Aromug: Mug-type Olfactory Interface to Assist in Reducing Sugar Intake

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Reducing the amount of sugar consumed from daily beverages is essential for well-being. However, since a sudden reduction in intake is mentally painful for those who prefer sweetened beverages, solutions are needed to help them gradually become accustomed to non-sweetened drinks. In this paper, we propose Aromug, a mug-type olfactory interface that amplifies the user's perceived sweetness by providing a sweet scent along with the action of drinking. Through user studies, we investigated the effect of the information presented by Aromug on the taste of iced coffee. The experiment results showed that the sugar-free coffee and chocolate aroma might enhance the perceived sweetness compared to the no-scent case. In addition, it was suggested that there were differences in preference for sweetness depending on age and frequency of coffee drinking.

CCS Concepts: • **Human-centered computing → Ubiquitous and mobile computing**; **Human computer interaction (HCI)**.

Additional Key Words and Phrases: Olfactory interface, Motion sensing, Sugar intake reduction, Sweetness amplification

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1 INTRODUCTION

Many beverages we are used to drinking contain a lot of sugar. The consumption of sugar-sweetened beverages has increased dramatically, especially in developing countries [15]. As a result, the number of diabetics worldwide is increasing significantly yearly [13]. Excessive sugar intake is known to increase blood glucose levels, increase the risk of diabetes, and increased visceral fat, which is a cause of metabolic syndrome [11].

Several methods have been proposed to help people reduce their problematic excessive sugar intake [9, 17]. These methods can temporarily encourage the selection of less-sugar soft drinks and reduce sugar use. However, for those who habitually prefer sugar-sweetened soft drinks, less-sugar or unsweetened water is often unpalatable. Therefore, a temporary intervention will not last long and will likely result in a return to the previous lifestyle of regularly drinking sugary drinks. Finding solutions to reduce the amount of sugar used gradually is essential from a well-being perspective, as extreme reductions in sugar intake can lead to emotional distress for the user [7].

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Following the finding that much of taste perception is influenced by scent [10], we aim to amplify the perception of sweetness by presenting scent information in a well-timed manner in conjunction with drinking movements. In this paper, we propose a mug-type olfactory interface, "Aromug", which has a function of sensing the action of drinking and presenting scent information to increase the sweetness of drinks. We also verify the effectiveness of the amplification of the user's perceived sweetness by the scent. A series of experiments demonstrated the superiority of the proposed method. Based on these results, we emphasize the importance of an approach that promotes the expansion of the sense of taste through olfactory intervention in reducing sugar intake.

2 RELATED WORKS

In recent years, various types of olfactory devices and interactions using them have been proposed. For example, head-mounted displays [12, 20] and neck wearable devices [1, 5] that provide scenting have been developed. Wang et al. propose an olfactory device in the form of a piercing, necklace, or on-face device worn on the face [18]. The proposed system is designed and miniaturized for easy use in daily life. Amores et al. propose a necklace-type olfactory device that can be remotely controlled from a smartphone and can change the intensity and frequency of scents based on biometric and contextual information [1]. Dobbelstein et al. developed a wearable scenting device that can be used in daily life to receive personal scent notifications [5]. Choi et al. have developed 3D printed glasses with a heating module embedded in the edge of the frame to release scent [3]. While such olfactory interfaces that are integrated into everyday life have been developed, mug-type olfactory interfaces that aim to amplify perceived sweetness remain new.

In this study, we focus on mugs, which are used daily for drinking, and search for an olfactory interface that is highly acceptable and can be integrated into daily life. Furthermore, we will study the interaction to reduce the actual sugar intake while amplifying the perceived sweetness by the proposed system.

