



EcoMeal: A Smart Tray for Promoting Healthy Dietary Habits

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Abstract

Dietary habits greatly influence one's health. Particularly, for the patients who suffer from metabolic syndrome, maintaining a healthy dietary habit is crucial to their health. In this paper, we aim to study the dietary behavior of such patients and design a system that can support their difficulties during food plating and eating process. We implemented a prototype to support the patient's eating speed, food portion control and calorie/sodium management. The preliminary evaluation results show both positive and negative aspects of our approach.

Author Keywords

Dietary behavior; persuasive computing; food sensing; healthcare; Internet of Things;

ACM Classification Keywords

H.5.m. Information interfaces and presentation: Miscellaneous; J.3 Life and medical sciences: Health.

Introduction

Dietary habit is known to be one of the main contributing factors for obesity, hypertension, and diabetes [4]. Although a healthy dietary habit is being emphasized, the recent statistics¹ show a sharp

¹ Health Insurance Annual Report, National Health Insurance (NHI) of Korea, 2014.

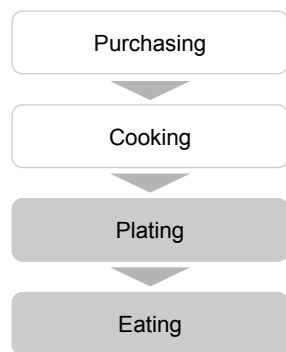


Figure 1. Point of decisions in a dietary process; we target plating and eating process

increase in prevalence of metabolic syndrome, which is a lifestyle disease involving all three conditions listed above.

Among the many dietary habits, slow eating is one of the most easy and encouraged methods to improve health. Results from dietetic researchers show that it takes at least 20 minutes to deliver the satisfaction signal to the brain that your stomach is full [1]. Therefore it can reduce the unnecessary food intake resulted from the insensitivity to satiety. Eating slowly is more than just reducing the food intake as it also increases the time of chewing which helps digestion. As the metabolic syndrome is known to be correlated with fast eating, the patients are prescribed to implement slow eating [7].

Further, other than the eating speed, nutritional control during cooking and ingredient purchase decisions are also important as they all are a part of important dietary processes that influences healthy eating (Figure 1). However, we limit our scope to the “food plating” to “eating” process that directly intervenes the food intake decisions of the patients.

In this study, we first explore the dietary behavior of metabolic patients and their strategies to maintain healthy eating. We then take those initial findings to design and implement a food tray called EcoMeal that supports the user to plate the food with the tailored portion and provide a real-time feedback on the eating pace. We also explore how the patients benefit from calorie and sodium intake management, which is quantified by our system. Our late-breaking work reveals both positive and negative effects from the patients, including successful eating speed control, food

and sodium management, and side-effects from using our system. We envision EcoMeal to be applicable not only for domestic purposes such as at home but also in greater organizations such as hospitals, schools and workplace cafeterias.

Related Work

Researchers of HCI community have been making constant efforts in supporting healthy choices throughout each point of decisions, from ingredient purchase to food consumption using different approaches. Foodle [6] used grocery purchase information to generate recommendation by comparing the nutritional information with the user’s dietary goal. Also prior work aiming healthy cooking was done by Chen et al., who introduced a calorie-aware cooking using camera and weight sensors embedded in the kitchen [2]. An information display provided the nutritional facts retrieved from the camera and the corresponding food portions through the weight sensors. These researches did not attempt to directly intervene one’s food intake process. For example, ingredient purchase and cooking could be done by one of the family member other than the one who is in need of healthy eating. Thus, it is an indirect way of influencing the patient at stake.

Interventions during the eating process have been studied by many researchers. A body of work focused on intake behavior recognition using various sensors. Accelerometers and gyroscopes embedded into the utensils and wrist bands enables capturing the eating patterns in real time [5]. Sensing Fork [3] used an interactive fork connected with a smartphone to provide a gameplay that encourages a child to maintain a nutritional balance during eating.

Our work aims to intervene the patient from the plating process to control the food portion, to the end of eating using sensing and feedback technology through an interactive system.

Initial Study

We conducted a semi-structured interview with metabolic syndrome patients to understand 1) undesired dietary behaviors from the past, 2) the efforts being made to maintain a healthy dietary habit, and 3) what are the difficulties they face while implementing their current strategies. We recruited five couples where at least one of them being a metabolic syndrome patient (Mean age = 59.3). Six of them were patients (five males) and among them, two were in a severe condition. The reason we engaged couples in this experiment is that dietary habit is formed not only by an individual but also by their families. So understanding how the food is cooked and served to the spouse could be very important. Moreover, confirming each other's statements was required for stronger information reliability.

