Identifying and Planning for Individualized Change: Patient-Provider Collaboration Using Lightweight Food Diaries in Healthy Eating and Irritable Bowel Syndrome

CHIA-FANG CHUNG, Informatics, Indiana University Bloomington
QIAOSI WANG, School of Interactive Computing, Georgia Institute of Technology
JESSICA SCHROEDER, Computer Science & Engineering, DUB Group, University of Washington
ALLISON COLE, Family Medicine, University of Washington
JASMINE ZIA, Division of Gastroenterology, University of Washington
JAMES FOGARTY, Computer Science & Engineering, DUB Group, University of Washington
SEAN A. MUNSON, Human Centered Design & Engineering, DUB Group, University of Washington

Identifying and planning strategies that support a healthy lifestyle or manage a chronic disease often require patient-provider collaboration. For example, people with healthy eating goals often share everyday food, exercise, or sleep data with health coaches or nutritionists to find opportunities for change, and patients with irritable bowel syndrome (IBS) often gather food and symptom data as part of working with providers to diagnose and manage symptoms. However, a lack of effective support often prevents health experts from reviewing large amounts of data in time-constrained visits, prevents focusing on individual goals, and prevents generating correct, individualized, and actionable recommendations. To examine how to design photo-based diaries to help people and health experts exchange knowledge and focus on collaboration goals when reviewing the data together, we designed and developed Foodprint, a photo-based food diary. Foodprint includes three components: (1) A mobile app supporting lightweight data collection, (2) a web app with photo-based visualization and quantitative visualizations supporting collaborative reflection, and (3) a pre-visit note communicating an individual's expectations and questions to experts. We deployed Foodprint in two studies: (1) with 17 people with healthy eating goals and 7 health experts, and (2) with 16 IBS patients and 8 health experts. Building upon the lens of boundary negotiating artifacts and findings from two field studies, our research contributes design principles to (1) prepare individuals to collect data relevant to their health goals and for collaboration, (2) help health experts focus on an individual's eating context, experiences, and goals in collaborative review, and (3) support individuals and experts to develop individualized, actionable plans and strategies.

CCS Concepts: • **Human-centered computing → Collaborative and social computing →** Empirical studies in collaborative and social computing

Additional Key Words and Phrases: Self-tracking, personal informatics, patient-provider collaboration, collaboration, patient-generated health data, food

Author's addresses: Chia-Fang Chung (cfchung@iu.edu), Informatics, Indiana University Bloomington, Bloomington, IN, 47405, USA; Qiaosi Wang (qswang@gatech.edu), School of Interactive Computing, Georgia Institute of Technology, Atlanta, GA, 30332, USA; Jessica Schroeder (jesscs@cs.washington.edu) and James Fogarty (jfogarty@cs.washington.edu), Paul G. Allen School of Computer Science & Engineering, DUB Group, University of Washington, Seattle, WA, 98195, USA; Allison Cole (acole2@uw.edu), Family Medicine, University of Washington, Seattle, WA, 98195, USA; Jasmine Zia (jzia@medicine.washington.edu), Division of Gastroenterology, University of Washington, Seattle, WA, 98195, USA; Sean A. Munson (smunson@uw.edu), Human Centered Design & Engineering, DUB Group, University of Washington , Seattle, WA, 98195, USA.

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1 INTRODUCTION

People increasingly collect data about their day-to-day activities, behaviors, and decisions, often with goals of understanding and improving their health and wellbeing [34]. This information has the potential to help people better understand themselves and make decisions about behavior change [48]. Personal informatics tools can also provide objective information about people's health and wellbeing more frequently than routine health checkups. However, many people face challenges when trying to make sense of the data, which often leads them to abandon tracking without reaching their goal [21,27,45].

When people struggle to interpret their data, they frequently share their data with health experts (e.g., physicians, dietitians, or health coaches), in the hope that an expert's medical knowledge can help in interpreting their everyday behavior data [34]. However, health providers often consider their time insufficient or training inadequate to provide behavioral counseling [25,44]. Current commercially-available systems are also designed to support individual use, which creates more challenges when people try to share their data with health experts. For instance, people and health professionals often find that systems are inflexible and do not support creating behavioral change plans tailored to individual health goals [19].

Dietary data is particularly important for many preventive care and chronic disease management goals. Dietary-related chronic diseases affect half of the U.S. adult population and result in more than $200 billion of medical costs [71]. Dietary consultation with health professionals can increase awareness of and monitoring of decisions around dietary and other health behavior [28,64,75]. However, traditional food diaries are often burdensome, and the challenges of data collection can nudge people toward pre-packaged food and other behaviors contrary to their goals [24]. Photo-based diaries can ease the burden of data collection and support reflection on eating behavior and context [7,18,23]. Photo-based diaries also allow diabetes educators to teach patients about how to reflect and analyze their diet [50].

To better understand how photo-based food diaries can support patient-provider collaboration, we designed and developed Foodprint, a photo-based food diary and visual summary supporting lightweight data collection and collaborative reflection. We designed Foodprint to scaffold the process of creating boundary negotiating artifacts [46] from patient data, based on previous results that patients and providers often transform self-tracking data into various boundary negotiating artifacts to support their collaborations [20]. Boundary negotiating artifacts are artifacts created and used to facilitate negotiations and discussions as people collaborate across boundaries of practices and roles (e.g., patient practices versus provider practices) [46]. For example, providers might create a new artifact by writing down findings from patient diaries to support discussion about diet change strategies. Patients and providers often use these artifacts to include patient goals and constraints in discussion, to collate information from various sources into clinical decision making, and to structure plans that patients can follow after visits [20]. However, current systems often do not provide enough flexibility or effective summaries to support the creation of these artifacts. Our research examines how to design photo-based diaries as artifacts to support individuals and health experts in individual and collaborative examination of healthy eating strategies and identification of symptom triggers.

Foodprint includes a mobile app for collecting food photos, a web app for individual and collaborative review, and a pre-visit notes to support patient-provider collaboration. In the web app, we designed two types of visual summary: (1) summaries presenting photo diaries based on healthy eating goals and IBS trigger identification goals and (2) summaries presenting quantitative analysis of IBS triggering nutrient adapted from [66]. We introduced Foodprint to 17 people with healthy eating goals and 7 associated health experts as well as 16 IBS patients and 8 associated health experts to understand its use in patient-provider collaboration. To explore how patients and providers would use photo-based visualizations solely or with more quantitative analysis, we presented the quantitative analysis visualization to half of IBS patient-provider pairs (i.e., 8 patients with 3 providers).

Participants and health experts used the photo-based visualizations as self-explanation artifacts (i.e., artifacts for individual use), inclusion artifacts (i.e., artifacts that include data from multiple sources to support discussion), and structuring artifacts (i.e., artifacts that help develop and coordinate actions). Participants used the Foodprint mobile app to collect data relevant to their health goals. They also reflected on their eating patterns using photo-based visualizations on their own. Participants and health experts used the photo-based visualizations as inclusion artifacts to identify trends and patterns related to individual health goals as well as to exchange knowledge to interpret data collaboratively. Reviewing

pre-visit notes also helped participants and health experts focus on participant goals, and reviewing data relevant to those goals, during the consultation. When IBS participants struggled to identify triggers using the photos alone, participants and health experts turned to the visualization of quantitative analysis to look for potential triggers at the nutrient level. Although we did not explicitly design for structuring artifacts, participants and health experts also used photos in the visualizations as examples for developing individualized, actionable plans.

Building upon prior research on patient-provider collaboration using self-tracking data, our results highlight design opportunities to support collaboration throughout the tracking process and to account for different individual goals and health expert roles. We demonstrate how a photo-based diary and visual summary system can be designed to help individuals and health experts collaboratively identify healthy eating strategies and IBS triggers and to develop individualized management plans. We also show how these designs can help individuals and health experts explicitly include individual goals and knowledge in discussions and in developing strategies and management plans. We further discuss the potential of adopting more automated analysis to support collaboration, but we caution that automated processes risk losing valuable qualitative contextual information. Although we designed Foodprint for healthy eating and IBS, our research provides insights that may extend to other health conditions involving identifying dietary strategies and symptom triggers.

2 BACKGROUND

Our research builds on prior examinations of self-tracking data to support healthy behaviors, chronic disease management, and patient-provider collaboration. In our research, we focus on two common challenges in which patients and providers seek to use personal informatics data: identifying healthy behavior changes and identifying symptom triggers.

2.1 Personal Informatics Systems

The prevalence of smartphones and wearable sensors has made health tracking more convenient and more accessible than ever. One in three people worldwide uses an online or mobile app or a wearable device to track their health or fitness [53] and numerous health-tracking applications have been designed to support various aspects of personal tracking.

Despite the range of available applications, many people report difficulty maintaining a habit of tracking and making sense of this data; they often give up tracking before achieving their goals [21,27,45]. Designers have attempted to ease the burden of data collection and improve data presentation to support people's tracking goals [16,43]. Using visual analysis techniques, systems can promote self-reflection on personal data [17,26]. Using quantitative analysis and machine learning models, systems can help users correlate and identify factors that might influence their health behaviors and outcomes [10,61].

People also use personal informatics data to diagnose and manage chronic conditions via self-experimentation. For example, people with IBS often keep track of their food and symptom data and undertake trial-and-error strategies to determine their likely symptom triggers. To provide more rigorous support of self-experimentation, TummyTrials helps IBS patients design, implement, and analyze results from self-experiments investigating whether a specific food could be a trigger of their symptoms [40]. People with diabetes also commonly track their food, exercise, and blood glucose level. Those who do so tend to follow their regular activities and routines until their symptoms or conditions disrupt their activities and create breakdowns in their routine. These breakdowns in routines create opportunities for people to reflect on and make sense of their data [50,51]. However, for people to be able to discover opportunities and strategies for change from their self-tracked data, they often need to go through various stages: selecting features/triggers that cause changes in glycemic control, hypothesizing relationships between those features and their perceived symptoms or glucose variations, examining collected data for evidence about the hypothesis, and setting future goals [49]. Our research builds upon self-tracking challenges reported in prior work. We designed Foodprint to support individuals as they collect, reflect, and act on their data. Specifically, using dietary data collection and review as an example, we examined how to support people collecting data relevant to their health goals, reflecting on patterns of tracked data, and developing individualized strategies.

2.2 Technologies to Support Dietary Data Collection

Dietary intake is one of the most popular and prevalent types of health-tracking data people monitor. Although automatically collecting food data through different devices can potentially alleviate tedious data entry, the cost of these devices and the concern for being socially inappropriate tend to stop people from adopting such methods [39]. Manual tracking also enables people to be mindful of what they eat [16]. Manual food diaries are still the most widely adopted food tracking technologies.

Despite the rich details manual food diaries can provide for understanding individual diets, tracking using these diaries is difficult to sustain [13,24]. Electronic diaries also rarely allow users to tailor the diaries to their health goals [23,24]. Most food tracking diaries require people to look up and manually enter food information such as food names, nutritional

data, and calorie count. Even with features to scan product barcodes and access crowdsourced databases, most people still find food tracking burdensome. These features also can nudge people toward eating food that is easier to track (e.g., packaged food) rather than food that supports their health goals (e.g., fresh, homemade food) [24]. The emphasis on calories also encourages people to rely on food-tracking applications to decide their eating time, content, and portion, instead of understanding individual needs [30]. Most food tracking technologies are designed to correct "undesirable" eating behaviors instead of focusing on the positive and delightful eating experiences [31].

