A multisensory augmentation system to enhance eating experiences

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An emerging way to promote healthy food consumption is to enhance consumers' food experiences with the help of extended reality (XR) technology. In this paper, we share the technical design of a multisensory augmentation system that uses simultaneous olfactory, visual, and haptic augmentation cues. We also report the results of a preliminary evaluation where the eating experience of plant-based balls was augmented with the three sensory modalities. The results suggested that it was possible to change the perceived size, weight, and odor intensity of the balls. We look forward to sharing our methods and experiences with others in the workshop.

CCS CONCEPTS • Hardware~Emerging technologies~Emerging interfaces • Human-centered computing~Human computer interaction (HCI)

Additional Keywords and Phrases: Multisensory augmentation, eating experiences, olfaction, haptics, augmented reality

1 INTRODUCTION

Consumers live in a contradictory situation being surrounded by different delicious high calorie foods but trying to maintain a healthy diet. Healthy foods can fulfill homeostatic needs, but hedonic needs are not necessarily fulfilled. Elements such as pleasure, creativity and playfulness are also connected with eating experiences. An emerging way to promote healthy and reasonable food consumption is to enhance food experiences with the help of extended reality (XR) technology.

Eating is a highly multisensory event where all the five senses contribute to the overall perception of flavor [8]. Researchers in the fields of human-computer interaction (HCI) and human-food-interaction (HFI) have used visual [5,6], auditory [9], haptic [2], olfactory [1,4], and gustatory [7] augmentation techniques to change the food flavor or related eating experience. Earlier work has shown, for example, that increasing the visual size of a cookie can lead to a decrease in cookie consumption [3] and that olfactory cues can affect the perceived sweetness of cakes [1]. Most earlier studies have had a setup where the augmentation cues have been produced with a single sensory modality. The aim of the current work was to introduce a multisensory augmentation system that uses simultaneously olfactory, visual, and haptic augmentation cues to enhance the experience of eating plant-based balls.

2 AUGMENTATION SYSTEM

2.1 Olfactory augmentation

Olfactory cues were presented with a custom odor display [1]. The operating principle of the display was to push air through a glass bottle containing the odor source. To enhance the experience of eating plant-based balls, an odor from beef and pork-based meat balls was used. A single meat ball was heated, cut into four pieces, and placed into the bottle. Odor presentation was controlled with solenoid valves that enabled and disabled air flow to the bottle when needed. From the bottle, the odorized air was delivered to the participants via polytetrafluoroethylene tubing. The tube outlet was placed on the chest so that it was facing towards the nasal area (Fig. 1A). This ensured fast odor delivery.

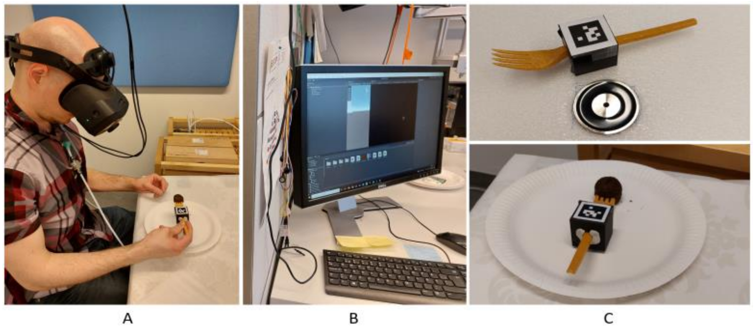

Figure 1: “A” shows the three augmentation systems: olfactory augmentation using the necklace device, visual augmentation using an XR headset and a QR code, and haptic weight augmentation using a custom fork. “B” shows the real-time workspace with live headset view and controls for augmentations. “C” shows the disposable fork with a 3D printed anchor that contained metal pellets. An electromagnetic actuator in the table interacted with the pellets and created the weight augmentation.

2.2 Visual augmentation

The visual augmentation was realized using a Varjo XR-3 extended reality headset capable of delivering human-eye resolution as well as streaming stereo video of the users' surroundings on the headset displays. The fork the participants used when consuming the food items was augmented with a 3.5cm x 3.5cm x 3.5m cube with a QR code on it (see Fig. 1C). This marker was programmatically tracked by the headset cameras and used as the origin point based on which the augmentation was offset. The augmentation showed a meat ball that occluded the real plant-based ball. In addition, the augmentation was made slightly larger than the plant-based ball to study whether the participants perceived a difference in the size.

Adding markers on all sides of the cube would allow for full 6 degrees of freedom of movement, but full range of yaw, pitch, and roll were not needed and changing the tracking origin sometimes causes jitter. We tracked just the top marker, which was found to be sufficient for this application. The benefit of camera-passthrough-based XR compared with more traditional augmented reality (AR) is that traditional AR devices overlay augmented information on the users' field-of-view usually resulting in translucent augmented content, whereas with the Varjo XR-3, we can achieve fully opaque augmented information completely occluding the physical food item from the users' view.

