Affecting Our Perception of Satiety by Changing the Size of Virtual Dishes Displayed with a Tabletop Display

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Abstract. In this paper, we propose a tabletop system for affecting our perception of satiety and controlling energy intakes by controlling a size of a projected image around the food. We hypothesized that ambiguous perception of satiety can be applied to control our food intake. Given that estimating portion size is often a relative judgment, apparent food volume is assessed according to the size of neighboring objects such as many cutleries. Especially, the effect of the size of dish on food intake has been debated. Based on the knowledge, we constructed a tabletop system which projects virtual dishes around the food on it, in order to change the assessed apparent food volume interactively. Our results suggest that the size of virtual dish change the perception of satiety and the amount of food consumption.

Keywords: Augmented Satiety, Human Food Interaction, Cross-modal Interaction, Augmented reality, Food Consumption.

1 Introduction

Obesity has become a serious public health concern all over the world [1]. To decrease rates of obesity, many researchers have developed systems and services in the field of engineering [2, 3]. Many of these promote physical activity and bring users to the attention of the amount of the food eating.

However, Sustaining highly conscious effort to control amount of food consumed adequately is difficult. One of the reasons is that humans cannot accurately assess the volume or nutrition value of the food they consume. Therefore, humans estimate the volume of food eaten by using indirect cues: distension in the stomach and bowels, elevated blood-glucose levels, and apparent size of food. This estimation is inaccurate because some kinds of cues are evaluated relative to an individual's surroundings.

Recent studies in psychology have revealed the apparent volume of food can influence eating behavior. Given that estimating portion size is often a relative judgment, apparent food volume is assessed according to the size of neighbouring objects such as dishes and cutlery [4, 5].

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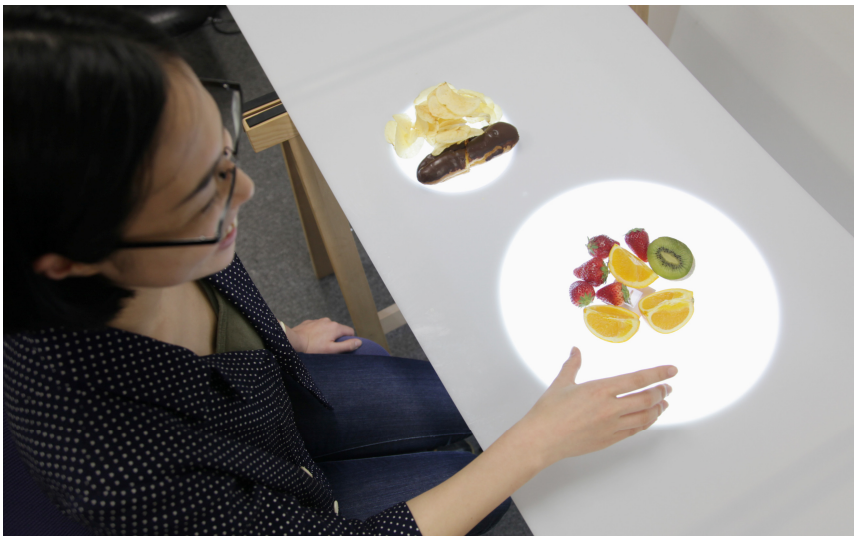

Fig. 1. Tabletop system which projects virtual dishes around the food for affecting the perception of satiety

Our early research focuses on changing the apparent size of food for affecting the perception of satiety as the cue. We have proposed a method for food-volume augmentation using shape deformation processing in real-time [6]. We have shown that our system could change the consumption volume from about -10% to about 15% by changing only its apparent size without changing perceived fullness.

Meanwhile, the previous system based on augmented reality paradigm has some limitations. First, it has strong limitation in target food and environment. It is useful only for food eaten with the fingers and cannot be used with arbitrary backgrounds. Second, the change in the apparent size of the food is presented to users by using a head-mounted display (HMD) in the system. However, use of wearable devices such as a HMD in every eating is unnatural and unrealistic.

To solve these problems, we propose a tabletop system for controlling perception of satiety (Fig. 1). The proposed system displays visual stimuli for affecting our eating behavior around the food on it using marker-based food tracking techniques. This enables us to use the system with any kind of food except liquids. It also eliminates the need to use wearable devices.

In this paper, we first explain the implement of tabletop system which displays virtual dish around the food for controlling perception of satiety. Next, we discuss its validity through an exploratory study.