Given these issues with traditional food diaries, researchers in HCI and health informatics have investigated photo-based diaries. Photos can help people recall their eating context [23] and become aware of their habits and routines [7]. When shared with others, photos can motivate people to reflect on their choices and to make diet changes [57]. Including photos with other health tracking data, such as glucometer data, can also help diabetes patients identify potentially unhealthy decisions [67]. Tracking food using photos is often more fun and socially appropriate than traditional food journals [18,23]. However, photos do not contain detailed nutrient information that is potentially useful, such as when patients need to strictly monitor specific nutrients due to medical conditions (e.g., monitoring sodium intake after cardiac surgeries). Our research examines the use of photo-based diaries in collaborative dietary review, a process used to address a variety of health and healthy eating goals. We designed Foodprint based on photo-based food diaries and augmented it with light-weight manual tracking that would support individuals in recording information relevant to their health goals but not otherwise captured in food photos.

2.3 Patient-Provider Collaboration around Personal Informatics Data

Interpretation of self-tracking data often requires both provider medical expertise and patient knowledge about their contextual factors, such as their everyday routines [4,20,52,54,66]. Although people often collect data on their own, health provider involvement and collaboration can influence how people make decisions about what, when, and how long to track; how to interpret the resulting data; and what to do based on the results [20,48]. Reviewing self-tracking data together can help providers and patients develop diagnoses and individualized treatment plans, increase patient adherence, and improve relationships between patients and providers [19,20,50,72]. Deeper understanding of patient conditions and insight into patient behaviors between visits provides an opportunity for providers to revise plans without additional clinic visits for patients [22]. Increased patient participation in collaboration with providers also might lead to the shift of responsibility to patients themselves [29].

However, health providers often question the accuracy, reliability, and completeness of patient-tracked data [29,66,74]. They also think they lack sufficient time to review patient-tracked data in short clinic visits [25,44]. While trying to make sense of this data collaboratively, patients and providers often prefer different data representations, and thus gain different insights from the data or focus on different problems. These differences between patient and provider perspectives make the collaborative problem-solving process challenging [62].

Researchers have started to investigate how to design tools that better support patient-provider collaboration. In *myRecord*, patients could annotate their implantable cardioverter-defibrillator data with their personal interpretations [3]. By reviewing this annotated data, clinicians were able to integrate patient interpretation of their condition and the sensed data into the decision-making process. Patient-provider collaboration has also been examined in Parkinson's disease, which may be treated with deep brain stimulation. Presenting the deep brain stimulation graph to patients and their providers helped providers consider patient perceptions and feelings in treatment decisions [55]. *MAHI* helped diabetes educators teach reflective skills based on patient tracked and shared dietary and blood glucose data [50]. *mFood* let patients log portion size, then presented this to clinicians data along with steps and sleep data tracked by wearable devices [42]. In an evaluation of mFood, provider involvement increased patient motivation for tracking, and clinicians thought the review process increased communication opportunities with patients. In a study with IBS patients, visually presenting the correlations between food nutrients and symptoms allowed providers and patients better understand the data and become more confident about the data quality and about each other's interpretation of the data [66].

This prior research shows potential for designs that use self-tracking data to support patient-provider collaboration. It demonstrates the value and importance of including patient experiences and provider knowledge in review of self-tracking data. However, research has continued to highlight challenges of using this data in clinical visits. Time constraints in visits sometimes prevent patients and providers from efficiently reviewing large amounts of data [29,73] or communicating and addressing patient goals and concerns [11,73]. Patients and providers also find it difficult to include contextual information and patient experience in the discussion to help collaboratively make sense of self-tracking data [19,20,29,63]. Current systems rarely provide effective summaries and actionable information to help patients and providers develop individualized, actionable recommendations [42,66,73,78]. Our research examines designs that address the challenges of collaborative review of self-tracking data. In particular, we designed Foodprint to support patients and providers in

explicitly communicating about individual goals, sharing contextual data and expertise in support of data interpretation, and developing individualized and actionable plans.

2.3.1 Boundary Negotiating Artifacts in Collaborative Use of Personal Informatics Data. We drew on boundary negotiating artifacts to design Foodprint and to examine collaborative use of Foodprint between individuals and health experts. Lee proposed *boundary negotiating artifacts* to describe the negotiating or coordinating processes individuals or groups go through in collaboration and the artifacts they use to support these processes [46]. Lee defined five types of boundary negotiating artifacts: (1) *self-explanation artifacts*, which are created for personal use; (2) *inclusion artifacts*, which are created to present new concepts in discussion; (3) c*ompilation artifacts*, which are created to develop shared understanding among multiple groups; (4) *structuring artifacts*, which are created to direct and coordinate activities; and (5) *borrowed artifacts*, which are augmented artifacts used in unanticipated ways.

To develop shared understanding about patient-tracked data, patients and providers often use and transform this data into various boundary negotiating artifacts [20,46]. *Self-explanation artifacts* allow patients to collect and individually reflect on tracked data, with or without provider instruction. For example, patients might create their own diaries or use paper diaries provided by providers. *Inclusion artifacts* help patients and providers to negotiate about including this data in medical decision making. For example, providers might take notes from or annotate patient diaries to support shared understandings. *Compilation artifacts* help combine patient-tracked data and data from other sources, such as medical examination. Notes in the electronic medical record (EMR) are a common compilation artifact in clinical settings: they include patient medical history, test results, and recommendations. *Structuring artifacts* support patients and providers to develop care plans following the visit. For example, providers might print out instructions from the EMR or provide additional handouts for patients to follow a specific diet. Designing systems that support the creation and transition of boundary negotiating artifacts can help individuals and health experts collaborate using data recorded by individuals. In this research, we implemented and evaluated one system. We draw on these results to describe nuanced design principles that support the creation and use of boundary negotiating artifacts in collaborations between individuals and health experts.

2.4 Study Context

In this research, we focus on two health challenges that often benefit from tracking and examining food data: healthy eating and IBS. We choose these two contexts because both populations commonly track food intake and work with health experts to make sense of food data. However, these two populations have distinct health goals and work with different types of health experts: people with healthy eating goals often work with *nutritionists, health coaches, or dietitians* to identify *behavior change strategies*, and IBS patients often work with *physicians, nurses, and dietitians* to identify *triggers for their symptoms*. Examining how these two populations use Foodprint allows us to identify themes supporting common dietary tracking and review as well as opportunities for customization based on health goals and health expert roles.

2.4.1 Healthy Eating. Eating a healthy diet helps prevent obesity and chronic illnesses such as cardiovascular disease and diabetes [71]. Healthy eating goals vary by person. Some want to eat more vegetables and fruit, others want to have balanced diets or avoid processed foods [24]. Working with health providers on healthy eating can help people interpret their own data [64], elicit behavior change [12], and achieve better health outcomes [9]. However, patients often feel that providers only offer general recommendations without customizing plans to address their concerns or cater to their constraints and preferences [4]. These patient concerns diminish patient-provider trust and lead to low adherence to these recommendations [28]. These concerns show that when patients and providers attempt to transform self-tracking data into boundary negotiating artifacts that support collaboration, they often face challenges in including patient goals and experience. Because current self-tracking systems do not support customizations based on individual goals, providers often spend most of the visit time eyeballing the patterns and trends in patient-tracked data, unable to focus on individual experiences. Systems supporting patients and providers reviewing dietary data together need to allow both parties to communicate about patient goals, concerns, and routines and to help patients and providers develop insights and individualized plans from the data [20].

2.4.2 Irritable Bowel Syndrome. Irritable bowel syndrome (IBS) is an example of a chronic disease in which patients benefit from collaboration with providers. IBS affects 12-30% of the population [76]. Patients with IBS also have significantly reduced quality of life, as a large number of factors, including foods, nutrients, and stress, might trigger symptoms such as constipation, diarrhea, bloating and abdominal pain [76].

IBS patients have individualized responses to potential triggers, and therefore are often advised to keep a diary to monitor food [2]. However, patients report that looking up and filling out nutrient information is time-consuming and burdensome. As a result, patients tend to fill out paper diaries long after they eat, which results in inaccurate and biased data [13]. Similarly, providers report challenges interpreting diaries during clinic visits [35]. Current clinical diary review relies on providers manually skimming paper diaries to identify correlations between potential triggers and symptoms. However, there is also no objective, validated methodology for determining individual triggers from these diaries [35,78]. As a result, many IBS patients

are dissatisfied with the feedback they receive from providers reviewing their diaries [32,38]. IBS patients need better support to use diaries as self-explanation artifacts that can help them collect data easily and identify their symptom triggers. When reviewing data in clinical visits, providers need systems that can help them to transform these diaries into inclusion artifacts that help them interpret the relationships between potential triggers and symptoms.

2.5 Research Question

In this research, we seek to understand how we can design photo-based food diaries to support people and health experts to collaboratively identify healthy eating strategies and IBS triggers. Through the lens of boundary negotiating artifacts [20,46], we focus on understanding common themes across these two different goals and pay attention to opportunities unique to each health goal. We focus on the following research question: Using photo-based food diaries as an example, how can personal informatics systems be designed to serve as boundary negotiating artifacts to support individuals and health experts in collaborative collection, review, and interpretation?

3 FOODPRINT SYSTEM DESIGN

To help answer our research question, we designed and developed Foodprint, a photo-based food diary and visual summary system. We designed this system to support the creation and sharing of boundary negotiating artifacts, based on prior studies in understanding patient and provider needs with IBS and healthy eating [19,20,66,77]. We focus the design on self-explanation artifacts and inclusion artifacts to support low-burden data collection and to help individuals and health experts include individual expectations and experiences in discussion as well as in the formulation of individualized and actionable plans.

Prior work has shown potential for using photo-based food diaries to support healthy eating [23] or to help people learn reflective skills from diabetes educators [50]. We adapted the design of photo-based diaries from prior studies to focus on helping people communicate their healthy eating goals and progress with health experts. Using food photos to identify IBS triggers, however, is different than using photo-based food diaries for general healthy eating goals [18,23]. Details about foods that are difficult to see in photos can be potential triggers (e.g., spice, extra oil/dressing, artificial sweeteners). Food preparation methods and sources are also important information for trigger identification. Finally, understanding patient preferences or constraints about food can help providers develop more personalized strategies. Therefore, we implemented ways for people to enter this information in the system to augment reviewing the food photos (Appendix 1). We iterated on the system design with ten pilot users and five health experts over the course of three months to refine design details and address usability issues.

Foodprint consists of three tools: (1) a mobile app supporting in-the-moment, low-burden food capture, (2) a web app presenting relationships between food and health goals, and (3) a pre-visit note asking participant summary about their data and their goals and expectations for the visit. We designed Foodprint as two main boundary negotiating artifacts: self-explanation artifacts (i.e., the mobile app and the web app) and inclusion artifacts (i.e., the web app and the pre-visit notes).

