Kaolid: Lid-type Olfactory Interface to Improve Taste of Beverages with Ortho-Retronasal Smell

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***Abstract*—There are two nasal pathways through which we perceive odors: "orthonasal smell," which comes from the tip of the nose, and "retronasal smell," which comes from the mouth and exits through the nose. In particular, the retronasal smell is known to be more critical in influencing perceived taste than the orthonasal smell. In this study, we propose a smart lid called Kaolid that changes the taste of beverages by presenting scent information as retronasal smell. Kaolid achieves retronasal smell by equipping a small, lightweight straw- or cup-type olfactory device with a sensor that senses drinking behavior and the amount of water in the cup. The straw-type device injects the scent into the tube through the middle of the straw, delivering the scent to the user's mouth simultaneously as the beverage is being consumed. The cup-type device injects the scent into the cup through the lid and delivers the scent to the user's mouth at the beginning of drinking to achieve in-mouth scenting. The concept of Kaolid is to promote water consumption, considered insipid, by altering the sense of taste through a scent presented when drinking the beverage.**

***Index Terms*—Olfaction, Olfactory Interfaces, Olfactory display, Scents, Taste evaluation, Smell, Olfactory Perception**

I. Introduction

Sweetened beverages have become a major source of sugar in our diets. Sugar-sweetened beverage consumption has increased dramatically, particularly in developing countries [1], [2], resulting in a significant annual increase in the number of diabetic patients worldwide [3].

Several methods have been proposed to help people reduce their sugar intake [4], [5]. These methods can temporarily encourage the selection of less-sugar soft drinks to reduce sugar intake. However, 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. From a well-being perspective, finding solutions to gradually reduce the amount of sugar consumed is essential, as extreme reductions in sugar intake can lead to emotional distress for the user [6].

In recent years, various types of olfactory devices have been proposed along with interactions in using these devices [7]–[11]. These studies propose wearable devices worn around the neck and on-face olfactory devices worn on the face in the form of earrings or necklaces, which can be used in daily life. There are also studies that have developed digital devices that mimic actual beverages by activating electrical and olfactory (scent) stimuli together [12], [13]. However, the approach to scent is limited to the orthonasal smell, and the effect of the different nasal pathways used to perceive scent on the perceived taste is unclear.

(a) Straw-Type Device **(b) Cup-Type Device**

Fig. 1. Overview of Kaolid ((a)Straw-Type Device, (b)Cup-Type Device)

There are two types of scents that we perceive: the "orthonasal smell," which comes from the tip of the nose, and the "retronasal smell," which is the smell of food in the mouth that passes through the nose, and each smell is processed by the brain in a different way [14]–[16]. In particular, retronasal smell, which contributes to the flavor of food and beverages, is known to be strongly related to the sense of taste [17]. Focusing on the fact that scent accounts for the majority of what is perceived as taste, we have been developing a mug-type olfactory device that amplifies the perceived sweetness by presenting a sweet smell when drinking a beverage [18]. However, the approach is limited to the presentation of orthonasal smell and does not present retronasal smell, which may be insufficient in promoting changes in taste perception.

In this study, we propose a smart lid called "Kaolid"* that changes the taste of beverages by targeting the retronasal smell in presenting scent information when the beverage is consumed. Kaolid is either a straw or cup-type small and lightweight olfactory device as shown in Fig. 1. To promote water consumption, Kaolid uses a straw-type device for drinking cold water or water at room temperature and a cup-type device for drinking plain hot water. The straw-type device injects the scent into the tube through the middle of the straw, delivering the scent to the user's mouth simultaneously as the beverage is being consumed. The cup-type device injects the scent into the cup through the lid and delivers the scent to the user's mouth at the beginning of the drinking operation to achieve in-mouth scenting.

*Inspired from "Kaori" meaning smell in Japanese.

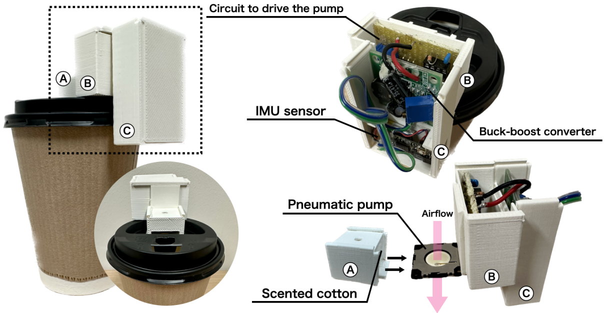

Fig. 2. Device Design of Kaolid

II. Overview of Kaolid

A. Approach

Consumption of sugar-free beverages is important for reducing sugar intake. However, people who are used to sugar-sweetened beverages are likely to be uncomfortable with odorless, tasteless water.

Therefore, following the finding that a considerable part of taste perception is influenced by scent [19], to change the taste of water, we present scent information in a well-timed manner in conjunction with drinking movements. The proposed olfactory interface called "Kaolid" is equipped with a sensing function for the act of drinking and a presentation function for scent information that changes the sense of taste.

B. System Design

1) Mechanism of Scent Injection: A pneumatic pump (MZB1001T02[†]) was used as the mechanism to inject the scent. The pneumatic pump is a device that draws air from one side and discharges air from the other side. The pneumatic pump used in this study is based on the principle of a piezoelectric diaphragm pump and achieves high pressure and flow rates despite its small size and thin profile by applying ultrasonic vibration.