3 AROMUG

3.1 Use Case Scenario

We introduce use case scenarios of how Aromug can be utilized in practice. Taro, a 30-year-old office worker, usually has bread and milk coffee for breakfast before going to work (Figure 1A). Taro has a big sweet tooth, and he always puts milk and four sugar cubes in his hot coffee or tea. In the office, he drinks three cups of sweetened milk coffee, and after coming home from work, he drinks a beer with his meal. Before going to bed, he reads a book with a cup of milk tea (Figure 1B). Taro's wife was concerned about her husband's high blood sugar level and wanted him to reduce his sugar intake. One day, when Taro's blood glucose level reached the borderline range during a physical

Fig. 1. The Aromug use case scenario.

examination, his wife gave him "Aromug" as a gift (Figure 1C). Aromug is an olfactory interface in the form of a mug that presents a sweetness-enhancing scent when a drink is consumed. Taro decides to start a reduced-sugar lifestyle using the Aromug. He decided to use the Aromug whenever he drinks a beverage in his office. Taro wanted to know the effect of Aromug on sweetness amplification, so he poured hot coffee into Aromug. He then used the Aromug with a smaller amount of milk and sugar cubes than usual. As soon as he drank it, a sweet scent was sprayed from the Aromug, and he enjoyed an unusual but sweet taste of milk coffee. At this time, Taro experienced a sense of satisfaction similar to that of the milk coffee he usually drinks (Figure 1D). Taro thought this might not be a problem even if he used less sugar. Taro liked the experience of drinking from the Aromug so much that he began pouring tea and milk coffee into it as well (Figure 1E). As Taro's use of the Aromug increased, he began to enjoy the slight sweetness. He began to develop the habit of drinking milk coffee and tea without sugar. A few weeks after using the Aromug, Taro sipped his regular sweetened coffee for the first time in a long time. At that time, Taro was surprised that he had been drinking such sweet coffee regularly. He was also reminded that too much sugar is not good for the body. A few months later, Taro began to choose less-sweetened drinks without Aromug (Figure 1F).

3.2 Design of Aromug

We designed a mug-type olfactory interface that presents a scent (Figure 2). Aromug is composed of a mechanism for sensing the user's beverage behavior and a display that enhances the user's beverage experience. Aromug aims to amplify the perceived sweetness by controlling the timing of the presentation of scent information during the act of drinking. Aromug has a olfactory device inside the mug. Aroma Shooter [1] from Aroma Join Inc. was used as the olfactory device for the prototype.

The mug is equipped with a display on top of the mug. The display outputs a simulated image of the beverage being poured into the mug and serves to enhance the user's beverage experience. The output image on the display changes in real-time based on motion sensing. The real-time control of the image enhances the user's beverage experience.

In addition, an IMU sensor (MetaMotionR+) [2] is mounted on the bottom of the mug. Aromug uses a sensor on the bottom of the mug to identify the time between the user holding the mug, and the user finishing a sip of the drink. During that time, a scent is sprayed into the mug. The relationship between the sensor data obtained from the IMU sensor installed on the bottom and the spray timing (pink part) during three times of drinking is shown in Figure 3. This sensor data shows the amount of posture variation (quaternion) concerning a mug placed on a desk. Both the y-component and w-component of the quaternion change depending on the drinking motion. The y-component

[1]https://aromajoin.com/products/aroma-shooter
[2]https://mbientlab.com/metamotionr/

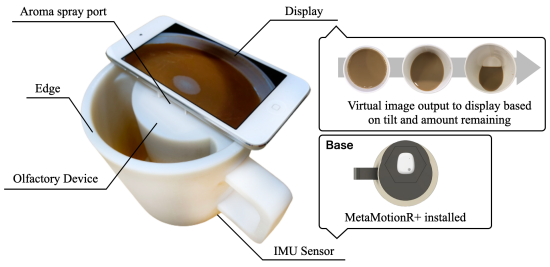

Fig. 2. Design image of Aromug.