3.1 Photo-based Food-Tracking App

We designed the mobile app as a self-explanation artifact that allows participants to record food data individually. Existing self-tracking apps often focus on counting calories and do not help individuals with goals other than weight loss to track data pertinent to their individual goals.

Participants start to record their food intake by taking a photo of their food using the mobile app (Figure 1, left). They can then optionally annotate the photo with a caption and additional details about foods and their eating experience (Figure 1, middle, full question list in Appendix 1). Participants can also reuse photos in their phones or upload a photo retroactively if they previously forgot. Participants can input additional details at the time of eating using the mobile app or later using the web app. This flexibility allows people to decide how much time they want to spend tracking in the moment. They can enter more details while the experience is fresh in their memory or enter fewer when they cannot afford the time, such as when eating in a social situation. Because questions are tailored to the individual's goals, this helps them focus on tracking just the data relevant to their goals.

For IBS patients, the mobile app also prompts them to enter their symptoms at the time of eating or at a frequency they determine (from one to three hours) (Figure 2, middle). We adapted a symptom scale focused on the impacts of symptoms on quality of life; prior studies of IBS self-experimentation found that patients were receptive to this scale [40].

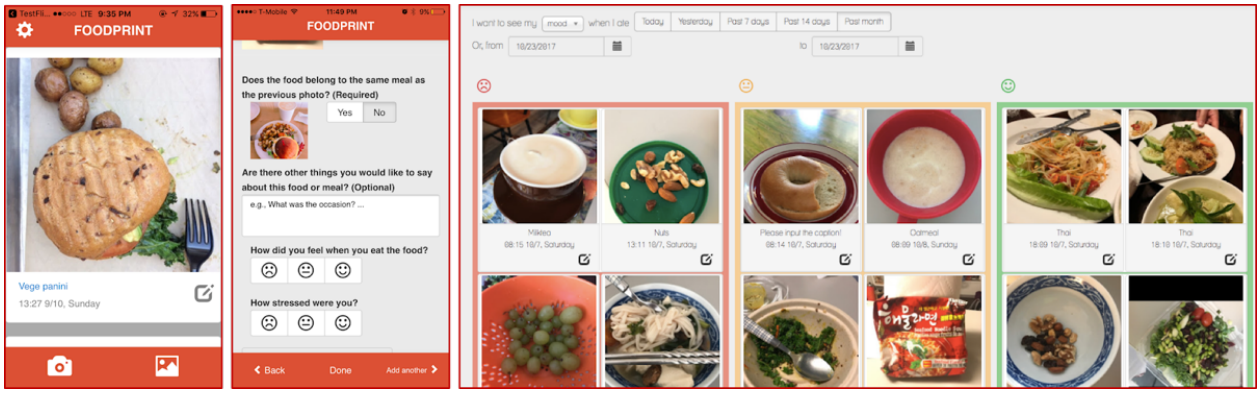

Fig. 1. Foodprint for healthy eating. Left: Mobile app presenting recorded food. Middle: Mobile app asking for (optional) additional details about food. Right: Web app presenting food and mood relationships.

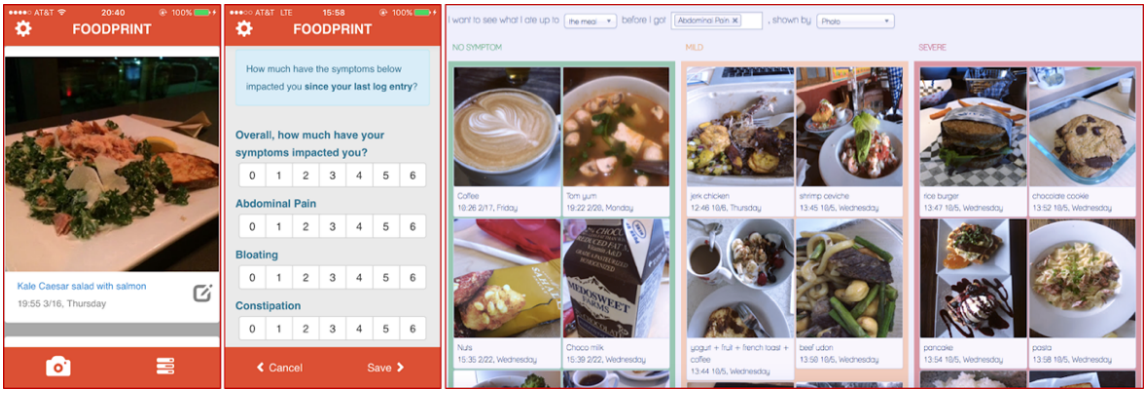

Fig. 2. Foodprint for IBS. Left: Mobile app presenting recorded food. Middle: Mobile app asking for symptom severity. Right: Web app presenting food and symptom relationships based on symptom severity.

3.2 Web App for Exploring Relationships between Food and Health Goals

We designed the web app to act as both a *self-explanation* artifact that supported individual participant reflection on their health goals and as an *inclusion artifact* to support collaborative review of data by participants and health experts. In previous research that presented Parkinson's patients and their providers with step data during office visits, the collaboration and review of data were largely physician-directed because patients did not have access to the visualizations beforehand [54]. In designing Foodprint, we chose to make the photo-based visualizations available to participants throughout the study. We anticipated that having access to these representations would encourage participants to reflect throughout the study and prepare them to take a more active role in collaborations with experts.

To support the creation of inclusion artifacts, we designed Foodprint to support focused review based on individual goals, contextual data and knowledge sharing, and individualized, actionable plan development. A lack of effective support often prevents health experts from reviewing large amounts of data in time-constrained visits [19], prevents focusing on individual goals [20], and prevents generating correct, individualized, and actionable recommendations [73,78]. We therefore approached these design goals by creating two types of visualizations that support patient-provider collaboration goals: (1) A photo-based visualization view that helps individuals and health experts to review food photos based on individual health goals or symptom severity and (2) IBS nutrient analysis report that helps IBS patients and providers understand correlations between potential IBS triggering nutrients and patient symptoms. The photo-based visualization used in collaboration review was the same that patients had access to during the study, which we believed would help create a shared understanding. We included the IBS nutrient analysis report to help us see when the capabilities it offered helped IBS patients and providers in collaboratively identify IBS triggers. The nutrient analysis report was not available throughout the study because sufficient, dietitian-coded data had to be available before the analyses were meaningful.

3.2.1 Photo-based Visualization View. The web app presents participants with a visual summary of their data. For healthy eating participants, the web app presents foods categorized according to participant goals (Figure 1, right). For example, for participants who would like to eat more balanced meals, the web app categorizes food photos based on participant-tagged food groups (fruits, vegetables, grains, protein, dairy, oils [70]). For participants who would like to monitor specific ingredients, the web app categorizes food photos by the ingredient amount specified by the participant ("none", "some", "a lot", "not sure"). For participants who would like to understand the relationship between food and mood or stress, the web app categorizes food photos based on their reported stress and mood level ("bad", "okay", "good"). We iterated on these categories with health experts in the research team to ensure the categories were easy to collect and useful for dietary consultation. Participants and health experts could also review food photos chronologically (Figure 3, left).

For IBS patients, the visual summary presents relationships between foods and symptoms. Patients can see these relationships in multiple ways, designed to support different questions patients and their providers might ask. First, Foodprint categorizes their food photos based on symptom severity (Figure 2, right). Patients can see the foods they ate up to 4 hours, 6 hours, 8 hours, one meal, or two meals before symptoms were logged. They can also choose to categorize their foods based on food source and preparation type. These categorizations allow patients and providers to explore what might contribute to their symptoms based on individual experiences, such as how soon patients usually experience symptoms after they ate or whether they might be sensitive to how their food was prepared. Second, patients can see their symptoms and the foods they ate over time (Figure 3, right). This allows patients to reflect on their day, to identify eating patterns or symptom patterns, and to explore triggers by recalling factors that might interact with what they ate (e.g., stressful days vs. relaxed days). Similar to the healthy eating version, participants and health experts could also review food photos chronologically (Figure 3, left).

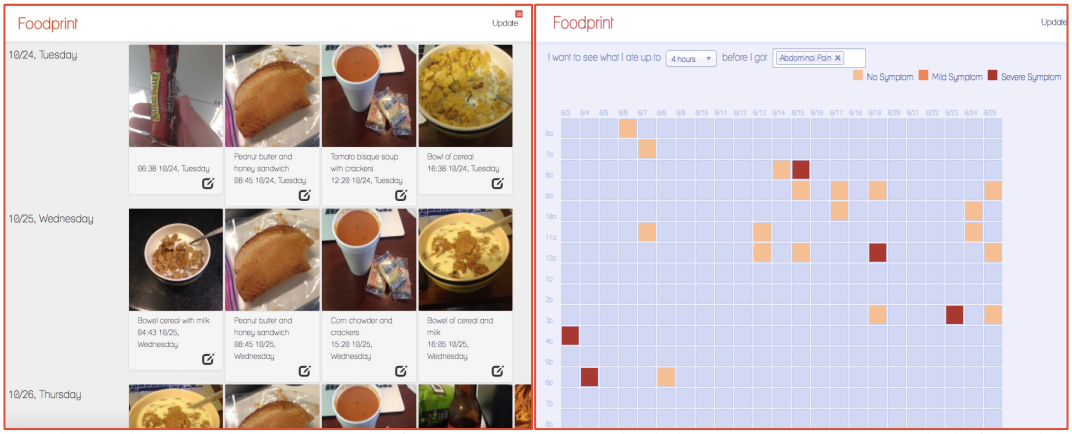

Fig. 3. Foodprint photo-based visualizations. Left: Web app presenting food photos chronologically, available for both healthy eating and IBS participants. Right: Web app presenting food and IBS symptoms relationship over time, with x-axis representing the record date and y-axis representing time of day. Each block was colored based on symptom severity. Users can click on the colored block to view photos of food eaten up to when symptoms were recorded (e.g., 4 hours ago).

3.2.2 IBS Nutrient Analysis Report. The IBS nutrient analysis report developed by Schroeder et al. [66] analyzed and visualized correlations between nutrients and symptoms to support hypothesis formation regarding possible IBS triggers. In this study, we adapted the bubble and bar chart visualization (Figure 4) from the original report as an example of a quantitative analysis visualization to allow patients and providers to explore high-level relationships between nutrients and symptoms.

A trained dietitian analyzed the food photos patients collected using the Nutrition Data System for Research (NDSR) [56] and decomposed these foods into 19 potential IBS triggering nutrients. We then performed regression analyses with reported symptoms as the dependent variable. We defined the independent variables as the amount of nutrient reported within four hours preceding a symptom report, informed by the time IBS patients reported between their eating and symptom flare-up in prior studies [59].

A NDSR analysis of six days of patient-tracked data takes 3.5 hours on average, and scheduling this analysis caused a 1-2 week delay before results were available. As a result, we introduced the visualizations of quantitative analyses to patients and providers at the post-interview; patients did not have access to it while tracking or preparing their pre-visit notes. This is consistent with patient experience in current practice that patients often only receive dietitian analysis during the visit [69].

