that protein is essential for the growth and repair of muscles and other body tissue. For the six emotion categories, we utilized different weather conditions that are metaphorically used to describe human emotion [65, p.165]: (1) Anger: Thunderstorm; (2) Disgust: Heavy clouds with a dark and gloomy sky; (3) Fear: Tornado; (4) Joy: Fair and clear blue sky; (5) Sadness: A downpour with thick clouds; (6) Surprise: Partial sun with light through the clouds. The overall postcard is designed in a 2D cartoonish style.

Front Side Design: Visual Design Validation

We validated the encoding scheme proposed in the design workshop by conducting an in-lab user study. We aimed to answer two questions: (1) whether the encoding scheme is intuitive enough for users to learn; and (2) whether users get a consistent interpretation of the trends based on our visual design. We recruited another 10 participants (3 females; $Mean_{Age} = 23.50$, $SD_{Age} = 3.01$) from a local university through word-of-mouth. Participants' backgrounds included automation, computer science, and design. Six of them had drawing skills or design-related experience.

Intuitiveness of Visual Encoding Scheme

We presented the nutrition and emotion encoding schemes separately to the participants to check the interpretability of our visual encoding. To further validate our encoding design decisions, we enlarged the element candidates pool by including other possible elements (*e.g.,* "flower", "fruit", "pond", "ground" for nutrition encoding; "sunny weather with a huge sun" for emotion encoding) employed by previous literature [14,24,37,65,69,78]. Therefore, the total number of data categories and potential visual elements were unequal. Then we invited participants to draw one-to-one bipartite matching between them by providing sample images for the potential visual elements. We also encouraged participants to suggest any new elements they thought would be more suitable or intuitive to encode the data than the given candidates. Finally, we used group consensus, if any, to support our final decisions.

For the nutrition encoding scheme, we provided five nutrition categories and nine landscape visual elements (including "flower", "tree", "nut", "fruit", "mountain", "stone", "waterfall", "pond", and "ground") for all participants. We demonstrated three sample images (Figure 2.(1)) selected from Freepik[5] to represent each element. During the study, participants attempted to associate nutrition with natural objects (*i.e.,* visual elements) that may contain such nutrients. This method worked for the mappings of "Trees-Fiber" (10 matches), "Nuts-Fat" (7 matches), and "Stones-Sodium" (6 matches). However, when it came to "Carbohydrates" and "Protein", participants had problems finding the ideal elements from the options, nor could they propose any meaningful alternatives. After we explained the design goals and rationale discussed in the previous workshop (section 5.1), participants all accepted the encoding and agreed that the mapping made sense.

For the emotion encoding scheme, we presented six emotion categories and seven representative weather conditions (including "fair and clear", "sunny weather with a huge sun", "tornado", "sunlight through clouds", "downpour", "heavy clouds", and "thunderstorm") images (Figure 2.(2)) to the participants. During the study, participants used prior knowledge or tended to imagine the emotion that they would have by putting themselves in a corresponding situation, which was similar to the process we initially went through when designing the encoding scheme. For example, participants chose "fair and clear" weather to represent the emotion of joy because a sunny and bright day made them "*feel positive*", but "a huge sun" reminded them of torrid weather. Similarly, for sadness, participants mentioned it was common practice to have "*...a rainy day when a film starts to play a sad story*". At last, the candidate that received the majority matching for each emotion category is the one proposed in the workshop. The final encoding scheme is shown in Figure 2.

Interpretation of the Visualization Design

To evaluate whether different users can acquire consistent interpretations from our visualization design, we organized the

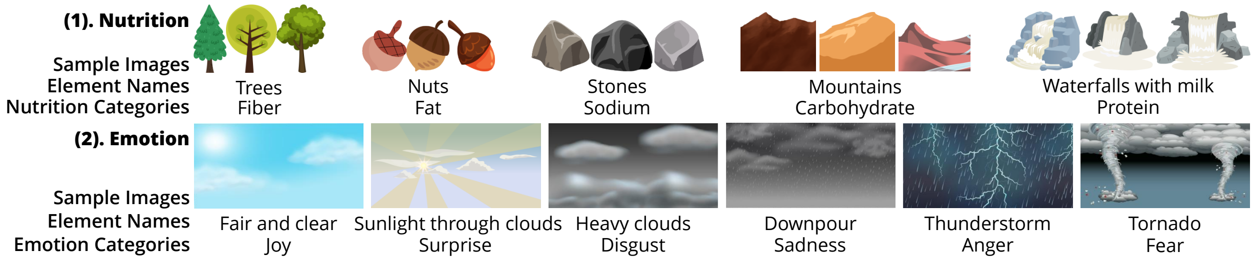

Figure 2. The encoding scheme and sample design materials applied in the front side of the postcard visual design.