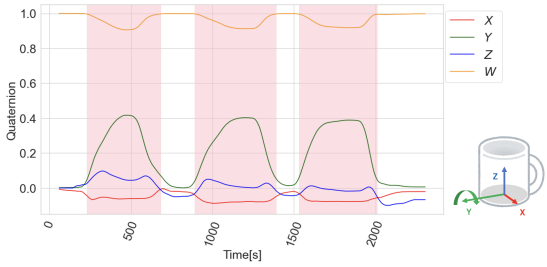

Fig. 3. Example of IMU sensor data and injection timing.

shows that the drinking motion is often accompanied by a rotational motion around the y-axis due to the direction of attachment. The pink part shows a series of drinking behavior, and Aromug is injecting the smell at this timing.

Thus, we designed a mug that closely resembles the usual beverage experience with sensing of the user's beverage timing and simulated in-cup video. Among other things, this paper presents the results of an investigation into the influence of scent on flavor sweetness amplification.

4 EXPERIMENT

In this study, a total of two sensory evaluation experiments were conducted using an Aromug prototype (Figure 2) to investigate the effects of various scents on taste perception. The experiment investigated the effect of olfactory stimuli on taste. Iced coffee was used in the experiment, and a questionnaire was administered to evaluate the taste of three types of iced coffee with different sugar contents and various scent combinations. The purpose and methods of the study and ethical considerations for the study participants were explained orally and in writing at the time the questionnaires were distributed. This study was conducted with the approval of the Ethics Committee of the organization to which the author belongs (Approval number: 2020-I-16).

4.1 Settings

In the Experiment, 33 university students and university clerks (15 males and 18 females) participated, ranging in age from their 20s to 50s (Mean=29.394, SD=10.503). Twenty participants in the experiment were in their 20s, and 13 were over 30 years old. Sixteen of the participants drank coffee frequently, and 17 drank coffee infrequently. In the Experiment, three types of iced coffee with different amounts of sugar (Sugar-free, Trace-sugar, and Ordinary) were used as base drinks, and three scents (Chocolate, Coconut, and Crème brûlée) were used. To reduce the bias caused by the order in which the participants smelled the scents, three different experimental patterns were prepared and conducted. Participants were asked to rest for 5 minutes between each stimulus and to drink water. After each trial, participants answered a questionnaire about the tasting. The questionnaire used in all experiments employed a 7-point Likert scale, in which participants evaluated the perceived taste satisfaction and taste sweetness of the drink.

4.2 Results and Discussion

Figure 4 shows the results of the mean and standard deviation of the ratings for all participants. The results of the Likert scale questionnaire are also shown in Figure 5. Each combination of coffee and scent is evaluated concerning the coffee without scent; this was considered as the standard for each coffee. The results for taste satisfaction did not exceed the standard when scents were added to the standard coffees, respectively. The sweetness of the taste was higher when

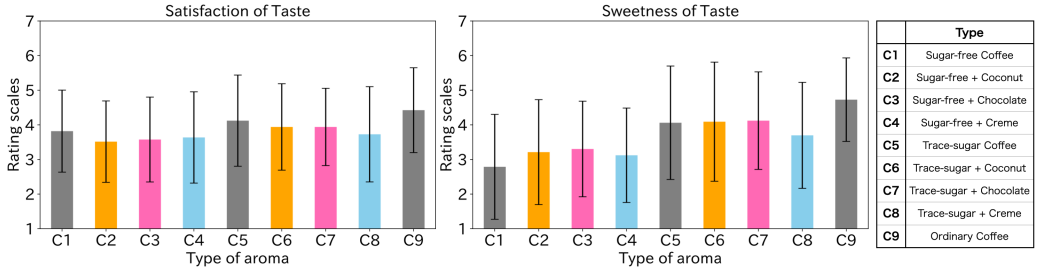

Fig. 4. Experimental results of taste changes due to different aromas (all participants)