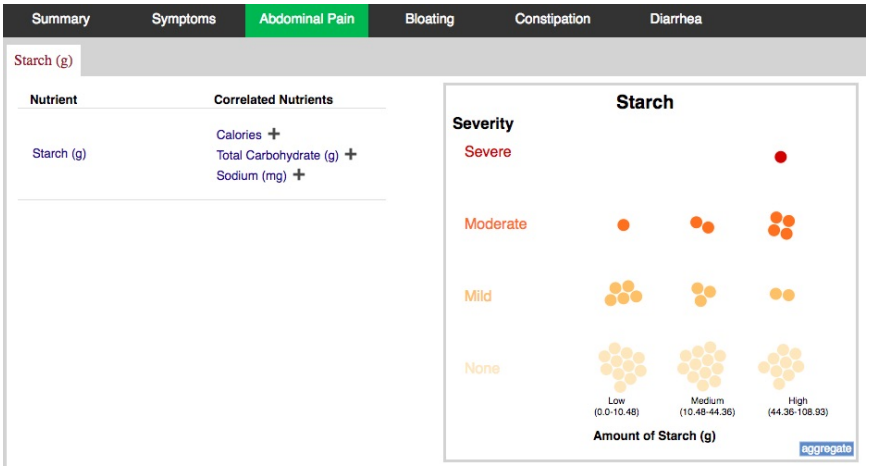

Fig. 4. Bubble and bar chart in the IBS nutrient analysis report showing correlation between a nutrient (Starch) and a symptom (Abdominal Pain). Every meal was represented as one bubble and categorized by the amount of nutrient (e.g., starch) contained in the meal and the symptom severity.

3.3 Pre-visit Notes

Prior research shows that understanding client goals helps providers collaboratively review self-tracking data [20,32]. We therefore designed a pre-visit note as an inclusion artifact that would help participants include their health goals in the collaborative review and discussion. We asked participants to fill out a pre-visit note summarizing their findings from the data, their goals for the upcoming visit, and questions they would like to ask health experts in the visit (Appendix 2). We designed the pre-visit note as a paper-based artifact that participants can choose to fill out at home and bring the paper to the collaborative review. When the post-interview was conducted remotely, we emailed a copy of the pre-visit note to remote health experts before the collaborative review. As we will discuss later, there might be benefits for recording and presenting pre-visit notes as part of the system, but paper-based notes provide better affordance to support collaboration [19]. Participants can review their data on the screen and fill out the paper-based pre-visit notes at the same time. Health experts can also refer to patient goals and questions on the paper-based pre-visit notes while reviewing the patient-tracked data on the screen.

4 METHOD

We conducted two studies to understand the use of Foodprint in healthy eating consultation and IBS trigger identification, following the same study design in each. The study was approved by our Institutional Review Board. Participants were compensated with a $30 Amazon gift card and a free consultation. Health experts were compensated with a $50 Amazon gift card.

4.1 Study Design

Each study consisted of four stages:

1. **Pre-interview**. During this 30-45-minute session, we interviewed patient participants about their experience pursuing healthy eating goals or managing IBS as well as tracking and sharing dietary intake data. We then introduced and installed the Foodprint mobile application on the participant's phone and explained the features of both the mobile application and the web application.

2. **Food tracking**. We requested that healthy eating participants track their food for three to four weeks, similar to prior studies of photo-based dairies [7,23]. IBS participants were requested to track their food and symptoms for six days following current clinical protocols [77]. For all participants, we recommended but did not require that they follow a "three-days-on and three-days-off" protocol (i.e., they start by tracking their food for consecutive three days, then take a break for three days, then resume the tracking for another consecutive three days) to avoid data entry fatigue [5,15,69]. We also instructed participants to take photos even when they forgot until after eating (e.g., empty plates, wrappers, or other objects), in part because prior research has suggested that such images can support individuals in recalling those meals [23].

3. **Post-interview**. Seven healthy eating participants and four IBS participants tracked until or beyond the post-interview. For the rest of the participants, the post interviews were scheduled between 4 and 84 (median: 27) days after IBS participants finished their tracking and 4 and 12 (median: 8) days after healthy eating participants finished their tracking. The variability in the post-interview schedule was due to health expert availability, participant availability, and the delay for us to conduct the quantitative analysis for half of the IBS participants. This duration and variance is similar to the time patients wait before a return visit with an IBS specialist or for a general diet consultation [69].

The post-interview consisted of two phases. In the first phase, we invited participants and health experts to review participant-tracked data separately using the Foodprint web application. Health experts also had access to participant pre-visit notes about their goals and questions to support their individual review (Appendix 2). This phase took 30-45 minutes.

In the second phase, participants and their paired health experts were invited to review participant-tracked data collaboratively in a 15-20 minute visit, which is similar to the amount of time patients and providers would spend in a typical primary care visit [68]. We then asked participants and health experts questions regarding their experience of reviewing participant-tracked data together. All IBS post-interviews were conducted in-person. Because we recruited health experts broadly and because many health experts already do remote consultations as part of their practices, 11 out of 16 healthy eating post-interviews were conducted with remote health experts via video conferencing tools. In these remote consultations, one party (i.e., the participant or the health expert) would share their screen with the remote party for collaborative review.

4. **Follow-up survey**. A month after the post-interview, we sent participants a survey asking what dietary or other behavior changes they intended to make after the study and what changes they had made since finishing the study.

4.2 Participants

Across two studies, 33 participants and 16 health experts used Foodprint.

4.2.1 Healthy Eating Participants. We recruited 23 people with healthy eating goals and 8 health experts with dietary consulting experience (Table 1, Table 2). We recruited participants with healthy eating goals through social media and mailing lists associated with the University of Washington. We asked potential participants to fill out a screening survey and used their responses to assign people into three different groups: balanced diet, ingredient monitoring, and lifestyle factor monitoring. We assigned people to the group matching the health goals they described in the survey, encouraging participants to focus on one goal at a time. We recruited 8 health experts through prior studies in the University of Washington and snowball sampling. All health experts were certified in nutrition consultation with more than two years of professional experience.

Table 1. Healthy eating participant demographics, goals, and paired providers

No.	Age	Gender	Study days	Tracking days		No. of photos	Avg. photos per day	No. of empty plates/wrappers	Paired expert	Co-review sessions
				Suggested	Actual					
Balanced diet										
HP2	19	F	36	18	27	46	1.7	0 (0%)	HD9	Remote
HP4	21	F	27	12-15	12	26	2.2	0 (0%)	HD3	In-person
HP5	40	F	28	12-15	19	80	4.2	13 (16%)	HD5	Remote
HP6	21	F	31	15	13	16	1.2	2 (13%)	HD3	In-person
HP12	18	F	35	15-18	26	53	2.0	10 (19%)	HD5	Remote
HP16	25	F	28	12-15	14	23	1.6	1 (4%)	HD5	Remote
HP17	30	F	22	9-12	14	50	3.6	1 (2%)	HD5	Remote
HP19	52	F	27	12-15	27	259	9.6	10 (4%)	HD7	In-person
Ingredient monitoring (All participants chose sugar except HP 8 chose lean protein)										
HP7	28	F	30	15	29	70	2.4	0 (0%)	HD7	In-person
HP8	20	F	47	21-24	26	52	2.0	0 (0%)	HD5	Remote
HP10	30	M	25	12-15	18	75	4.2	9 (12%)	HD3	Remote
HP20	66	M	21	9-12	18	55	3.1	1 (2%)	HD4	Remote
HP21	69	F	26	12-15	14	20	1.4	0 (0%)	HD5	Remote
Stress and mood monitoring										
HP18	26	M	25	12-15	23	116	5.0	10 (9%)	HD8	Remote
HP23	27	F	34	15-18	22	50	2.3	4 (8%)	HD6	In-person
HP25	25	F	40	18-21	40	247	6.2	2 (1%)	HD10	Remote
HP26	25	M	23	9-12	14	35	2.5	0 (0%)	HD7	In-person

Table 2. Healthy eating expert demographics

No.	Gender	Expertise	Years of practice
HD3	F	Health coach	7
HD4	F	Clinical dietitian	10
HD5	F	College sport dietitian	9
HD6	F	Dietetic Intern	2
HD7	F	Dietetic Intern	2
HD8	F	Supermarket dietitian	11
HD9	F	Nutritionist	14
HD10	F	Nutritionist	3

Of all 23 people who participated in the pre-interview, two decided to prioritize other aspects of life over healthy eating goals during the second week of the study. Another four did not respond to our invitations for the post-interviews. These six people tracked for 6 days on average, ranging from 2 to 8 photos per day. In the following sections, we report the findings based on the remaining 17 participants and their interactions with the health experts. Despite our efforts to recruit diversely, more of our participants were female (13) than male (4). The gender difference was potentially due to self-selection: women tend to eat healthier and choose healthy food more than men [8,33]. On average, these 17 participants tracked for 21 days (SD=7.6) with 3.5 photos per day (SD=2.1), which is more than our recommended number of tracking days. Participants on average took 3.7 (5%) photos of empty plates or wrappers (SD = 4.6 (6%)) during the study. All participants completed the pre-visit notes before post-interview.

4.2.2 IBS Participants. We recruited 16 IBS patients (13 females and 3 males) and 8 providers with experience working with IBS (Table 3, Table 4). The participant gender distribution is potentially due to gender disparity in the diagnosis of IBS: women are 1.5 to 3 times more likely to be diagnosed with IBS than men [14]. We recruited patient participants through prior studies conducted at the University of Washington and provider participants through our medical collaborators. We randomly assigned patients to the Foodprint only group, in which patients used the Foodprint system with photo-based visualization view throughout the study, or to the nutrient analysis group, in which patients used Foodprint system with photo-based visualization view throughout the study but had access to the IBS nutrient analysis report during the post-interview. During the consultation, IBS patients and providers in the NA group could review patient data using photo-based visualization view, IBS nutrient analysis report, or both views. We chose to provide the nutrient analysis report to only some participants to facilitate comparison between collaboration using photo-based visualizations alone and collaboration using photo-based visualizations alongside quantitative visualizations. As quantitative analyses of food diaries are often resource-intensive (i.e., time and cost), understanding these comparisons could help us provide insights into when each visualization is preferred and necessary. On average, these 16 participants tracked for 12 days (*SD*=9.3) with 5.1 photos per day (*SD*=2.4). Participants on average took 4.6 (7%) photos of empty plates or wrappers (SD = 5.8 (7%)) during the study. All participants completed the pre-visit notes before post-interview.