second user study with the same 10 students. We divided the study into two sessions. The first session focused on finding similar nutrition intake patterns. We selected 18 posts from three Instagram accounts (6 bread-making posts, 6 vegetarian posts, and 6 barbecue pitmaster posts) and labeled their nutrition patterns as "carbohydrate", "fiber", and "protein, fat, and sodium". For each post, we generated a landscape visualization through our automated pipeline with a randomly selected template. Then we printed all the visualizations on cards and shuffled them into random order. When introducing the study, we told participants about the total number of groups (*i.e.,* three) and the characteristics associated with each group, without telling them the exact number of postcards generated for each group. Next, we asked participants to sort those cards into three piles based on similar visual features and perceived patterns from the visualization. Participants were asked to complete the tasks independently. In the second session, we aimed to validate participants' interpretation of emotional patterns. We selected another 18 posts from Instagram (6 healthy-eating influencers' posts, 6 unhealthy looking food posts, and 6 posts about food waste) and labeled their emotional patterns as "joy", "fear and disgust", and "sadness, anger, and surprise". We followed the same process as in the first session and collected participants' feedback for analysis.

After collecting all the participants' sorting results, we measured their interpretation consistency via intraclass correlation coefficient (ICC). For the interpretation of nutrition patterns, the average measure ICC among the 10 fixed raters was .76 with a 95% confidence interval from .55 to .90 ($F(17,153) = 4.16, p < .001$); while the average measure ICC of emotional pattern interpretation was .90 with a 95% confidence interval from .82 to .96 ($F(17,153) = 10.34, p < .001$). The study results indicate that our design is capable of maintaining a good consistency among different persons in visualizing both nutrition and emotional patterns [36].

Backside Design: Contextual Information Layout

We designed the backside with contextual information and a legend by following real postcard examples. The backside includes the textual message, stamp, postmark, address, and the legend for the front side visualization (Figure 1.(1)). Taking the traditional postcard backside design as an example, we placed the textual message on the top-left corner, and the remaining space on the left-half is for the legend; we arranged the stamp, the postmark, and the address on the right-half sequentially. We designed the postmark and address with the metadata, and replaced the denomination and text on the real postage stamp with the total calories and dish name in our design. The perforation and postmark shape were designed with existing vector graphics.

IMPLEMENTATION

To automatically compose the front side layout yielding reasonable, harmonious, and diverse designs, we adopted a template-based method leveraging real landscape photos. To be more specific, we took the COCO (Common Objects in Context) dataset [40] with segmentation labels and object localization information as the template; then we mapped the collected visual elements to the corresponding target regions according to the geometric center of the segmented area; finally, we adjusted the size and position of all the visual elements based on detailed design constraints. COCO is a large-scale dataset that annotates real-world images with object segmentation, caption, types and geometric information at the pixel-level. It contains 1.5 million object instances with 80 object categories [40]. Since we only adopted the objects related to the natural landscape (*e.g.,* "plant", "solid", "sky", and "ground"), we excluded the unrelated categories (*i.e.,* "person", "animal", "vehicle") from our template pool. In the end, we got 316 templates which denote landscape layout information and applied them to further element mapping on the front side design.

We collected copyright-free graphical design resources from Freepik[5] in vector format. For each element, we ensured that there were at least five different visuals to increase the final design diversity. Following the encoding scheme, we encoded the nutrition information into (1) element size: for "mountain" and "waterfall", we assigned the value to the height of the graphical elements; and (2) number of elements: for "tree", "stone", and "nut", we applied the rounding off value to the total number of graphical elements. We fine-tuned the design by following two constraints. (1) Following real-world common sense: we applied different weights for certain types of visual elements to maintain a natural-look for the audience. For example, the size of the nuts and stones are usually smaller than trees. (2) Using the geometric perspective: along the vertical axis of the canvas, we placed all the visuals based on the order of their size. For the same type of visual elements, we fixed the size of the nearest and furthest items and scaled the rest proportionally by their positions according to the template. After getting a rough arrangement of all elements, we adjusted the position of all the visuals by following the above two rules. To eliminate the individual differences in food consumption behavior, we standardized the recorded value for each user over all the aggregated historical tracking records.