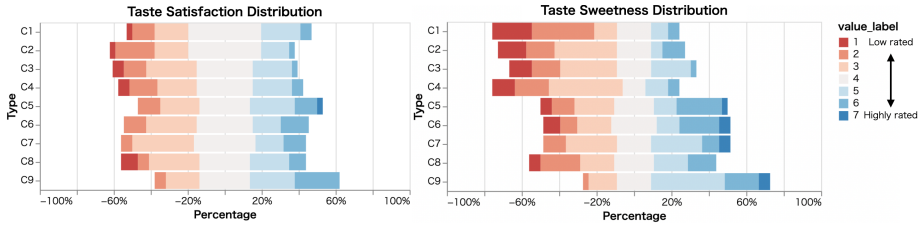

Fig. 5. Likert Scale Assessment Results (Left: Satisfaction, Right: Sweetness)

coconut, chocolate, and crème brûlée aromas were added than when no scent was added to the sugar-free coffee. The perceived sweetness amplification was confirmed by the combination of sugar-free coffee and sweet scent. Furthermore, the amplification of the sweetness of the scent of chocolate was the most significant. Participants commented that "When I drank it, I could smell it and felt it was sweet. It was a strange experience". These suggested that sweet scent may affect the perceived amplification of sweetness. However, the results for adding a scent to trace-sugar coffee were almost identical to its standard. Additionally, the sweetness of trace-sugar coffee was not significantly different from that of the standard. Next, to analyze the results in more detail, we analyzed users by type of attribute.

Analysis Results by Age. In order to evaluate the taste according to age, the subjects were divided into two groups: "20s" (20 participants) and "Over 30" (13 participants), and analyzed. Results for sweetness varied between those in their 20s and those over 30 years of age. Both groups rated chocolate and crème brûlée as the best combination with sugar-free coffee. However, the combination of sugar-free coffee and coconut aroma received the highest rating among those in their 20s compared to the standard. Although there were changes in the evaluation of sweetness by scent according to age, a common trend of amplification of sweetness was confirmed. In fact, it is generally known that the ability to discriminate scents differs depending on the age of the individual [4, 6]. In a study by Wysocki et al. [19], it was reported that men in their 20s and women in their 40s showed a decrease in the sense of smell. Furthermore, differences in food preferences were observed between the elderly and the young, indicating that different ages have different food preferences. The same results were obtained in this experiment.

Analysis Results by Frequency of Coffee Drinking. In order to evaluate taste according to the frequency of coffee drinking, participants were divided into two groups: "Frequent coffee drinkers" (16 participants) and "Infrequent coffee drinkers" (17 participants). The "Frequent drinkers" consisted of those who selected 5 or more on a 7-point Likert scale. The results for the sweetness of the taste differed depending on the frequency of coffee drinking. The results for the combination of sugar-free coffee and scent tended to be higher for frequent coffee drinkers. Furthermore, on this group, the combination of sugar-free coffee and scent tended to be evaluated the same as ordinary coffee without added scent. The combination of trace-sugar coffee and scent tended to be evaluated as the same as that of ordinary coffee alone. This indicates the possibility of using scent to amplify the sweetness of coffee and to change the behavior of people to reduce their sugar intake.

5 CONCLUSION

In this paper, we propose Aromug, a mug-type olfactory interface that amplifies the user's perceived sweetness by providing a sweet scent along with the action of drinking. The experiment results showed that the sugar-free coffee and chocolate aroma might enhance the perceived sweetness compared to the no-scent case. In addition, it was found that there were differences in preference for sweetness depending on age and frequency of coffee drinking. The results

provided insights for future context-aware presentation of scent information based on user attributes. In the current proposed system, beverage sensing is limited to a threshold-based method, but in the future, we will also consider a motion recognition approach using machine learning methods to achieve optimal scent presentation control. Future work will explore approaches that can extend the beverage experience based on visual and olfactory presentation, such as controlling the image projected on the top of the mug in response to the user's beverage motion sensing. There are two types of scents that we perceive: "Orthonasal smell", which is smelled from the tip of the nose, and "Retronasal smell", which is the scent of food in the mouth passing through the nose [2, 8, 16]. In particular, since retronasal smell which contributes to the flavor of food and beverages, is known to be strongly related to taste, we will consider ways to present scents that affect oral scent [14].

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