2 The Effect of the Size of Dishes on the Estimation of Volume of Food and Food Consumption

Among some eating utensils, the effect of the size of dishes on the estimation of volume of food and food consumption has been vigorously debated [5, 7]. However,

recently, a possibility is indicated that the effect of the size of dishes on amount of estimation and consumption of food based on principle of the Delboeuf illusion [8].

Delboeuf illusion is phenomenon that is concentric circles surrounded by a largecircle around seems smaller, and concentric circles surrounded by almost same size circle appear larger (Fig 2) [9]. This is known that the former effect is most effective when the ratio of external diameter of the circle to inner circle is 1 to 3, the latter effect is most effective when the ratio of external diameter of the circle to inner circle is 2 to 3. Also this has no effect when external diameter to the circle and inner circle is 1 to 2.

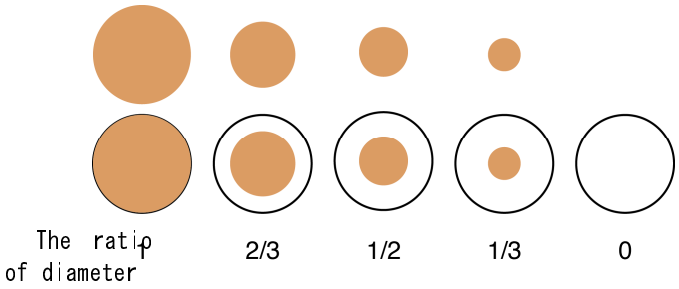

Fig. 2. Delboeuf illusion

Ittersum et al. showed that the size of dishes affect on the estimation of amount of food in the range about -10% to 12% even in the same amount of food by Delboeuf illusion (Fig 3) [8]. Through the experiments, Ittersum et al. have confirmed that the above-mentioned paradoxical results between [5] and [7] can be explained by the effect of this illusion.

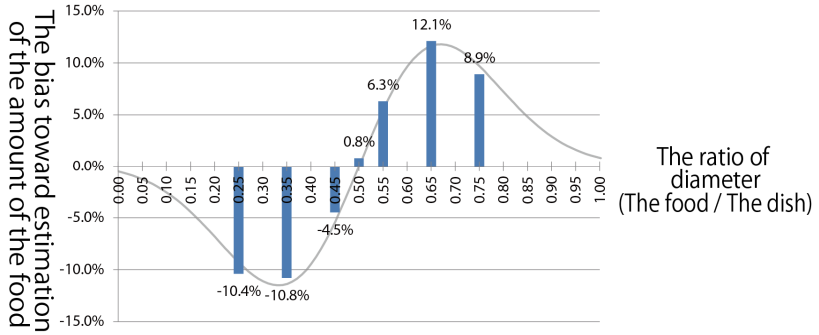

Fig. 3. The bias on estimation of food volume based on Delboeuf illusion (created based on [8])

While this experiment showed that estimation of the amount of food change depending on the size of dishes, whether amount of food consumption varies or not depending on its. Considering the result, amount of food intake that is influenced by

the size of the dish will be similar to reversing plus and minus of the estimation of amount of food in above experiment. On the basis of above knowledge, we control our satiety and amount of food intake by changing the size of virtual dish displayed around the food using the system we propose.

3 A Tabletop Display for Affecting Our Perception of Satiety

We propose a method for controlling the perception of satiety by changing a size of projected image around the food using a tabletop display. We aim to affect the perception of satiety by changing the size of projected dishes and the relative size of the food on it. This gives the users the impression that there is a difference in food-volume on a virtual dish although amount of food is same.

Figure 4 shows the setup of our system. The system consists of a laptop PC, transparent plastic plates with AR markers, a semi-transparent lacteous acrylic board, a WEB camera, a mirror and a projector. The users put food on the transparent plastic plate. Each transparent plastic plate is attached an AR marker for detecting the position of the plate and food on it. The AR markers can be seen through the semi-transparent lacteous acrylic board from under the table when the plates are put face up on the board. A WEB camera put under the table captures the AR tags and the system calculates their position. This enables the tabletop system to aware position of each plates and food on it, and projected virtual dishes around each plate.