To prepare the backside layout template, we first allocated five sub-areas to arrange the content of the message, stamp, postmark, address, and legend. We adjusted an initial size for all five areas with the maximum character counts of collected posts. We identified a common postcard message template

[5] https://www.freepik.com/

from the Internet, which includes one greeting sentence, the main body of users' posts, and one closing sentence with wishes, to fill in the message area. The greeting and closing sentences were varied according to the recognized emotion. Then we anchored the upper-left corner of each area. We further chose copyright-free handwritten font for messages and addresses to provide the man-made forms. Finally, we assigned the corresponding content from the processed data for each area based on our design for the backside.

STUDY DESIGN AND DATA COLLECTION

To fully understand how people interpret and respond to our postcard design and explore how emotion and nutrition intake affect one another, we conducted a three-week study (which includes an exam week) to collect users' posted data based on real-life experiences. During the process, we aimed to achieve the goal by: (1) Exploring participants' opinions on the postcard design and the auto-generation pipeline. We presented the postcards based on the food post of a single meal, the summary of a period, and the comparison of multiple periods for users to reflect upon. (2) Investigating participants' feedback of food and emotion reflection with the postcard's design. We interviewed participants about their reflection on the data, context, action, and value subjects [67]. (3) Examining participants' comments towards the reflection experience with the help of the postcards as well as the insights into other usages of the postcards (*e.g.,* for social sharing or retention).

Participants

Similar to previous technology probe research, our goal is to gain a descriptive understanding of salient issues by focusing on a smaller sample size in this research [31, 50]. Since the target user group represents a relatively young, educated, and technologically literate demographic [38], we set the user scope of our study on university students, who are referred to as digital natives [43]. We recruited another batch of 20 participants (7 females; $Mean_{Age} = 22.25$, $SD_{Age} = 3.13$) from local universities through online advertisements and word-of-mouth. All the participants were willing to share their food posts on social media websites and they all had personal Instagram accounts. Six participants were from Europe and the Middle East, including Switzerland, England, and Turkey. The remaining participants were mainly from Asia, including China and Korea. Participants' backgrounds covered computer science, psychology, management, and mathematics. Before the study, we checked with participants if they had any special eating habits. Two participants (P2, female, 20; P16, male, 19) pointed out that they were on a diet, and no one reported that they had an eating disorder. We recompensed them for their participation with a gift card worth USD$15, and a lottery entry to win a Kindle Paperwhite.

Procedure

After getting the participants' consent to join the study, we approached the study in the following way. First, we sought participants' authorization to access the food posts from their Instagram accounts. To simulate real-world food posting behavior, we asked the participants to post their food and emotion as usual and with no specific requirements on timing and frequency during the study. Then we kept track of participants' Instagram accounts and built a database to record their food posts for three consecutive weeks. We implemented the postcard auto-generation pipeline based on the database running on a MacBook Pro laptop. At the end of the three-week period, we processed the posted data and fed the results into the pipeline according to the time sequence. Specifically, we came up with the postcards generated in different granularity sets (*i.e.,* a meal, a day, a week) along the time series data for different reflection purposes. For the postcard generated for a day or a week, we summed up the nutritional data and picked the most frequent emotion in that period to design the front side visualization. After ranking all the posts by their total numbers of "likes" and comments, the pipeline selected the top one as the representative to design the backside (*i.e.,* message, stamp) of the postcard. Finally, we sent all sets of postcards (*i.e.,* per meal/day/week if there was any) to participants through email three months later, and invited them to hold an on-site or a phone interview to obtain their reflections on their food intake and emotional status through our design.

Dataset Description

We collected the data from 20 individuals who had been posting their detailed food-emotion information over three weeks. These three weeks cover the final exam period, *i.e.,* before, during, and after the exam week. After removing the invalid food posts (*e.g.,* no food image input), the final food post dataset contains 513 entries in total, including 151 breakfast entries, 183 lunch entries, 169 dinner entries, and 10 snack entries. Each entry consists of a photo of the food accompanying the text post and metadata including the post timestamp and location. The participants have given an average of 25.65 posts per participant (*min*=5, *max*=58) over the course of three weeks, thus posting at least once per day of their food footprints.