2.3 Haptic augmentation

The haptic augmentation was developed to modify the perceived weight of food products. The aim was to understand whether the perceived weight or force envelope can affect user’s eating habits. To achieve this, a physical cube with metal pellets inside was attached to the fork (Fig. 1C). The cube was 3D printed to ensure that the fork did not have additional weight associated with it, except for the pellets. Electromagnetic actuators used for augmenting the food items were embedded in the table surface on which the food plate was placed. Turning these actuators on with the experimental interface (Fig. 1B) increased the perceived weight of the plant-based ball on the fork.

The haptic augmentation was activated at the same time with the visual and olfactory augmentations. The actuators were controlled using a 5V optical relay circuit and triggered using an Arduino system. There was no perceivable delay in relaying the actuation and triggering as the optical relays and the actuators had less than 10ms delay, which during our piloting was outside the perceptual threshold.

3 USER STUDY

The augmentation system was tested in a pilot study in which participants were asked to eat plant-based or meat-based balls while using the headset, necklace, and fork. The study was conducted in a controlled laboratory environment and the aim of it was to discover if eating experiences were influenced by the three augmentation modalities.

3.1 Participants

Fourteen participants, eight female and six male, took part in the study. Participants were mostly students and researchers of Tampere University, Finland. They participated in this study voluntarily and no reward was given to them.

3.2 Procedure

The participants arrived at the laboratory where the study was explained before they signed a consent form. Following this, they were helped to put on the headset and the odor necklace display. Then, the participants were given some time to practice taking the fork to their mouth while seeing a colorful virtual ball through the headset. In addition, some advice was given on how fast/slow the fork should be moved and from where to grab it. Once the practice was over, the participants proceeded to three different test conditions:

- ***Condition 1: Plant-based ball.*** Plant-based ball with olfactory augmentation OFF, XR headset worn but visual augmentation OFF, and haptic weight augmentation OFF.
- ***Condition 2: Augmented plant-based ball.*** Plant-based ball with olfactory augmentation ON, visual augmentation ON, and haptic weight augmentation ON.
- ***Condition 3: Meat-based ball.*** Meat-based ball with olfactory augmentation OFF, XR headset worn but visual augmentation OFF, and haptic weight augmentation OFF.

After each condition, the participants were asked to rate the perceived weight of the ball, odor intensity, odor pleasantness, visual size of the ball, and overall pleasantness while eating. Once all the conditions were completed, the augmentation system was removed, and the participants were asked a series of open-ended questions.

3.3 Results

The results from each condition are presented in Fig. 2. Overall, the results showed that the subjective perceptions of the eating experiences could be changed with the tested augmentations. For instance, odor intensity of an augmented plant-based ball was perceived as stronger than the intensity of a non-augmented plant-based ball. Similarly, the visual size of the ball was perceived to be bigger with the augmentation.

The perceived weight of the ball was the heaviest in the augmented condition. In contrast, the general pleasantness of eating was slightly reduced in the augmented plant-based ball condition. This could be related to the answers collected from the open-ended questions, where participants defined the eating experience as fun, positive, good, interesting, unusual, pleasant, and similar to real life. However, two participants mentioned that they would have preferred to be able to see what they were eating, but this was not possible with the visual augmentation. Six participants reported difficulties trying to find their mouth while wearing the headset. Eight participants considered that the eating pleasantness was increased by olfactory and/or visual augmentation, while two participants remained unsure.

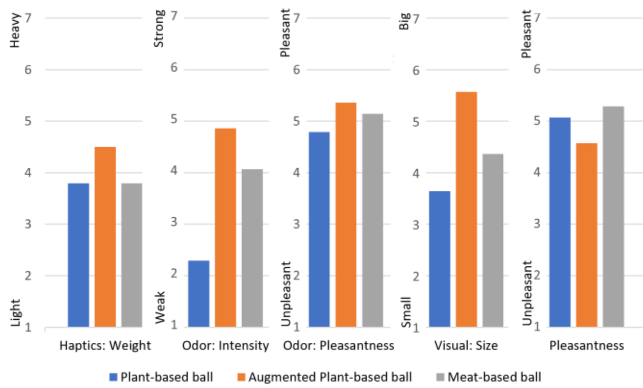

Figure 2: Means: haptic weight augmentation, odor intensity, odor pleasantness, size of the ball, and general eating pleasantness.

4 CONCLUSION

We introduced our experimental system for studying multisensory augmentation of eating experiences. The results suggested that the augmented plant-based ball was perceived to be heavier, bigger and the odor was more intense and pleasant compared to the non-augmented plant-based ball. However, these observed effects as such do not make a product healthier or promote healthier diets. In the future, the system could be used to investigate whether a smaller food portion would be consumed when the sensory-related eating experience is enhanced by the combined augmentations.

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