Table 3. IBS participant demographics, goals, and paired providers

					Tracking days					
No.	Age	Gender	Years of symptoms	Study days	Suggested	Actual	No. of photos	Avg. photos per day	No. of empty plates/wrappers	Paired provider
Foodprint only										
IP4	37	M	10	9	3-6	6	29	4.8	0 (0%)	ID4
IP5	36	F	4	7	3-6	6	19	3.2	0 (0%)	ID3
IP6	74	F	30	15	6-9	10	33	3.3	0 (0%)	ID4
IP7	31	M	2	11	3-6	7	48	6.9	0 (0%)	ID5
IP12	64	F	50	10	3-6	8	33	4.1	6 (18%)	ID4
IP14	27	F	17	17	6-9	10	60	6	9 (15%)	ID7
IP15	27	F	4	16	6-9	9	104	11.6	21 (20%)	ID7
IP16	27	F	2	15	6-9	9	35	3.9	5 (14%)	ID8
Foodprint + Nutrient analysis report										
IP1	40	F	3	8	3-6	6	33	5.5	4 (12%)	ID7
IP2	36	F	15	22	9-12	23	123	5.3	13 (11%)	ID1
IP3	27	F	8	11	3-6	8	33	4.1	1(3%)	ID2
IP8	43	F	24	11	3-6	8	44	5.5	3 (7%)	ID2
IP9	40	M	10	47	21-24	43	169	3.9	4 (2%)	ID1
IP10	34	F	12	20	9-12	13	53	4.1	0 (0%)	ID6
IP11	32	F	11	11	3-6	10	101	10.1	6 (6%)	ID2
IP13	54	F	2	21	9-12	13	62	4.8	1 (2%)	ID6

Table 4. IBS provider demographics

No.	Gender	Expertise	Years of practice
ID1	F	Dietitian	18
ID2	F	Gastroenterologist	20
ID3	F	Dietitian	21
ID4	F	Primary care physician	21
ID5	F	Nurse practitioner	34
ID6	F	Nurse practitioner	4
ID7	F	Gastroenterologist	10
ID8	F	Internal medicine physician	3

4.3 Analysis

We audio recorded and transcribed all pre-interview and post-interview sessions. We analyzed the transcripts using a mix of inductive and deductive methods. We first analyzed the transcripts using affinity diagram analysis [36]. From the transcripts, we created around 1800 affinity notes, which we iteratively organized into 80 first-level categories and 15 second-level categories. After iterative discussions, we focused on themes related to patient-provider collaboration and tradeoffs between different ways of collecting and reviewing food data to support healthy eating goals and IBS trigger identification. To understand how these themes address our research questions, we then coded the first-level affinity categories according to types of boundary negotiating artifacts used or produced [46]. During the coding process, we also iteratively broke down categories when there was more than one type of boundary negotiating artifact observed. This theory-driven aspect of our coding is similar to directed content analysis [37].

5 CASE STUDIES

We first introduce four case studies before presenting the themes in section 6. We selected these four case studies because they represent the variety of goals participants have and provide an overview of the variety of ways participants and health experts used Foodprint in collaboration. These case studies also illustrate how participants and health experts share their expertise and knowledge to support discussion and data interpretation.

Healthy Eating Case Study 1 - Weight loss as a medical student (HP10 and HD8): HP10 wanted to lose weight, eat healthier, and decrease sugar intake. He had previously used MyFitnessPal to count calories but found that he had problems fitting the food tracking and analysis process in his busy schedule. When he met with HD8 in a remote consultation session after using Foodprint for 18 days, they first looked at the analysis page, which categorized HP10's food photos by the amount of sugar. HD8 was surprised that his photos were full of granola bars, cereals, and peanut butter sandwiches. She then switched to the chronological view to understand HP10's day-to-day food choices. HP10 then explained that he was a medical student on rotation and therefore did not have time to prepare food and did not have regular eating schedule. His main food source was the cafeteria in the hospital, which unfortunately did not provide many healthy eating options. Therefore, instead of providing general healthy eating recommendations, such as eating more vegetables or home-made food, HD8 spent time recommending alternatives to the cafeteria, such as healthy snacks or easily-made food that HP10 can incorporate into his routine.

Healthy Eating Case Study 2 - Balanced diet as a college student (HP6 and HD3): HP6, a college student, wanted to make sure her diet was balanced. When HD3 reviewed HP6's Foodprint data, she first looked at the analysis page that presented HP6's photos based on food groups. HD3 was surprised that there were very few photos. After switch back to the chronological view, she found that HP6 only had one photo a day and suspected that she forgot to track her food. When HD3 met HP6 in-person, however, HD3 found that HP6 only made one meal a day (dinner) and ate it throughout the evening and the next morning. She also mentioned that she often forgot to eat during day time when she was occupied by school and her part-time job. Although HD3 thought each meal she ate was balanced, she also realized through conversation with HP6 that HP6's eating routine might have affected her sleep and energy level. Therefore, HD3 worked with HP6 to brainstorm strategies and helped her to setup reminders to incorporate more frequent meals throughout her day.

IBS Case Study 1 - Identifying additional triggers and finding food substitutions (IP2 and ID1): IP2 has had digestive symptoms for 15 years and was diagnosed with IBS 8 years ago. She knew that she could not tolerate dairy, greasy food, or large portions of foods but still had symptoms even when she avoids these choices. When she met with ID1 in-person, ID1 first asked about her prior IBS diagnosis and experiences of symptom management. Then ID1 asked about what she found through IBS Foodprint. Using the analysis page that categorized her photos based on symptom severity,

IP2 pointed out and explained that she had a severe symptom flare-up after a dinner in an Indian restaurant. She thought that it might have been because Indian food tends to be greasier. However, ID1 looked across the food photos in the severe-symptom column and offered another observation: she asked if IP2 used onions and garlic in other food photos shown in the severe-symptom column. ID1 explained that onion and garlic looked like common ingredients in her foods, but they are also one of the common FODMAP (Fermentable Oligosaccharides, Disaccharides, Monosaccharides and Polyols) foods that can trigger IBS symptoms. ID1 then suggested that removing onions and garlic from her diet could be an easy next step and more feasible than adopting the whole low FODMAP diet or an elimination diet trial. Knowing that IP2 appreciates delicious food, ID1 also offered recommendations on substitutions for onions and garlic, such as scallions, garlic-infused olive oil, and asafoetida. In the follow-up survey, IP2 responded that she had been experimenting with different recipes with garlic and onion substitution.

IBS Case Study 2 - Eating routine change to manage symptoms (IP7 and ID5): IP7 has had digestive issues for two years. Previously, he had two visits with his primary care doctors and one visit with a dietitian, through which he determined that his IBS symptoms might be triggered by spicy food, dairy, and overeating. During his in-person visit with ID5, they first went over his practices for recording food photos using IBS Foodprint to understand how representative the 7-day record in the system was. Then they looked at the photos categorized by symptom severity. ID5 noticed that P7's symptoms usually occurred during early morning and asked about IP7's routine from dinner to the next morning. IP7 originally wanted to eliminate caffeine, but after discussing with ID5, he thought it might be difficult to overcome his caffeine dependence. IP7 then decided to try smaller, frequent meals but did not know how to start. ID5 offered some best practices based on other patient experiences and strategies for further food and symptom tracking to understand the influence of his new diet plan.

6 HOW DID FOODPRINT SUPPORT PARTICIPANT AND HEALTH EXPERT COLLABORATION?

As we can see in these case studies, interpreting self-tracking data required both an individual's expertise about their own routines and experiences as well as health expert medical expertise. Across all healthy eating and IBS visits, participants and health experts did not review ingredients or nutrients item-by-item, as prior research has found they often approach text-based diaries [78]. Instead, photo-based visualizations allowed them to get an overview of eating patterns and context. Participants and health experts were then able to focus on communicating participant goals and expectations, exchanging observations and knowledge to support collaborative interpretation, and developing individualized, actionable plans. Health experts said reviewing participant-tracked data using Foodprint was feasible in the visits and ten (ID1, ID3, ID6, ID7, ID8, HD3, HD5, HD6, HD7, HD8) asked to continue using Foodprint with other patients or clients.

Participants and health experts used Foodprint as different types of boundary negotiating artifacts to support collaboration. When participants started tracking, the mobile app and the web view served as *self-explanation artifacts* that allowed participants to record their food data and review food relationships based on their health goals. When participants met with health experts, they reflected on their data, goals, and expectations for the visit using the pre-visit notes. Participants and health experts used these notes and the web view as *inclusion artifacts* to include participant tracked data, health goals, routines, and expectations of the visit in discussion. When developing individualized symptom management plans or healthy eating strategies, participants and health experts used data in photo-based vidualizations as *structuring artifacts* to help participants follow plans.

6.1 Self-Explanation Artifact: Mobile App and Web View Made Participants Aware of Their Eating Behaviors

As in prior studies of photo-based diaries [6,18,23], most participants thought it was easy to see their overall eating patterns from photos. IP4 and IP5 both found that their diet was more restricted than they thought and saw they tend to eat the same foods. IP4 found visual display of photos made it easy for him to see this pattern:

> *"'Cause taking a picture of the food, it's there. You can see. As opposed to just trying to guess and going to some website to figure out what it is. And that was really helpful, it made it really easy so I can actually, physically see, 'Oh, this is what I ate for three days.'"*

Healthy eating participants also found that the photo-based visualizations helped them learn and reflect on what they ate. HP10 found categorizing food based on his healthy eating goal helped him recognize opportunities to change:

> *"I'm looking at this and actually seeing the pictures lining up, more on the eating habits, and it's like, 'Oh man I really do eat a lot of that[sugar], maybe I should change that.' it is quick and convenient."*

Participants also felt the process of taking photos and answering questions made them mindful of what they ate. IP8 commented that although she has had IBS for more than 20 years and she had a good understanding of her triggers, she found taking a photo of food made her reflect more:

> *"I had to stop, see, and think about what I was eating, and what was in what I was eating, and how did I feel a couple hours after I ate something, so I think it made me more aware, more cognizant of what I was putting in me and what my body's response to that was."*

She also realized that spicy food can be a trigger through answering additional questions Foodprint asked. HP5 found that answering questions helped her reflect on the progress toward on her health goals:

> *"when I was answering those questions, I was like, 'Oh, and I eat this thing more than half of the days.' It was fish. Fish or seafood or sardines. Actually, that's my goal, is to get more fish in."*

Even IBS participants who considered themselves in control of their symptoms thought Foodprint could be useful when their routines change or if they would like to try new foods. IP15 thought seeing photo-based visualizations would be helpful when she travels to new places:

> *"if I was traveling or in a place where I wasn't in control of preparing my very regimented safe meals, it would be helpful to see because, I'm eating lots of new things and I might not remember it, so if I could take a picture and track that in new situations, that could be helpful."*

Reflecting on how IBS symptoms and triggers can change over time, IP3 thought that it would be useful to use the IBS Foodprint again even without providers reviewing the data: "*If my symptoms changed, I would be interested in doing it again for myself.*"

6.2 Inclusion Artifacts: Pre-visit Notes Supported Explicit Communication about Participant Goals

Understanding patient goals helps providers focus on patient priorities and manage visits to address patient needs [19]. However, patient-provider communication in visits is constrained by time, and patients and providers often have different concerns and cannot address all at the same time [11]. For example, in the pre-interview, IP2 described her frustrating experience working with providers:

> *"doctors were like, 'Oh my time's running short, here's a list of things like follow this, like here's the FODMAP diet.' They would do all that, take a diary, do an elimination diet, all this stuff, and I'm like well but that still doesn't really give me any answers."*

In Foodprint, to support patient-provider communication about goals, all health experts had access to participant pre-visit notes during collaborative review (Appendix 2). In both the healthy eating and IBS studies, all participants completed the pre-visit notes before their post-interviews. These pre-visit notes served as an *inclusion artifact* that made health experts more aware of participant expectations and questions for their discussion. When we asked health experts and participants what helped during the collaborative review, many experts pointed to having the pre-visit notes so they could understand participant goals and focus during the 15-minute visit:

> *"Because I could see her goals and so I had an idea of what I was going to talk about. And fit the session within the timeframe that we had. It's nice to be able to see what the client wants to go over, and things that you're gonna plan on talking with the client on" (HD5).*

In particular, healthy eating participants often had more than one health goal, and having this information helped health experts recognize these goals and orient their conversation. All healthy eating participants mentioned in their pre-visit notes that they would like to know if their diet was considered balanced and if there were other nutrients or types of food they should increase or avoid in their diet. In addition to their primary goals, participants also wanted to increase energy (HP6, HP7, HP8, HP21), monitor portion size (HP4, HP12, HP23), understand relationships between food and health concerns (HP7, HP19, HP20, HP23), and find ways to accommodate their diet restrictions or preferences (HP2, HP10, HP18, HP26).