FINDINGS

Our postcard design provoked a range of reflections in the study. In this section, we describe participants' feedback towards the postcard design and the auto-generation method. We also report the collected reflections unfolded across different individuals on the data, context, action, and value subjects.

Initial Impressions

Overall, all participants felt it was a nice surprise to receive the postcards. They commented that they never thought about receiving such postcards for self-reflection. As participants mentioned, "*I felt happy when I received the postcards, as I really like to remember memories*" (P17, male, 18), and "*the postcard is very interesting and surprising*" (P4, female, 21). One participant regretted, "*if I had known I would receive such interesting postcards, I would post more...*" (P5, male, 27).

Participants got even more excited about the postcard when they were told that the front side encoded their past posts on food and emotion. When first looking at the postcard's front side, participants were eager to understand the specific meaning of the content by referring to the legend. After looking over one or two of the postcards, participants praised the design as being "*simple*" (P1, male, 22), "*thought-provoking*" (P9, male, 27), and "*not packed with heavy numbers*" (P7, male, 26). One participant replied, "*It does not require a high level of data literacy. The legend helps me understand the mapping...there is zero learning effort when I read the next [postcard]*" (P14, male, 22). Participants agreed that the backside is also attractive, and they commented, "*The backside is more informative to me, it is like a real postcard*" (P8, female, 22), and "*I can see my posts from [the backside], which provides a lot of memory cues and clues*" (P11, male, 21).

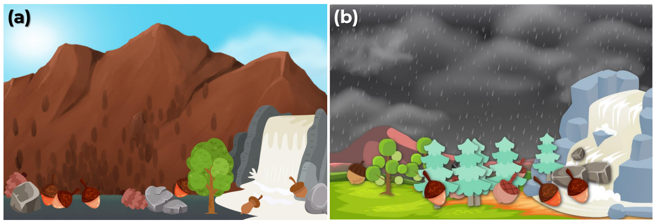

Figure 3. The front side design of two representative postcard designs: (a) reveals a joyful status with high carbohydrate intake (P1, male, 22); (b) indicates a sad status with a lot of fiber and protein (P13, female, 22).

When introducing the method of generating these postcards, participants admitted "*[the pipeline] is convenient for me to understand the underlying information*" (P6, male, 30), and "*...I do not need to google those food names to understand what I ate*" (P10, male, 24). They also thought the summarized results provided a lens for reflecting on their data at different granularities, "*I really posted differently among the [exam] weeks...I did not realize that until I focused on the weekly posts*" (P3, female, 21). Participants can also get summarized results for coarse-grained reflection on their food posts, "*I did not post regularly during the three weeks...thankfully I can still learn my weekly eating patterns*" (P19, male, 23).

Reflection with the Postcard

During the interview, participants reflected on their food posts with the help of the postcards and gained insights of various levels of depth from data readings to contemplation of personal values and attitudes.

Reflections on Data: Exploring Food & Emotional Experience

All of the participants explored the postcards designed for a specific meal's, day's, or week's reflection, including examining the detailed records and extracted information, identifying the patterns and trends, and exploring the relationships of the recorded data. When receiving the postcard for the first time, participants would refer to the backside first to become familiar with the specific meal and the message. While turning to the front side, they could learn about their emotion and nutrition intake by referring to the legend.

Reflections on each meal and the related nutritional and emotional records allowed participants to understand the correlations between their emotion and food choices. For example, P2 (female, 20) realized that she used to feel happy when she had the salad with high-quality proteins. While P1 (male, 22) found that he preferred high-calorie food when he felt joyful, "*I really had a lot when I was happy. I think food can soothe my heart*" (Figure 3.(a)). P10 (male, 24) also boosted himself up with calorie-rich foods when he felt down, "*during the exams, I felt energetic after I had the fried chicken and cheese pizza*". On the contrary, P3 (female, 21) felt negative when she had high-calorie dishes, "*I felt guilty when I took the fast food, but I had no choice because I was so busy at that time*". In total, 16 (out of 20) participants found that they ate differently before and after the exam, while two of them reflected that they seemed to exhibit stress eating during the exam week.

Reflections on the aggregated data of a period caused participants to recall their previous eating habits and characteristics. For example, P16 (male, 19) said, "*I can identify that I aimed to have enough fiber on Monday, while there is an obvious increase in protein and fat on Tuesday*". Additionally, dietary preferences can easily be extracted from the patterns revealed from the postcards. For example, some participants realized that they usually preferred lightweight salads or fast food during the exam week as they can "*keep a clear mind*" (P2, female, 20) and "*save time*" (P12, male, 23). Some participants noticed their patterns on the choice of food, as P14 (male, 22) realized that he "*used to take Chinese food a lot*", and P7 (male, 26) found that he had the same breakfast every morning.