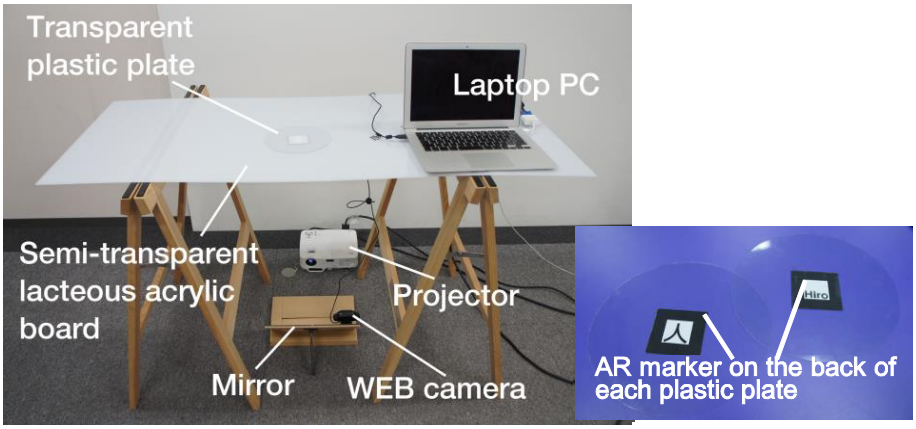

Fig. 4. System configuration

4 Exploratory Study

We conducted an exploratory study to investigate how the perception of satiety and food consumption would change by changing the size of projected dishes. In the current study, we examined whether our system would change consumption volume

even though users are not consciously paying attention to a change in volume. Participants were not made aware of the true purpose of the experiment.

4.1 Subjects

The study consisted of 9 subjects and they were all males. The subjects' ages ranged from 21 to 25 and the average age was 22.6 years-old. The subjects were screened to determine that they were in good health, had no food allergies/restrictions, were not currently dieting for weight- loss or trying to gain weight, were not depressed, were not using medication known to affect appetite.

4.2 Experimental Design

The exploratory study used a within-subjects design. On 3 separate days, subjects came to our laboratory to eat potato chips. The area where is put the potato chips were confined to area on transparent plastic plate. The size of the plate acts as a benchmark of comparison between the size of food and virtual dishes. The diameter of the plate is 17.0 [cm]. The amount of the food that is put on the plate at once is 50.0 [g] and its energy density was 5.6 [kcal/g].

During each testing session, subjects were presented with one of three apparent size of the virtual dish changes by our tabletop display system: small dish condition (× 1.0, 17.0 [cm]), medium dish condition (× 1.5, 25.5 [cm]) and large dish condition (× 2.0, 34.0 [cm]). The appearance of the virtual dish and potato chips in each condition is shown in Figure 5. To eliminate any effect of presentation order of the size, the presentation order was randomly assigned and balanced across subjects. The test days were separated by at least 2 days in order to prevent any satiation effects.

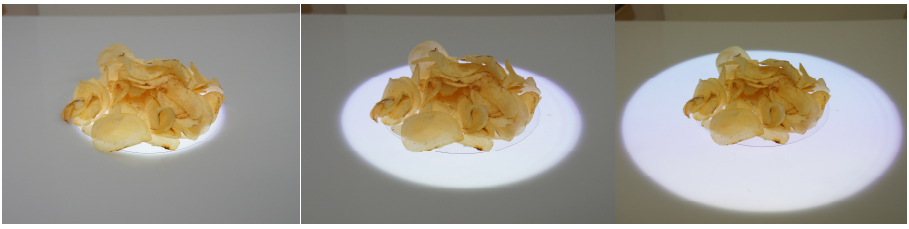

Fig. 5. Projecting a virtual dish around the food on plate (Left: small dish, Middle: medium dish, Right: large dish)

4.3 Procedures

Subjects were asked to keep their activity level as similar as possible on the day before each testing session. They were also asked to eat a similar meal as their last meal prior to the experimental session. During the day of each testing session, subjects were instructed not to consume any food for 2 hours prior to the exploratory study. Subjects kept a brief record of their activity patterns and food intake on the day

prior to, and each day of, the testing session. Prior to each testing session, subjects recorded their life cycle and we made sure that subjects had followed the prescribed protocol prior to each session: at least two hours had passed since their last meal, there was no significant change in diet since the previous testing session and that their activity level had been similar as previous days prior to the testing session (e.g., no all-night work or hard exercise). If activity patterns and menu differed from that of the day prior to the previous testing session, we postponed the testing session for at least one day.