As shown in Fig. 2, a pneumatic pump and a circuit driving the pump are installed inside a container created by a 3D printer. The power source voltage is boosted by a buck-boost converter to drive the pneumatic pump. In the pneumatic pump, the output pressure varies depending on the input voltage. The input voltage is proportionally related to the air pressure of the pneumatic pump mounted on this device. In this device, the input voltage to the pneumatic pump is set to 15 V, and the air pressure is approximately 1.6 kPa. This air pressure is sufficient for producing a faint scent at a distance of approximately 30 cm from the device. Aroma oil is used as the scent, and the container is filled with cotton that has been soaked with the scent. The pneumatic pump is used to inject the scent that has been filled in the container.

2) Prototype of Kaolid: In this study, we created a straw-type device and a cup-type device to change the taste of beverages by presenting scent information to the mouth. The straw-type device, shown in Fig. 1 (a), has a separate opening from the center of the straw, which injects scent into the straw. As a result, the device can deliver scent to the mouth and produce a retronasal smell. The cup-type device, shown in Fig. 1 (b), has a device that injects scent into the upper part of the cup to deliver scent into the mouth during drinking, thus producing a retronasal smell.

[†]https://www.murata.com/ja-jp/products/mechatronics/fluid/overview/lineup/microblower_mzb1001t02

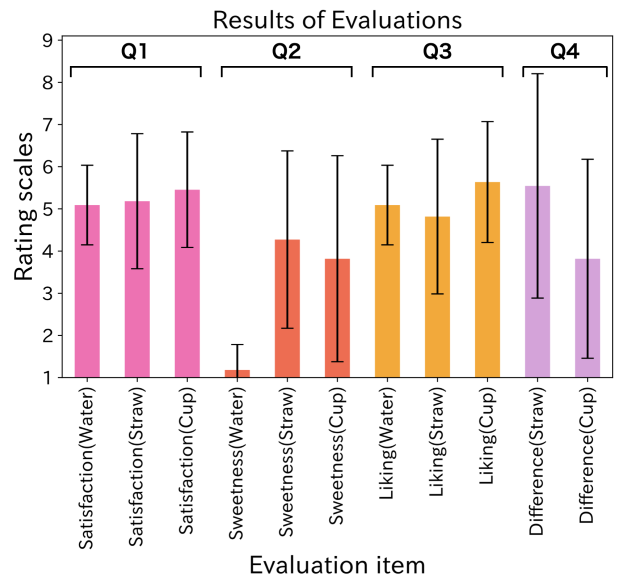

Fig. 3. Experimental results

3) Experiment: To investigate the effect of Kaolid on taste, a preliminary experiment was conducted on 11 participants (7 males and 4 females), ranging in age from 10 to 70 (mean = 37.3). Pineapple, orange, and muscat were used for scent, and room temperature water was used as the beverage. To prevent possible bias arising from the order of the devices used in the experiment, six different experiments were conducted, each with a different order of devices. After each experiment, the participants were asked to answer a questionnaire about their tasting experience. The questionnaire, utilizing a 9-point hedonic scale, asked respondents to answer the following four items (Q1: taste satisfaction, Q2: taste sweetness, Q3: taste preference, Q4: taste difference). In Q4, we evaluated the change in the taste of the water drank with Kaolid compared to water without scent. Therefore, Q4 could not be evaluated in the experiment without scent. Fig. 3 shows the mean and standard deviation of the questionnaire results. It was confirmed from Q2 that the sweetness of the taste was considerably amplified by the use of Kaolid compared to water without scent. From Q3 and Q4, it was confirmed that the taste of the straw-type device was more changeable, but there was a preference for the cup-type device over the straw-type device. This is presumably because the mechanism of the straw-type device, sending air into the straw, is difficult to use.

C. Implementation

Kaolid consists of a mechanism that sprays scent, a beverage-sensing mechanism, and a sensor that detects the amount of water in the cup, as shown in Fig. 2. The sensing mechanism of the beverage is equipped with an IMU sensor (MetaMotionR+: sensors – 100 Hz quaternion three-axis accelerometer/gyroscope; dimensions - L29 × W18 × H6 mm; weight - 5.7 g), as shown in Fig. 2. The IMU sensor signals are transmitted to the gateway device via Bluetooth Low Energy (BLE). The gateway device analyzes the IMU sensor signals and recognizes the user's drinking behavior. It performs time-series signal processing and controls the mechanism that sprays the scent. First, the attitude angle of the device is calculated from the acceleration and gyro signals obtained from the IMU sensor. The system recognizes three actions (lifting the cup, drinking, and releasing the cup), as constituting beverage behavior, based on the acceleration data and gyroscope sensor data. Currently, the beverage drinking time is determined by a threshold value, but in the future, a machine learning model that recognizes timing will be used. The signal from the IMU sensor recognizes the beverage drinking time and activates the pump so that the scent is sprayed. The device also has a water level sensor that detects the amount of water in the cup. A variable resistor is mounted on the water level sensor with the resistance value changing according to the amount of water. Specifically, the change in the sensor is inversely proportional to the depth to which it is immersed in water. This mechanism logs the number of beverages consumed by the user throughout the day. In the future, the system will be equipped with a module that recognizes the kind of beverage poured into the cup [20]. Checking the beverage log by the user contributes to a better understanding of healthy beverage intake.

III. Kaolid demonstration

In the demonstration, the participants experience how the Kaolid changes the taste of water. As shown in Fig. 1, an in-mouth aroma is produced, and the scent achieves the change in taste. Scents are selected from a group of 10 odors that humans can perceive, with the citrus group considered to be compatible with water [21]. Kaolid enables users to easily change scents and experience a variety of tastes depending on the type of scent. By changing the taste according to the scent, the user feels satisfied with the tasteless water and is expected to increase the amount of water consumed. Kaolid can also estimate the amount of water in the cup using a water level sensor. The user can check the water intake log to see when and how much beverage has been consumed over medium to long term. Kaolid is expected to contribute to the development of healthy and adequate hydration habits.

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