Past dietary behaviors

All six patients had experience with fast eating, and four of them still had a hard time eating slowly. They stated that their meal time duration was between 3 to 10 minutes maximum. P3 mentioned the reason for eating fast was the chewing time being too short saying that "the food just slides through the throat after few chews". It was interesting to note that not only the patient, but also two out of four healthy spouses said they eat at a similar speed. P4 stated, "when I saw my husband eating at an aggressive speed, I found myself eating at the same pace without any intention".

The food portion was also excessive. The portion was described subjectively. However, they were able to confirm that "compared to my wife" or "compared to the recommended portions from the prescriptions" it was excessive. Interestingly, the two patients with a severe condition neither ate fast nor did they consume excessive amount. P8 said, "After understanding my severe condition, I do not eat as much and I am mindful of the speed as well". We could infer our main target group could be the patients with less severity.

Regarding nutrition management, P1 said, "I loved sweet and salty dishes, also greasy ones. I still do, but my wife does not cook like that anymore." Fat and salt are known to have a critical influence on the metabolic syndrome patients, and they were being managed well by their wives.

Current strategies and their difficulties

Half of the patients used personal tray or personal plates rather than sharing a large portion of the dish with their family members. This way they were able to control the portion and not overeat. However, there were two identified difficulties regarding the portion control.

The first difficulty is that they were uncertain of "the right portion". Once the food was served, they rarely left any food in the plate, and so if the food is not served in an appropriate portion, it is likely that they will overeat. P5 said, "I always fill up my personal rice bowl up to 80%. I am satisfied with that portion, but I have no idea whether it is the correct amount." The second difficulty is that the wives refused to serve a small portion. P3 and P9 brought up this interesting issue saying "I feel my rice is too much, but my wife

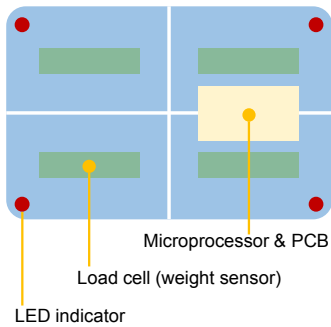


Figure 2. Top view of the prototype

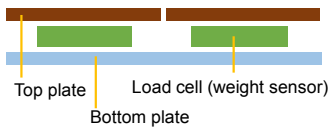


Figure 3. Side view of the prototype



Figure 4. Final prototype of EcoMeal

refuses to give me less, saying it is impolite to do so.” P3’s spouse P4 said, “I give him another empty bowl so that he can take out some of the rice if he wants, but I feel that I do not treat him right if I serve less”

All of them were well aware of slow eating. Five of them used either a clock or a timer to keep track of the time. They mostly aimed eating for more than 15 minutes. However, there was one difficulty identified with the current strategy; during eating, they usually forgot to watch the clock. Some replied that even if they were aware of the time, they were not able to control the speed according to the left over portion, finishing the meal only after half of the time had passed.

All of them controlled their sodium levels well. However all patients expressed a certain level of stress, for some being very stressful eating bland dishes. P1 said, “I know I should not eat salty foods, but this is too bland!” P10 said, “The doctor recommended me not to drink up all the soup, as the soup includes a vast amount of sodium, but I have a hard time complying with this.”

Design insights

Based on the interview, we could derive the following functional design criteria that are in needed for those patients and their spouses:

- A personalized tray
- Quantification of the initial serving portion
- Real-time feedback on their eating pace
- Daily calorie and sodium management

Prototype Design

Based on the initial study, we designed EcoMeal, a personalized dietary habit guidance system (Figure 4). It consists of two parts: the tray that senses the food

weight, and the smartphone application that personalizes the tray according to the user and food profiles.

Tray

The tray is divided into four sections; each section is capable of sensing one type of dish/food as shown in Figure 2 and 3. Accuracy of the gram level load cell is used to weigh the change in food placed on the corresponding plate. The weight data is processed by the microprocessor and then communicates with the smartphone to decide whether the placed food is within the recommended weight. If not, the corresponding LED will light up providing a warning signal to indicate over plating. This way either the patient or the spouse who is plating the food can immediately choose to serve less at the point of decision. Also, the simple indicator saves the effort of holding and looking into the smartphone to confirm whether the portion is appropriate.

Smartphone Application

The smartphone is first used to input the user’s physical profile including gender, weight, height, and daily exercise level to compute the recommended calories per day. The Harrison Benedict equation was used to derive BMR (Basal Metabolic Rate).