When comparing the three weeks' postcards, participants can easily identify the similarity, the difference and the trends presented from the front side. For example, P11 (male, 21) found that he got a huge intake of protein and carbohydrates during the exam week, as he reflected "*I guess I probably consumed a lot of energy during that week*". Most participants found that the visual design is comparable and they could tell whether there was a clear drop or increase of a certain nutrient among these weeks. "*When I compared with [week #1], I see even fewer carbs than the one in [week#2]. The amount of protein has more or less to say...I have reduced the sodium intake remarkably in the second week*" (P9, male, 27). Participants observed their aggregate emotional experience by comparing the weekly postcards. P15 (male, 20) recognized that he "*felt down*" and "*nervous*" in the first two weeks, but lightened up after the exam week. He added, "*I can see a notable difference among those weeks, as the sunny weather [on the postcard front side] dominates the last week*".

Reflections on Context: Recalling Post-Related Memory

In this section, we report the interpretations of the postcards in the light of the context of the food posts. Most obviously, after seeing a postcard generated based on a specific meal, every participant naturally started to recall and describe the scene that happened at that moment. The message, the image, and the address on the backside enabled participants to recall the details of the past event, such as what they ate and whom they ate with. P9 (male, 27) mentioned, "*...that was a big union and I was surrounded by a couple of friends*". After reading the backside, P12 (male, 23) recalled, "*...the shrimps with the egg, I remember this meal very well...That was the one that I had during the trip after the exam. It reminds me of a lot of happy moments*". What is more, the changes in the "weather" on the front side visualizations demonstrated participants' emotion variations, as P13 (female, 22) explained, "*I was good during the first two weeks, but I felt low in [week #3] because I did not perform well in the exams*" (Figure 3.(b)).

Participants further recognized personal life routines or patterns by reflecting on the whole set of postcards. Some of them found places they preferred to go, "*When I feel sad or down I used to go to Starbucks and have a lot of desserts...It was convenient and relaxing*" (P8, female, 22). Some others discovered their social habits through reflections on the food, "*I enjoy eating outside together with my friends at the end of the week*" (P9, male, 27). P7 (male, 26) mentioned that the postcard reminded him of the events which happened before and after having the food, as "*the postcard suddenly reminds me a lot of stuff, like how we got there, how we chatted with each other at a special place chosen by our host, and I still remember the hiking part after the dinner*". The sweet memories brought back by the postcards reminded P8 (female, 22) that she had not contacted her dear friend since they graduated. These reflections triggered in the participants' a series of recollections of the past, not only the meal but also that period of life, the people they met and what impressed them the most.

Reflections on Action: Triggering Future Reaction

Participants also motivated and developed actionable strategies. Postcards helped participants identify problems in their eating habits that they never realized before. For example, P10 (male, 24) found that "*I kept a good control on carbohydrate intake, but I might take too much sodium...I also need to have more vegetables in my future plans*". P6 (male, 30) noted, "*I had bacon almost for every breakfast...I need to change that habit...The postcard would be helpful as a healthy eating check reminder*". On the other hand, some participants confirmed their past healthy lifestyle and became more confident and determined to stick to their goals, "*I kept a balanced diet during these three weeks. That makes me feel proud as I can take care of my health*" (P2, female, 20). P16 (male, 19) confirmed the habits he has kept, as he follows the "Meatless Monday" rule to keep healthy. "*I am pleased to see that the postcard proved that I do keep the habit*", he said. At the same time, participants started to recognize their life patterns after referring to the postcards and became inspired to try something new. "*At some special moments, I would turn to western food, which should be different*" (P14, male, 22); "*I will try another dish for breakfast*" (P7, male, 26). The postcards also positively influenced participants' social activities. The pleasant memories from the past encouraged participants to cultivate social relations, and the postcards provided an opportunity to reconnect with friends. "*This postcard brings a lot of memories. I cannot wait to contact my friends*" (P8, female, 22).