Healthy eating participants and experts also used pre-visit notes to facilitate the review in remote sessions, when only one of them could control the web view in those remote sessions. As represented by Healthy Eating Case Study 1 with HP10 and HD8, eleven out of sixteen pairs of healthy eating collaborative review sessions were conducted remotely because remote consultations were already part of the practices of these experts. Five out of eight healthy eating experts (D3, D5, D8, D9, D10) had experience conducting dietary consultation by video conference or by phone. They were comfortable using screen-sharing during these remote consultation sessions. For example, HD3 and HD5 had experience

sharing their analyses of client food diary during remote consultations. In our study, during nine of the eleven remote sessions, health experts chose to share their screens with participants; two participants shared their screens. In these cases, only the person who shared the screen could control the web view. When health experts shared the screen, participants relied on health experts to scroll to or point at photos to which participants wanted to refer. In these cases, health experts used patient goals and questions from the pre-visit notes as a guide to choose which page to focus on. Participants, having reflected on their data while filling out pre-visit notes, also actively shared their interpretation based on their knowledge about the data. When participants shared the screen, they pointed at photos when they referred to questions from the pre-visit notes or wanted to provide contextual information. They also scrolled or changed the pages when health experts asked to use particular views or photos to answer participant questions or explain their recommendations.

IBS health experts appreciated learning patient preferences toward dietary changes from pre-visit notes. For example, ID7 described how the pre-visit note changed the direction of her consultation with IP15. When reviewing data before the visit, ID7 could see that some fruits might have caused mild symptoms for IP15. However, during collaborative review, IP15 emphasized her goals in the pre-visit note: she did not wish to restrict her diet more. ID7 and IP15 thus went on to talk about another finding IP15 listed on her note: her symptoms might have been exacerbated by stress. Following up on this finding, ID7 and IP15 spent the rest of the visit brainstorming strategies for managing stress. Participants also appreciated that they could communicate their expectations and preferences to health experts. IP8 said that she was okay with mild symptoms, but she would like to know more strategies for mitigating severe symptoms. Having a conversation with ID2 that focused on these goals helped IP8 identify how to choose food even when she has limited food options (e.g., volunteering in a summer camp) or when she has no control over what triggers her symptoms (e.g., menstrual cycle).

6.3 Inclusion Artifact: Photo-based Visualizations Provided Information Useful for Dietary Consultation

At the beginning of the study, many health experts thought that photos would not contain sufficiently detailed nutrient and caloric information and would therefore not be useful. However, after collaboratively reviewing photos, health experts and participants commented that photo-based visualizations helped them see overall eating patterns, provided a record of what participants actually ate, and contained details that were useful for dietary consultation.

As in self-explanation, all experts and participants thought it was easy to see overall eating patterns from photos when they reviewed the data together. Even though healthy eating participants recorded an average of 75 photos across 21 days and IBS participants recorded an average of 61 photos across 12 days, experts thought they could see the patterns of eating habits in a glance using the photo-based visualizations. One dietitian described how she could sit down with her clients and talk about their diets right away:

> *"it's relatively easy to glance through [photo-based visualizations] fairly quickly because it's photos and your brain takes it in pretty rapidly opposed to reading words. That makes it so easy right in the session, I think it's easier to look at that versus even a food journal that's written out or the MyFitnessPal" (HD4).*

HP23 shared similar thoughts about how photo-based visualizations supported HD6 in understanding her eating patterns: "*I think it's pretty interesting that [HD6] captured my eating habit pretty quickly through glancing through this summary, which I feel is useful.*" Healthy eating experts also thought categorizing foods based on healthy eating goals created an opportunity for education using participant data:

> *"the one that we looked at today [photo-based visualization with HP5] could be really helpful for individuals with diabetes, that just occurred to me when we were talking about carbs because often times I want to go over more specifically how much carbs they're consuming and sometimes portion sizes can be really misunderstood so it would be nice to be able to get a snapshot" (HD5).*

Because photo-based visualizations made it easy for health experts to skim participant patterns on the spot, some health experts did not think their clients or patients need to review their own data before the visits. Some health experts considered reviewing data to be their own responsibility, not that of their clients, and would prefer not burdening their clients with reviewing the data beforehand:

> *"No. [I would not need my clients to review the data beforehand.] I just want them to live their life, record it, and then we talk about it together. Because I think people get bogged down with things and they get a lot of self-doubt and overwhelmed" (HD3).*

Because healthy eating participants often had more than one health goal, participants and experts often switched between the analysis page and the history page to answer different questions during visits, as seen in Healthy Eating Case Studies 1 and 2. Health experts used the analysis page to get an overview of participant eating patterns associated with

particular goals (e.g., "*when you're stressed out what are you eating?*" (HD7 & HP26)) and then turned to the history page to see more general eating behavior (e.g., "*it's great that your normal routine is really consistent. we recommend three meals a day for sure.*" (HD6 & HP23)).

IBS participants and providers also found it helpful to see food photos categorized by symptom severity and time. Many IBS patients and providers found new relationships or discussed suspected relationships between food and symptoms using photo-based visualizations. Of the sixteen IBS patients, nine patients (IP1, IP2, IP3, IP5, IP7, IP8, IP10, IP13, IP14) found new foods that might be potential triggers. Five patients (IP4, IP6, IP9, IP12, IP16) substantiated triggers they knew before participating in the study. Two patients (IP11, IP15) even identified non-food triggers after using photo-based visualizations to rule out potential food triggers. ID4 thought the visualization could help focus her conversation with a patient during the visit:

> *"if I sit down with a patient I would be like 'Okay, it looks like your symptoms cluster around after breakfast, maybe when you're getting into work. Is there a connection there? Let's see what you had for breakfast on the 22nd, 23rd, and the 28th.'"*

ID1 thought that comparing food across different symptom severity categories helped her identify or rule out triggers:

> *"I like how you can look across and then you can also see oh, here when they had a cashew yogurt parfait one morning, it didn't bother them but then the very next day it caused severe symptoms. So maybe it was how much was in there or how much they had had in a day."*

IBS patients and providers mostly focus on trigger identification and management strategies and thus often stick to the analytics page, as seen in IBS Case Studies 1 and 2. IBS patients and providers switched to different visualizations in only five cases: when trigger identification was difficult using photo-based visualizations, three patients (IP6, IP8, IP10) and providers used the IBS nutrient analysis report to look into nutrient-symptom relationship; when visualizations showed that foods might not be triggers, two patients (IP11, IP15) and providers switched to the timeline view and discussed what other factors might contribute to patient symptoms

Ten health experts (HD3, HD5, HD7, HD8, HD9, HD10, ID1, ID3, ID6, ID7) liked photo-based diaries more than text-based diaries because they could see what participants actually ate. HD4 thought that photos provided them a representation of portion size instead of participant estimation:

> *"I thought that was super interesting to be able to see their actual pictures of food because patients will tell me their portion sizes, but I don't actually see it."*

ID2 also thought that photos allowed her to have a better understanding of participant overall diet:

> *"[With Foodprint] I get an idea of what their overall diet is like. I think when people do a diary, sometimes they're not entirely truthful, or they always say, 'I eat really healthy.' So, if they take a picture, then maybe it's a little bit better record."*

All health experts and participants also thought photo-based diaries provided details that are useful in dietary consultation. As in previous studies focused on personal use of photo-based food diaries [24], Foodprint participants found that instead of caloric information, photos captured more contextual information (e.g., when, where, how) and were more interpretable using general nutritional knowledge. Additionally, health experts in our study found that this information helped them better assess participant eating behavior and provide better-personalized recommendations. HD7 compared the photo review experience in the study with her prior experiences reviewing client records in MyFitnessPal:

> *"I think you get more information of what things, what their meals look like. I think it's interesting to have the information of who were they eating it with, how were they feeling when they ate it, how did they prepare it? I think that, to me, is more useful than how many calories or grams of fat were in something."*

6.4 Inclusion Artifacts: Photo-based Visualizations Enabled Participants and Health Experts to Exchange Knowledge and Context to Support Collaborative Interpretation

Despite the importance of including contextual data and patient experience when interpreting data [3,54,66], patients and providers find it difficult to incorporate this information when reviewing self-tracking data [19,20,29]. Using photo-based visualizations as an *inclusion artifact*, participants and health experts found it easy to include eating context in the discussion. For example, ID7 found IP14 had photos showing the same breakfast in the car every day. These foods might not show consistent patterns of what triggers IP14's symptoms, but the photos communicated IP14's busy work routine.

This discovery led them to have a conversation about how IP4's work routine might have exacerbated IP14's symptoms and what strategies they could adopt to address the situation.

By surfacing eating context and patterns, photo-based visualizations also prompted health experts and participants to ask more questions about routines, which helped them interpret the data together. For example, once health experts understood current eating patterns, they could ask questions about what strategies participants had tried and what barriers they had encountered. This helped them contextualize the eating patterns and provide more personalized diagnoses and recommendations. ID2 found out that IP11 ate a trigger food (cherries) out of preference rather than lack of knowledge. Instead of suggesting IP11 to eliminate cherries, ID2 focused the discussion on other potential triggers.

These questions about participant routines, combined with conversations about participant tracking practices, helped health experts understand how they should interpret the data. For example, IBS participants often have individual definitions of "severe symptoms" versus "mild symptoms." Therefore, patients and providers often need to clarify the definition during collaborative review. IP2 only recorded her symptoms as binary (i.e., "severe" or "no symptom") because it was easier for her to record and it better described the acuteness of her symptoms. On the other hand, IP9 described his symptoms as mostly "mild," but occasionally he would have "severe" episodes such that "*I barely made it [to the bathroom], and I couldn't get out of the bathroom for a really long time.*" Talking about these definitions helped ID1 better understand IP9's experience and provide more individualized diagnosis and treatment.