Food-type sensing is another domain of research that requires additional sensors such as photocells sensors [3] or cameras [2]. Therefore, we employed a semi-automated method for inputting food type and its nutritional information. The user may select one of the tray sections displayed in the user interface (Figure 5). Then, the user chooses to either select the dish from the database or add a new dish with the unit calories and sodium. The unit calories and sodium is then

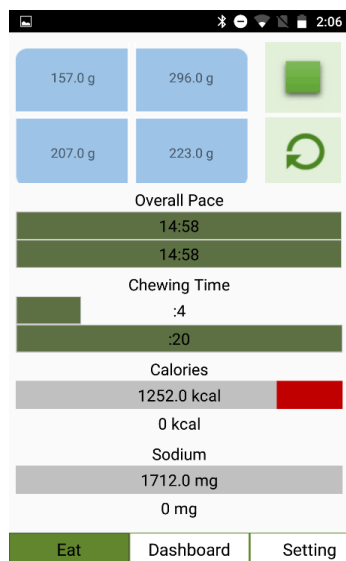


Figure 5. User interface of EcoMeal application; Eat mode

multiplied by the actual weight to acquire the total calories and sodium.

Once the user is ready to eat, the timer starts counting down by pressing the start button. The user's eating pace is estimated in real-time by: goal time \times (current food weight/ initial food weight). As the user eats faster than the pace he is supposed to, the bar graph blinks in red with an estimated time of meal time duration (Figure 7). This way the user may evenly intake the food during the goal time.

The chewing time was excluded from this late-breaking work due to unsatisfactory accuracy. Our pilot test showed many instances where the user repeatedly crammed the food even before fully chewing and swallowing that mouthful. We also concluded by controlling the total eating time, chewing time will likely to be increased.

Total calories and sodium are instantly displayed on the display when the food is placed on the tray. While eating, the user is able to observe every spoonful of calories and sodium intake that accumulates to one's daily total.

Evaluation

We again recruited three couples where at least one of them suffers from metabolic syndrome (Mean age = 60.1). Among the six participants, four of them were patients (two males). We conducted a one day, two-meal experiment from lunch to dinner. In this evaluation we aimed to understand the patient's and the spouse's experience with our prototype from the food plating to eating process.

Food plating process

In this study, all wives plated the food for their husbands using EcoMeal. As most Koreans do, rice was

placed in the left bottom section and soup on the right bottom. There were two sections left, with more than five dishes to plate. As shown in Figure 6, all participants plated three to four dishes onto one plate. Therefore, accurate measurement of calories and sodium on those plates was not possible. In the initial study, there were often cases when the wives "over plate" the rice for the sake of "being polite." However they were given the "over plating LED signal" and took out some rice until the LED went off. For those, whom the LED signal did not blink, said that they were satisfied with this "confirmation from the accurate device for appropriate food portion" of which they were uncertain before usage of this system.

Eating process

During eating, the smartphone was placed beside the tray. Four people (two households) finished after the 15 minute goal (avg = 19.5min) and two (one household) finished earlier (avg = 12.1min). The slow eaters reported that the real-time pace bar changing its color to red kept them from eating fast. However, one of the two fast eaters who happened to be a healthy participant said, "watching the timer ticking down made me eat faster than usual." The other fast eater stated that "I did check my pace on the smartphone, but then watching my wife eat made me pace up with her".

From this result as well as the initial study when P4 stated "naturally pacing up with my spouse" we could infer that the social impact needs to be further considered into the dietary interventions.

Regarding the calorie and sodium intake, not all participants observed the data during eating. However, those data drew their interest after finishing the food. They showed a great interest toward the sodium data since it is a great influential factor for hypertension. Particularly, P1 who showed a great discomfort in bland



Figure 6. Several dishes placed into one plate section



Figure 7. Eating with EcoMeal; a red blinking bar is shown if the eating is too fast



Figure 8. Spoon placed into the bowl was falsely recognized as food

cooking said “now that I know I took such little sodium, I don’t need to eat bland food for dinner.”

Conclusion and Future Work

In this work, we built a working prototype for guiding healthy dietary behavior based on the interviews with metabolic patients. From the evaluations, we were able to confirm that real-time feedback during eating can be helpful. However considering the observed side effects that ticking-down timer encouraged faster eating, the presentation of the feedback should be reconsidered; possibly toward more simple and ambient feedback. It is also important to note considering the target users of the current prototype are metabolic syndrome patients who are usually over the age of 50, simplification of the user interface is crucial. In addition technical limitations have been found, such as Figure 8 where the user places the spoon into the bowl that the system falsely recognized it as additional food. Also the chewing time which was a neglected function from this late-breaking work will be included in our future work.

We plan to deploy EcoMeal to organizations such as schools, hospitals, or workplace cafeterias to promote personalized healthy eating. In this environment, the need for individual input of food calories is not needed, because the menu could be centrally managed by the organization. Therefore it could greatly enhance usability and user experience with our system.

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