Compared with the conventional food tracking method, participants agreed that the auto-generation pipeline would encourage them to post food. Traditional software often asked users to manually upload data. Such complex procedures have led to a laborious and time-consuming process. In contrast, the pipeline offers an opportunity for users to track their food and emotion with a better user experience. As P8 (female, 22) commented, "*I will be very motivated to continue posting instead of...you know, searching for a nutrition database. I tried a couple of the tools but I can only keep the practice for two to three days. Now I see that it's a potential way to improve this situation*".

Reflections on Value: Involving Personal Pursuit

We report participants' reflections on the contemplation of personal values, characteristics, and attitudes in this section. Participants rediscovered their behavioral patterns with the comprehensive analysis of their daily and weekly postcards. For instance, P6 (male, 30) agreed that "*I am a workaholic. I do not have very special demands on the food quality*" as his postcards showed little variance in the size and number of front side visual elements. P12 (male, 23) realized he usually just grabs anything convenient, and several visual elements (*e.g.,* "tree") occasionally appeared in the front side landscape design. The information extracted from postcards that are related to personal values and eating is regarded as a manifestation of behavior. "*I can align my value of health with the way I eat. I am happy to see that eating is not just something that I have to do for survival but which also can be part of my core values*" (P4, female, 21). P7 (male, 26) reflected on and revised his previous personal expectations, "*Now I see that maybe I am more conscious than what I believe...I see that I didn't have any hesitation or any kind of resistance within me to eat healthier food*". As for personality, P1 (male, 22) himself initially thought he was a good-tempered person with a positive personality. However, the participant doubted this after he found most of the front side pictures showed bad weather. "*I feel frustrated with the exams. I think I should face it and seek help when necessary*". Furthermore, the front side of the postcard design also invoked participants to think widely about their personal contribution to society. After seeing the image with unhealthy food on the postcard, the natural landscape on the front page triggered P9 (male, 27) to contemplate the meaning of a low-carbon life. He thought the awareness of eating healthily is not only good for himself but will also have a positive impact on the people around him.

Overall Perception

Throughout the whole reflection process, all participants commented that the visual design of the postcards was appealing and interesting. Meanwhile, the visual elements and metaphorical encoding scheme, which carries information revealing health and well-being, eliminate the discomfort caused by a direct translation of the raw data. As participants commented, "*I feel relieved when looking at the visualization. I know that I had excessive amounts of food, like in the buffet, but it doesn't make me feel bad. It is a comical way to see things and it is very light-hearted*" (P14, male, 22), and "*the postcard fits my goal of keeping track of my health in a pleasurable and convenient way...without the precise numbers, I am not worrying the tiny difference varied from my goal*" (P3, female, 21). Two participants (P2, female, 20; P18, female, 18), who minded sharing and comparing personal health information with strangers, were very pleased with the postcards. As the metaphorical encoding hides the original information and maintains a non-judgmental mindset in an inoffensive manner, the visual design eliminates social media anxiety [64]. However, four participants (P6, male, 30; P13, female, 22; P16, male, 19; P19, male, 23) were not accustomed to this representation and pointed out there were no "*clear values to measure nutrition*". We understand that the participants are used to evaluating their performance by looking at the specific values and scales for precision. Instead, we aim to create an attractive and appealing visualization for self-reflection rather than a "number-centric" design with critical and obsessive measurements.

As the postcards collected and presented information along the time series, participants expressed their willingness to retain the received postcards. P4 (female, 21) preferred to print out the postcards and keep them as a collection for food and emotion records. P13 (female, 22) mentioned, "*I would create a slideshow to present all the postcards...listing the front and the back of the postcard side by side...I can observe how I changed from slide to slide*". Furthermore, P20 (female, 19) said she would hold an exhibition to present her postcards with others. This feedback reflects that our design has the potential to support long-term reflection goals and eliminate the "learned enough" situation [22] due to the design diversity.

DISCUSSION

Non-Judgmental Design for Self-Tracking

In this paper, we apply a casual visualization to foster users' non-judgmental reflection on their social media food posts. Our design elicits less judgment and deeper reflections beyond self, and facilitates users' interpretation of the metaphorical mapping in an experienced way. It also reunites users with their memories and engages them. However, such metaphorical mapping also brings challenges in decoding information behind the representation. First, it takes time to learn the encoding when users first see such design as it is not as straightforward as the raw number. It also requires users' cognitive costs to avoid diagnosing behavior when reflecting on the past. As P7 (male, 26) confessed, "*my judgmental mindset makes me want to evaluate my calorie with numbers...the landscape design urged me to think differently*". Second, the non-judgmental design is not a panacea to treat all the problems when designing user interfaces for self-tracking. Especially when professional measurement data is required, self-tracking users need to be aware of the exact value to understand their performance. "*I would refer to the statistical number to follow my food tracking when taking my muscle building seriously*", commented P6 (male, 30).