The patterns shown in photo-based visualizations also led to detailed discussion about specific foods or meals, especially when participants had questions about particular foods, when experts explained their recommendations, or when the visualization indicated these foods potentially trigger severe IBS symptoms. For example, ID3 found that IP5 had a very restricted low FODMAP diet but had nuts (a high FODMAP food) in most of her meals. When ID3 asked how well IP5 tolerated those nuts, IP5 explained that she found soaking the nuts helped with digestion, but she did not know why. ID3 then explained that soaking helps leach out some of the FODMAPs. She also went on to provide another food recommendation:

> *"We see that with tofu, too. Firm tofu is low FODMAP because they've kind of drained all that liquid out of there. And the FODMAPs and fermentable carbs tend to leach out with that. Whereas silken tofu, they blend that liquid in there so there's more FODMAP content in there."*

Using photos as references, health experts could explain nutritional knowledge through real-life examples. Both HD8 and HD5 pointed out that HP8 and HP10 ate more Cheetos and chips when they were stressed and tired. Both experts explained that in their experience, people tend to eat crunchy foods when they are stressed. Both experts also recommended alternatives, such as dry roasted edamame or wasabi peas.

Even though photo-based visualizations allowed patients and providers to see eating patterns and have conversations around these patterns, some IBS providers wished for more support that could help them more efficiently review large amounts of data during time-constrained visits, such as by helping them focus on key data or questions. One gastroenterologist asked if Foodprint could automatically hide photos of the same food if they appear in both "No Symptom" and "Severe Symptom" columns:

> *"it would be helpful if there is a way to isolate foods that are only associated with severe symptoms and not associated with no symptoms. Cancel them out if they appear in both places. So like, this cashew yogurt parfait appears in a couple of places, so we can probably not relate it and same with the coffee. It would be nice to say this naan and curry only appeared in the severe column and didn't appear over there, or something like that. That might help us focus a little bit faster" (ID2).*

Providers unfamiliar with FODMAPs also wanted the systems to show them whether and what type of FODMAP each food photo contains. ID4 commented on how analyzing FODMAP from photos might be challenging for physicians:

> *"I think I know a lot more about FODMAPs than a lot of people, but it's not very easy to pick it up with FODMAPs and I think most doctors are not able to do that. So, it's challenging to translate the picture of the food into potential triggers."*

For physicians, having someone in the clinic go through the data might also help them focus on key questions during time-constrained visits. For example, ID7 thought that having a medical assistant go over these details could help her focus on setting the right filters in the system, which might provide a more specific dataset for collaborative review:

> *"[To help review the systems together,] I would make my medical assistant do the drop down menus that meant the most to her [IP15]. So, I would make her [IP15] decide on what she wanted to focus on based on her self-discovery so that I can make something meaningful out of it."*

6.5 Inclusion Artifact: Photo-based Visualization and Quantitative Analysis Visualization Provided Different Support toward Trigger Identification

IBS providers and patients thought that photo-based visualizations provided an overview and supported discussion that incorporated patient experiences and eating context. On the other hand, quantitative analysis provided potential explanations for underlying causes of patient symptoms. This different support influenced when and how patients and providers used each visualization.

During the collaborative review stage, all eight IBS patient-provider pairs who had opportunities to see the IBS nutrient analysis report (Figure 4) chose to review the photo-based visualizations first. These IBS providers (ID1, ID2, ID6, ID7) thought that photo-based visualizations provided a good overview to start conversations with patients. They also thought that going through photos helped patients remember the food details and eating context, which was helpful for trigger identification and symptom management. ID2 thought that talking about food through photos is a more natural conversation to start with than nutrient details:

> *"They [patients] can remember what they eat, and that's easier than pulling up something like, fructose, when you have to go explain what fructose is, and that's not something people talk about as much."*

All providers and patients also thought that compared to quantitative analysis visualizations, photo-based visualizations might be easier for patients as they start looking for potential triggers, especially when patients were new to IBS.

However, when patients and providers could not find clear relationships from the photos, they appreciated having the visualizations of quantitative analyses to support more in-depth analysis. Three patient-provider pairs (IP6, IP8, IP10) chose to use the IBS nutrient analysis report. For example, ID2 noted,

> *"You can really go through every single thing and say, just by all the different foods you ate, with different levels of carbohydrates, we haven't found food that triggers it. Maybe it's not food."*

When patients struggled to identify triggers, visualizations of quantitative analyses could help both patients and providers understand underlying nutrient-symptom relationships.

Providers and patients appreciated having two different representations to support IBS trigger identification management. They also considered the tradeoffs among the benefits of each system as well as when they can receive the feedback and who should be involved in the review. Patients with more experience with IBS but who were still struggling to find triggers indicated a willingness to wait for their photos data to be coded, in hopes of gaining additional insights. IP8, who already knew some major food triggers and had limited her diet to avoid them, compared the two systems by reflecting on her own experiences:

> *"10 years ago probably the other one [photo-based visualizations] would have been more helpful because I wasn't as aware of what my problems were, but this one [IBS nutrient analysis report] breaks it down more and would be helpful for me now."*

When asked about the tradeoff between getting instant feedback through photo-based visualizations and waiting for NDSR analyses for quantitative analysis visualizations, she said she was willing to wait for extra processing time:

> *"this [IBS nutrient analysis report] isn't real time because someone has to analyze it, but I've had this for 20 plus years. Doesn't bother me to do it for longer."*

However, some patients worried that they would not understand the IBS nutrient analysis report by themselves and preferred to review it with a provider:

> *"there's a lot of information here, and I don't understand everything exactly. I like how it's broken down, but I think I would probably have ended up confusing myself a little bit" (IP2).*

ID2 shared a similar concern regarding going through visualizations of quantitative analyses with patients who might not be familiar with it:

> *"For people who aren't as comfortable with this data representation, it may take a little bit longer to go through and to explain how we're interpreting it and why."*

Physicians who did not have nutrition training also had mixed feelings about reviewing quantitative analysis visualizations directly with patients. They appreciated that the IBS nutrient analysis report saved them the effort of decomposing foods into nutrients and trying to estimate the correlation during a visit. However, they worried that the

report could show nutrient-symptom relationships that they would not know how to explain, if they had not also independently reviewed the report prior to meeting with a patient.

6.6 Structuring Artifacts: Seeing Patterns and Eating Context Enabled Individualized, Actionable Plan Development

Traditional diaries rarely provide effective summaries to help providers develop individualized, actionable recommendation [19,78]. Because of this, many IBS patients said they only received generic recommendations based on the provider's training and aggregate experiences with prior patients:

> *"the main answer I got from him [primary care doctor] was, 'Yup, it sounds like a textbook case' and then we talked for a while about the different responses that people sometimes have. It was instructive, but in terms of pinpointing them [potential triggers] or anything else, it was more of me trial and error" (IP11).*

In our study, we found that health experts and participants were able to identify eating patterns or potential triggers and used Foodprint as a structuring artifact to discuss actionable next steps.

Once health experts and participants identified potential food related triggers, they focused on eating strategies or trigger food substitutions. Most health experts had conversations with patients about their personal preferences, routines, and limitations to identify at least one thing they can try. For example, HD8 found out from the photos that HP18 usually had takeout for lunch and knew that he wanted to improve that from the pre-visit note. She then asked what HP18's lunch routine looks like to understand what they could work on:

> *"maybe you don't have fridge at work and maybe you only have the option [eating out]. Socially too maybe that's what your coworkers are doing is going out to eat. So you certainly don't wanna miss out on that, but even with going out we can focus on healthy choices."*

In IBS Case Study 2, knowing that IP7 wanted to adopt small, frequent meals, ID5 asked about his work schedule:

> *"Is the kind of work that you do, do you have control over your day, so that you could actually every two hours step out and do something or are you at a kind of job where you can take breaks at specified times?"*

They also went back to the food photos and found examples of small-portion meals that IP7 could replicate later. This conversation helped them design strategies to split meals into smaller portion across a day. ID3 thought IP5 had too restricted of a diet and tried to help her increase the variety of food in small quantities. To do so, she provided a handout and highlighted recommended portion of high FODMAP foods that IBS patients might be able to tolerate.

Health experts also suggested ways to experiment and understand the effects of these eating strategies or other factors that might trigger patient symptoms. HD5 encouraged HP16 to add more protein to her breakfast:

> *"Just experiment and see. Maybe for a week, try a slightly higher protein breakfast, and see if you feel a little bit more energized in the morning. Maybe you notice that you're not getting quite as hungry before lunchtime, too."*

ID7 and IP15 determined that stress might be the trigger that IP15 was most willing to change. ID7 asked IP15 to use IBS Foodprint to record her stress instead of food using photos:

> *"why don't we consider re-doing this: let's have you rate your symptoms with your fingers. You could put a five or four with your fingers to rate your stress at the end of the day so we can get a better sense."*

7 DISCUSSION

Designed through the lens of boundary negotiating artifacts, Foodprint supported participants in their collection of food data relevant to their health goals and as they reflected on their data. In their collaborations with health experts, it helped keep the focus on patient goals and experiences. In this section, we first reflect on our findings and discuss future opportunities to support use of self-tracking data across individual and collaborative contexts. We then further discuss supporting the creation and use of inclusion artifacts according to various health goals, workflow constraints, and potential adoption of more automated analysis into systems like Foodprint.

7.1 Designing for Boundary Negotiating Artifacts

As seen in the study, supporting data collection and use across contexts can help individuals communicate their experiences and elicit knowledge from others in support of health goals. The lens of boundary negotiating artifacts can help surface these design opportunities and important design principles. In this research, we used this perspective to

design Foodprint to support the creation and use of artifacts that would help individuals describe their everyday experiences and enlist the expertise of health professionals in building understanding and planning actions based on that understanding. In this section, we reflect on how design helped people transform self-tracking data into different boundary negotiating artifacts [20,46].

Self-explanation artifacts. To help participants create self-explanation artifacts, we designed Foodprint to focus data collection on *what participants should track* to support their health goals and their collaboration with health experts. We configured the Foodprint mobile app based on participant goals (i.e., IBS trigger identification, balanced diet, ingredient monitoring, stress and mood monitoring). This process might be automated, such as through a getting started walkthrough that could minimize the need for individuals to make a series of choices about what to track or when to consult experts for help with this decision. Automatically configuring tracking tools based on an individual's goals is a promising technique for designs to support goal-oriented customization without burdening users with choices they may not know how to make [65].

Additional questions about foods in the mobile app and web app, configured according to participant goals, encouraged participants to reflect on their food choices at the time of eating and tracking. Participants could access the photo-based visualizations without health expert involvement, which supported reflection on their eating patterns even before health expert visits. To support individual reflection over time, future systems can propose reflective prompts and questions (e.g., [47]) when people configure tracking goals and when they review data on their own. These reflective questions may further help people think about their data even without, or with fewer, face-to-face visits with health experts. Future systems can also record individual goals and questions from the pre-visit notes over time. Systems can then present a history of hypothesis development, verification, and behavior modifications that might help individuals reflect on their experiences, choices, and goals.

Inclusion artifacts. Using Foodprint's photo-based visualizations, participants and providers iteratively talked about participant experience and identified eating strategies or trigger management plans in every collaborative review session. Inspired by previous research on review of step data by patients with Parkinson's disease and their providers [54], we designed Foodprint so that patients had access to their photo visualizations throughout the study and were prompted to reflect on their data in the pre-visit note, which we then made available to the health experts. In contrast to the collaboration in Parkinson's, which was largely physician-directed, we found that participants in our study took an active role in interpretation and collaboration, even when the providers were controlling the interface during remote sessions.