First, subjects were asked questions regarding their hunger conditions. We describe these questions below. After this test, subjects were instructed to eat as much potato chips and drink as much water as they desired (Fig 6.) Subjects were told that they did not have to eat the entire potato chips on the dish and we allowed them to have leftovers. In the beginning, 50.0 [g] of the potato chips is put on the dish. Subject were also told that they can order additional potato chips or water, if they ate up the potato chips or drank down a cup of water and desire much further them. In this case, 50.0 [g] of the potato chips were put on the plate per an addition. In order not to be affected perception of satiety and food intake by other external cues, we asked subjects to focus on the food and the table before they ate it. After the subject stopped eating, we asked questions identical to those asked prior to the exploratory study.

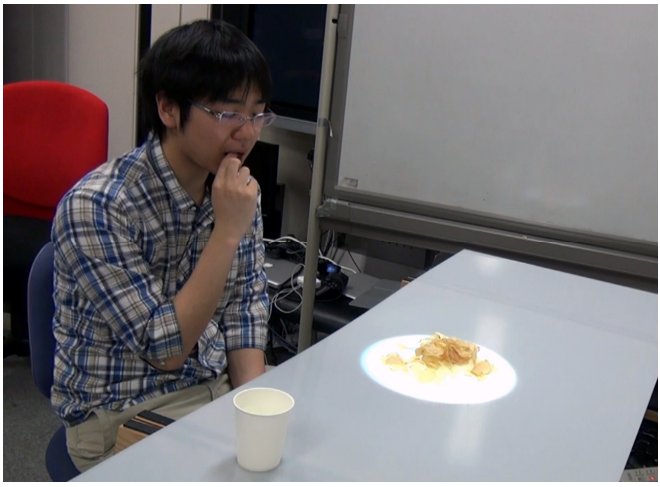

Fig. 6. A Subject eating potato chips using our system

4.4 Visual Analogue Scale Ratings

Subjects completed ratings of hunger and satiety immediately before and after the exploratory study. Subjects rated their hunger, thirst, nausea and fullness when completing the analogue scales. All questions are shown in Figure 8.

For example, subjects answered the question “How hungry are you now?” by rating hunger on a 100 mm line anchored by “not hungry at all” on the left and

"extremely hungry" on the right. Other anchors in other questions consisted of the phrases "not at all" and "extremely" combined with the adjectives "thirsty," "nauseated," and "full." If a rating during the current testing session had changed more than 30 [mm] compared with the rating from his/her prior testing session, we postponed his/her testing session.

The subjects were asked to rate the palatability of the potato chips on a 100 [mm] visual analogue scale prior to the experiment. We originally planned that subjects whose palatability rating was less than 40 [mm] would be excluded from this experiment in order to avoid inflicting them. However, all subjects found the potato chips highly palatable; thus, no subjects were excluded based on this criteria.

4.5 Results

Average potato chips consumption volume and standard error of the mean in each experimental condition are as follows: small dish condition: 72.1 ± 7.9 g; medium dish condition: 59.7 ± 7.7 g; large dish condition: 66.9 ± 9.9 g (Fig. 7). Figure 7 illustrates the normalized results based on the consumption volume under small dish condition by subject. The curve in figure 7 illusrates expected amount of food consumed from biases which affects on estimation of food volume by the results of Ittersum's experiments [8].

The amount of food consumed was expected to be going todecrease by about 12% under medium dish condition than small dish condition. Actual food consumption under medium dish condition decreased by an average of -13.4%. than small dish condition. Also amount of food consumed under large dish condition increased by average of 2.7%. this is a result that agree with the expectation that the amount under large dish condition is almost same as under small. Though clear significant difference is not shown, this result gives close agreement with expected changing amount of food intake from [8].

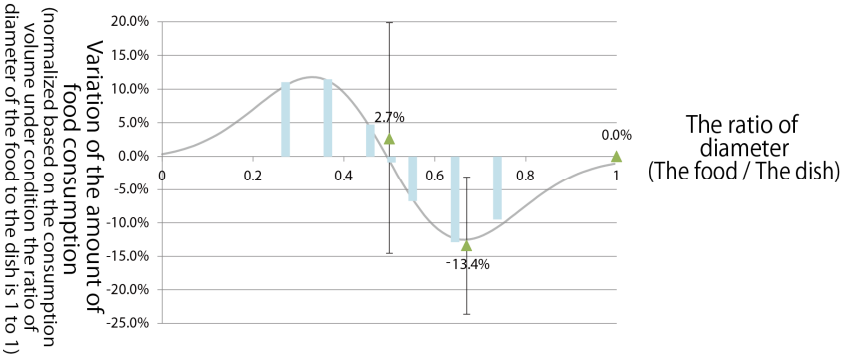

Fig. 7. Amount of potato chips consumed (± standard error of the mean) by the size of the projected dish