Automation versus Personalization in Design

The automatic approach in our design enables users to reflect on their past behaviors by looking for patterns, and we also implement the design with randomness to increase visual diversity. From participants' feedback on our auto-generation pipeline and postcard design, we find automation reduces error-prone processes and decreases the dependence on human resources for self-tracking, but it does not support the expression of personalized differences and present personal style. Users can also interpret each other's visualization information on the postcards' front side since they share the same encoding from the automated process. However, personalization can protect users' privacy by asking them to choose their favorite design elements or encoding scheme, although the overly personalized settings may mislead users into focusing on decorating their personal postcards instead of reflecting upon the represented information. Since experiences are unique and personalized, it is impossible to find an almighty encoding approach for all users, and different themes could provoke diverse reflections beyond self. Personalized mapping strategies [33] may be considered in casual visual design to provide a better experience. Designers may consider automated processing with personalized feedback to enable self-reflection, where automation is the basis for personalization.

Adopting Postcards for Self-Reflection

The postcard is a slower communication medium that combines both textual and visual content, capturing particular moments and memories [32]. As a carrier, the postcard is an appropriate way to help users recall past experiences by reproducing their data, because it facilitates the reflection on data, context, action, and value [67] with basic levels of reflection [23]. In particular, participants appreciated it, as the reminiscence content on the backside (*e.g.,* address, stamp) supports revisiting their personal data, while the front side provides an explanation of the information extracted from their posts. Information on time, location and past photos functioning in tandem with the casual visual design, provide direct memory cues of the context for users. As for the textual content design, the form of writing to oneself [49] worked well for self-motivation and action since it was more natural and closer, as "*I like reading letters from others. [The message] makes me feel encouraged and close to people*" (P18, female, 18). Together with the front side visualization, the postcard provides a wider implication to evoke users' thinking about the value. Therefore, it is worth considering and adopting the postcard when aiming at self-reflection. Designers could also consider physicality – printing out the postcards [28, 42] as participants mentioned in the interviews – to foster active engagement with familiar actions and materials.

Limitations and Future Work

This work has several limitations. First, this paper only considers the postcard designed on a full-scale landscape in a 2D cartoon style. We expect that the postcard design would be varied in different styles, and we would expand the auto-generation pipeline with extended design libraries by investigating the postcard design space in the future. It is also interesting to know how different visual designs would impact users' self-reflection results. Second, the sample size in our study is too limited to be considered representative. Future research could be to enlarge and diversify the demographics and explore how different populations would reflect upon their food posts, or to investigate how the postcard design would impact people's behaviors in real-life. As participants expressed interest in posting more food with the proposed pipeline, we are interested in validating this assumption and exploring whether such a design could play a positive role in changing users' behaviors through a longitudinal study. Third, there is a gap between the predictions computed by the state-of-the-art models [75] and human's original interpretations. Since the precision enhancement of the final results is beyond the scope of this paper, we leave such improvements for future work. Future research could also consider a more comprehensive comparative study by exploring differences in reflection upon the postcard design and the raw food posting records.

CONCLUSION

This paper delineates an exploration of users' self-reflection on their food posts with an auto-generated postcard design. In this paper, we first present the postcard auto-generation pipeline to transform social media food posts into a postcard design. The information provided in the postcard includes the nutrition, emotion, and context information extracted from the multimedia food posting data. Specifically, we extract the nutrition information from the imagery data by applying image recognition techniques together with the nutrition database; we retrieve the emotion labels from the textual data based on a meta-learning approach. Secondly, based on the mined information, we design a visual encoding scheme based on metaphors for the front side of the postcard. This is to minimize the judgmental issue during the self-reflection process. The backside of the postcard provides the contextual information in more detail (the original form of the data) together with the legend to help people digest the postcard. We aim to encourage users to reflect on their life records and spot patterns between personal nutrition intake and varying emotion in a non-judgmental manner. Lastly, our study feedback indicates that our design boosts pleasant aesthetics and achieves effective self-reflection towards data, context, action, and value subjects. We discuss any potential issues identified in designing self-tracking visualizations and possible directions for future research in the context of creating tools for self-reflection.

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