At the same time, many healthy eating consultations are conducted remotely, and we also saw that choices in screen-sharing technology could influence how people and health experts interact with data. Although participants actively shared their interpretation based on their knowledge about the data and health experts acknowledged patient goals and questions from the pre-visit notes, participants were not able to interact with the visualizations directly when health experts shared their screens. Prior research has suggested designing for co-interpretation in collocated consultations [54]. Allowing both parties in remote consultation to simultaneously interact with a shared web view could help participants and health experts to be even more engaged in the co-interpretation process.

Compilation artifacts. In our research, we did not design for compilation artifacts because the creation of these artifacts often involves multiple data sources. For example, health experts often review data from other systems, such as EMR or client management systems that record prior visit histories, to create compilation artifacts. These artifacts are then recorded as new entries back to the EMR or client management systems. As our goal was to design and evaluate a flexible prototype to examine design principles for individual and collaborative review, the complexity of integrating these systems was beyond the scope of this research. Future research should examine practices for integrating the results of this review into other systems, and also drawing on data from other systems to support collaboration.

Structuring artifacts. As we describe in prior sections, although we did not design for structuring artifacts, participants and health experts used the photo-based visualization and the mobile app as structuring artifacts. Health experts referred to photos in the photo-based visualizations as example meals for participants to follow after visits. They also created new tracking plans to further verify their hypotheses. However, participants and health experts still had to take their own notes about action plans or do the work to identify the right tools to support those plans. Post-visit summaries with photo examples might remind participants of their conversation with health experts and understanding or plans developed during the consultation. Participants might also refer to such examples when making food choices or diet changes. Integrating other tools that support further examination of healthy eating strategies or IBS trigger identification can also be valuable next steps. For example, IBS patients might need different tools to support further hypothesis formation and testing [41]. Potential triggers identified using Foodprint could then be used to configure these tools and provide a more focused direction for further examination.

7.2 Supporting Individuals with Myriad Health Goals

In both the healthy eating and IBS studies, participants and health experts found that collecting and collaboratively reviewing the data helped them identify patterns and develop actionable plans for addressing individual health goals. However, because these two different groups came in with different health goals, their uses also differed. IBS patients and providers focused primarily on trigger identification and management, and thus focused on using data to identify potential causal relationships. Healthy eating participants and health experts spent more time discussing potential goals and reviewing the data to identify and consider various possibilities.

Prior research on individual self-tracking practices has emphasized the importance of customization based on individual goals [65] and the need to facilitate transitions among different tools to support concurrent goals [18]. Here we emphasize the importance of supporting multiple and sometimes competing goals when creating inclusion artifacts. In our research, having access to pre-visit notes surfaced various goals and questions. This helped participants and experts focus their review on these goals while also not focusing too narrowly on just one goal. Future systems like Foodprint can use these goals and questions to configure or suggest configurations of the web view for collaborative review. For example, systems can suggest filtering by meal time when participants have questions around how to incorporate healthy eating strategies in their busy schedule. Analyzing these goals and questions over time can also help participants and health experts understand how individual goals and practices change over time, discuss about why specific strategies work or do not work, and determine feasible strategies in the long run.

7.3 Supporting Health Experts in Different Roles with Different Workflow Constraints

Health experts found Foodprint useful for dietary consultations and many wanted to use it outside of the study, but they envisioned different ways it might fit into their workflows. They all found reviewing photos before and during the visits to be more efficient than their previous experiences reviewing text-based diaries. However, some health experts thought they would encourage their clients or patients to review their own diaries beforehand. Others did not need their clients or patients to prepare before the visit because photo-based visualizations already made it easy for them to review on the spot.

Health experts with different roles and workflow constraints also had different expectations regarding how to potentially integrate Foodprint in future visits. Many dietitians and nutritionists review diaries as part of their day-to-day work. They also have the nutritional knowledge for detailed dietary review and have 30-60 minutes to do so with each patient or client. They felt photo-based diaries saved their time and, because they could easily complete a review and develop an individualized, action plan in the allotted time, they did not need clients to do more of the reviewing tasks. In contrast, physicians normally have limited time to review diaries before or during a 15-20 minute clinical visits. Many physicians, as a result, expected their patients to review data before they met and would be able to provide more insights to help with review. When reviewing the IBS nutrient analysis report, physicians also worried that they need to spend more time to interpret the relationship before and during the visits. Even though all health experts (a dietitian, a nurse, and two physicians) appreciated the time and effort saved by the report, the two physicians without nutrition training worried that they need to spend more time and effort to prepare for explaining the results to patients and answering questions during collaborative review.

Our research shows that photo-based visualizations made it easy for participants and health experts to see eating patterns and relationships between food and health goals without extra preparation. It also shows that pre-visit notes helped health experts focus on participant goals and questions when reviewing food photos. This is consistent with the recommendation from prior research [66] that suggested systems should provide easy interpretations and allow patient annotations in-between visits to help providers prepare for collaborative review. One opportunity to further decrease health expert burden is to integrate the pre-visit notes into systems and allow individuals and health experts to customize the photo-based visualizations based on individual goals and questions in these notes. For example, when IBS patients have questions about whether and how probiotics influence their symptoms, those patients and associated health experts can choose to categorize the food photos based on symptom severity and when they took probiotics. Such goal-directed customization could then help health experts answer questions using the data the individual collects. It could also support patients and health experts in configuring new tracking plans focusing on data that can answer their questions.

7.4 Tension between Automated Analysis and Over-quantification

Health experts in this study and in previous research (e.g., [1,60]) have proposed ways to use automated filtering and analysis to help people review diaries more efficiently, especially when health experts need to review large amounts of data in time-constraint clinical visits. More research is needed to develop and evaluate automated mechanisms while retaining the value of photos and having people involved in the process [16].

Automated filtering could potentially help people and health experts focus on data most relevant to their health goals. For example, providers thought they would benefit from having systems filter out foods that might not be a trigger, such as when they appear in both "No symptom" and "Severe symptom" columns. However, each individual often has a personal threshold for FODMAP carbohydrates, meaning different people can tolerate different cumulative amounts. The ability to look at foods across a day instead of in a single meal provides a better understanding of what these thresholds might be, and so hiding some images could obscure this insight.

Automated analysis could also save the time that people and health experts spend on understanding the content of the food. For example, having a system show whether and what type of FODMAP each food photo contains can save individuals and health experts from decomposing food into nutrients by themselves. Automated or semi-automated analysis might someday replace the process of dietitians coding photos to support quantitative analysis, reducing costs and the delay between patients recording data and getting this feedback. However, automated analysis also can risk over-quantifying self-tracking data and overlooking contextual information. Subtle differences in food preparation and context can result in different patient symptoms. Context captured in photos also often allows health experts to better understand their patients or clients, which is useful for identifying strategies for change as well as supporting affective needs, as we saw in section 6.4 with ID7 and IP14, with photos showing IP14 eating in the car every day.

Personal informatics researchers have questioned to what extent systems should automate the integration and reflection stages of *tracking* [16]. Our research surfaces additional tensions in deciding what *analysis* should be automated, as well as who should engage in different integration and reflection activities when data from personal informatics systems are collaboratively reviewed. For example, more automated analysis could save time in a short clinical visit, but at the risk of obscuring information that is necessary for identifying a trigger, for a patient receiving affective support from their provider, or for developing an appropriate plan for adjusting one's diet.

Future research should continue to investigate how to best design and integrate automatic filtering and analysis into collaborative review. Further research will need to examine the benefits and challenges of adopting automatics features to help designers trade off design decisions between increasing efficiency and encouraging individual and collaborative reflection. Future research should also examine what contextual data is important and how design can better support the collection and integration of this data into the automatic analysis process.

8 CONCLUSION

To support people in sharing self-tracking data and collaborating with others across contexts, extensive research has examined the practices and challenges of using such data and proposed design considerations to support such use (e.g., with family members [58], with people in local communities [57], with health providers [20,62]). Our current research builds on these understandings and takes a step further to design a photo-based diary to support collaboration in the context of dietary data collection and consultation. Our research demonstrates how to design a photo-based diary system to support the creation and sharing of boundary negotiating artifacts. By supporting people in transforming their self-tracking data into various artifacts, we prepare individuals to collect data relevant to their health goals, help health experts focus collaborative review on individual context, experiences, and goals, as well as enable individuals and health experts to develop individualized and actionable plans and strategies. As more technologies become available to improve ways people can collect, integrate, reflect on, and act on self-tracking data in collaborative contexts, researchers and designers should continue to examine how design can support various individual and collaboration goals, expert roles and workflows, as well as tradeoffs between automatic analysis and having people involved in the process.

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APPENDIX 1 ADDITIONAL QUESTIONS ABOUT FOOD DETAILS AND EATING EXPERIENCE

Symptom [IBS participants only]

How much have the symptoms below impacted you since your last log entry?
Overall, how much have your symptoms impacted you?
0-1-2-3-4-5-6
Abdominal Pain
0-1-2-3-4-5-6
Bloating
0-1-2-3-4-5-6
Constipation
0-1-2-3-4-5-6
Diarrhea
0-1-2-3-4-5-6
Stress
0-1-2-3-4-5-6

Symptom Tracking Key

0	No symptoms
1	I only noticed my symptoms when I focused on it
2	I could ignore my symptoms most of the time
3	I could continue what I was doing
4	I had difficulty concentrating on some tasks
5	I had difficulty concentrating on any tasks
6	I couldn't do anything

Food

Did you add anything to this food at the table? (Check all that apply) [IBS participants only]
Added Fat
'butter/margarine', 'salad dressing', 'gravy/sauce', 'mayonnaise', 'cheese'
Sugar
'table sugar', 'artificial sweeteners', 'other (honey, agave, syrup)'
Milk
'lactose based', 'soy', 'other (almond/hemp)'

Is this food gluten-free? [IBS participants only]
Yes, No, Not sure

How spicy is this food? [IBS participants only]
Not spicy, Mild, Medium, Hot, Very hot

Which meal of the day was it?
'breakfast', 'lunch', 'dinner', 'snack', 'beverage'

Where was your food prepared?
'home made', 'packaged', 'restaurant made', 'fastfood', 'other types'

How was the food prepared? (Check all that apply)
'baked/roasted', 'grilled/broiled', 'fried/sautéed', 'deep fried', 'steamed/boiled', 'not sure', 'n/a', 'other'

Who did you eat the food with? (Check all that apply)
'alone', 'significant other', 'family', 'friends', 'co-worker', 'others'

APPENDIX 2 PRE-VISIT NOTES

Goal of the visits

Use one or two sentences to describe what you would like to get out from meeting with the doctor or dietitian.

Summaries to the doctor or dietitian

(a) Have you found any relationship between your food and symptoms? Do you have any suspicion about any foods?

(b) Write down three or more major things you found in your data

Questions to the doctor or dietitian
Write down three questions or more you would like to ask your doctors or dietitians

Other information to share with your doctors or dietitians
This can be other information about you or your eating that you think your doctors or dietitians should know, such as special events, physical activities, sleep.

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