This shows possibility that amount of food consumption is predictable by effect of Delboeuf illusion when ratio of size of virtual dish to the food is changed using a tabletop display. Therefore, this result suggests a possibility that the ratio between diameter of dishes and food should be decided based on the effect size of Delboeuf illusion to change the amount of the food intake as it is intended.

Figure 8 shows the ratings of hunger and satiety before and after the testing session by experimental condition. Across all conditions of the size of the projected image, no significant differences were found prior to the testing session on ratings of hunger, thirst, nausea and fullness. There were also no significant differences on these ratings after each testing session.

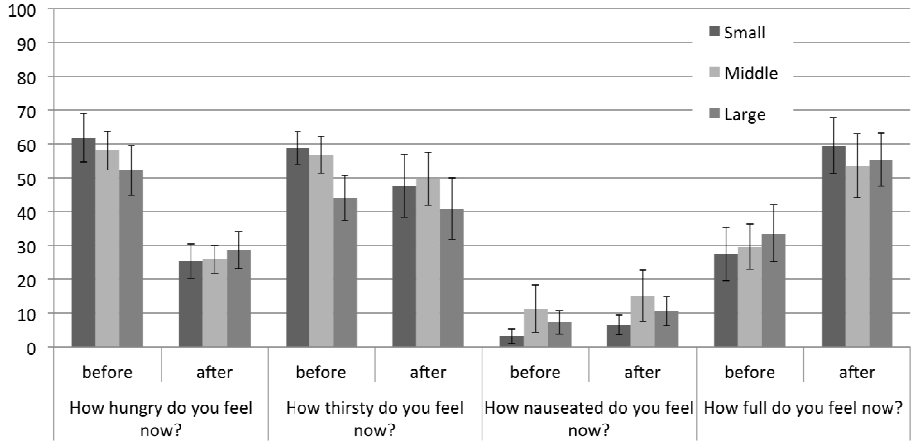

Fig. 8. Ratings of hunger and satiety before and after the testing session in each experimental condition. (Average ± standard error of the mean).

4.6 Discussion

Our results suggest that the size of a projected virtual dish affects food intake and the perception of satiety; this is accomplished from the same amount of food during a single meal. These results also suggested the validity of our experimental design, because there were also no significant differences on these evaluation values on survey item before and after each testing session. These results also showed that our system maintains perceived fullness even after subjects ate the food, since there were no significant differences about perceived satiety after each test session, this result suggested a possibility that our system changed amount of food consumed of subjects with remaining satiety of after each eating, or can change perceived satiety derived same amount of potato chips.

According to questionnaires after experiment, more than half of subjects were aware of different of the size of virtual dishes. Nevertheless average of amount of

food consumption changed mostly like the result of [8]. This shows our system affects on perception of satiety regardless of being conscious or not of subjects.

It was considered about the evoking of strangeness to the users when they put food on the plate and eating it. However, subjects answered they did not have feelings of resistance toward eating the food on the plate in their free description after all session. Therefore, it is thought that putting the food on the plate did not affect the experimental design.

5 Conclusion

In this paper, we proposed a tabletop system which displays virtual dishes around the food in order to control consumption volume of the food. It displays virtual dishes as visual stimuli for affecting our eating behavior around the food using marked-based food tracking techniques. This is based on previous research in the field of psychology. With this method, we can create the illusion of apparent food size and the perception of satiety. We developed a prototype system for implementing the proposed method. Also we conducted the exploratory study to evaluate the effectiveness of the proposed system.

Our study examined how the size of virtual dishes affects our "consumption volume" of food on these. As the result, we suggested that the ratio between size of food volume and virtual dish should be determined based on the effect of Delboeuf illusion to change amount of food intake.

We will test validation of the system through further sophisticated experiment with more subjects and expansion in the range of the ratio between the size of the virtual dishes and the food. Also we will discuss validation of cutleries, food and chromaticity contrast between dishes and tablecloth described in the reference of Ittersum et al. Through these assessments, we aim to realize a more effective system.

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