Straw-like User Interface: Virtual experience of the sensation of drinking using a straw

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ABSTRACT

The Straw-like User Interface is a novel interface system that allows us to virtually experience the sensations of drinking. These sensations are created based on referencing sample data of actual pressure, vibration and sound produced by drinking from an ordinary straw attached to the system. This research of presenting virtual drinking sensations to mouth and lips is the first in the world to have been attempted, and comes with high academic expectations. Moreover, due to the high sensitivity of the mouth and lips when used as a sensor, it is possible to develop many unique interfaces and so this could facilitate an extension of research fields in both interactive arts and entertainment.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interface - *Interaction styles*

General Terms

Design, Experimentation, Verification.

Keywords

Drinking sensation, Tactile interface, food texture, entertainment, Virtual reality

1. INTRODUCTION

The lips and mouth are one of the most sensitive parts of the human body, and are considered to hold a similar level of sensitivity as fingers. For this reason, we believe that research into the field of presenting various applications to the mouth and lips will be more widespread in the near future.

Some reports into applications relating to the mouth have already been presented. "kirifuki" [1] has the ability to control graphical user interface (GUI) objects by applications of breathing. The position and angle of the head of a user are recognized by attaching a three-dimensional position sensor to the head, and operation of the GUI projected on a desk from the projector is carried out by blowing or inhaling toward a microphone attached to the lips. This system can carry out fundamental operations such as the movement of a window, expansion and reduction, cutting and pasting an icon, and command execution. "Jellyfish Party" [2] is a Mixed Reality installation work that can blow a computer graphic (CG) bubble by blowing a breath into a device called a straw gun. By seeing through a see-through type head mounted display (HMD), a bubble can be felt as if it was blown off to an actual space. A spirometer as used in medical applications is used for the straw gun. The quantity of the breath blown through this is measured, and a natural feeling of blowing is experienced. These applications effectively use the operation of the mouth as input; however, the feeling of a presentation to the lips and mouth is lacking.

There is some research into a "food texture display" [3], a haptic interface that presents feeling to a mouth by presenting a biting force. This system generates a force representing the force profile captured from the mouth of a person biting real food, and then presents the food texture by controlling the occlusal force against food on a pressure sensor. However, this system essentially only responds to hard food and cannot effectively be used for the presentation of the feelings of soft food and drinks etc. "Edible Bits" [6] is the result of research into a taste presentation system.

This research approached the replacement of the painted information of a computer monitor with tangible edible information by the Edible User Interfaces they developed. The system uniquely uses taste, but there are sanitary problems in its method of taste presentation.

In this research, we focus on the "drinking" action, a basic human behavior, and we realize the virtual presentation of drinking sensations. This action has various amenities. This act of presentation can be carried out for anyone. For example, it is possible to implement it for an elderly person whose power to bite has declined, a suckling without teeth, a sick person, etc. Furthermore, another unique aspect is that it is possible to virtually experience drinking sensations of most kinds of foods (liquid, solid, gel, etc). Further, the drinking sensations are effective in the field of the entertainment. Usually, when we eat and drink we enjoy drinking sensations to the mouth and lips with those of taste and smell at the same time. The instinctual action that infants do immediately after birth in order to live is to drink when a nipple on a breast comes in contact with their mouth. In addition, it brings with it a feeling of comfort; for the first time after birth. This is clear from a baby's expression while breast-feeding. Moreover, a baby wants to put anything he/she sees into their mouth. This is because the stimulation that comes from the lips and mouth is extremely interesting, containing, as it does, quite a lot of information on the external world. Thus, the drinking sensation is a kind of essential pleasure for humans. Happiness, freshness and comfortableness are very important points in entertainment. Drinking sensations can possibly be developed for a modality as new entertainment. In conventional entertainment, interactions using the hand and the body are the main route. Input by voice has come to be much used but the output to the mouth and lips had not been undertaken. Consequently, it is said that this research is significant in the entertainment area and is a new and interesting field of research.

We developed a novel interface, the "Straw-like User Interface (SUI)", which presents the sensation of food using an actual straw. A drinking action is new action as an entertainment. In this report, we first explain the drinking sensation and the composition of the SUI in Chapter 2, and in Chapter 3 we present the experimental evaluation of this sensation. In Chapter 4, we show the installation that used the SUI. In Chapter 5, the conclusions are set out and future possible work noted.

2. STRAW-LIKE USER INTERFACE

2.1 Drinking Sensation

Everyone feels various types of resistance when drinking with a straw. For example, juice enters with little resistance but jelly type liquids feel an intermittent resistance. This feeling in the mouth and lips when drinking food with a straw is the drinking sensation. With usual meals, we strongly feel the taste and smell but are hardly conscious of tactile sense information, including the drinking sensation. We postulated that it would be possible to experience a new sensation by extracting the drinking sensation from that of taste and smell, and in doing this present a comfortable and exciting sensation to the lips and mouth.

When drinking food with a straw, the following elements are part of this sensation.

- The pressure change in the mouth generated when food blocks the straw
- Vibrations of the collisions and friction of food
- Sounds at the time a vibration occurs

Therefore, we thought that it would be possible to acquire a sensation that was highly accurate and real by recording the sounds, vibrations, and air pressure changes when drinking food with a straw and by reproducing using a SUI.

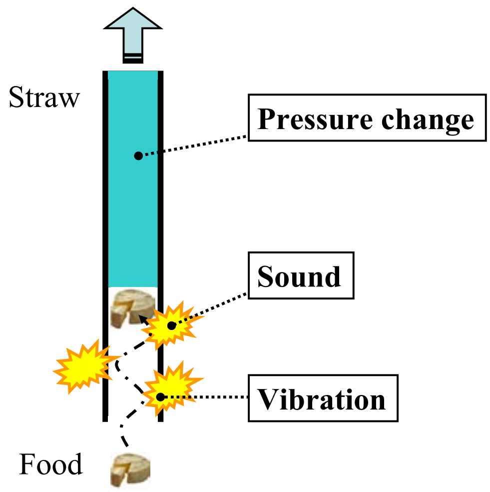

Figure 1. Elements of drinking sensations

2.2 Composition of SUI

The SUI can reproduce the pressure change in the mouth and transmit vibrations to the lips. For sound, which is one of the three elements of this sensation, it is necessary to have a clear and loud volume; thus we output sounds from an external speaker synchronized with the operation of the SUI. The straw used on the SUI can be any ordinary straw, thus it can be disposed after each user; eliminating any concern in respect to hygiene.

The SUI is composed of a push-pull solenoid, a R/C servomotor (Yoshioka model, Atom49), a valve, a cam, a speaker and a pressure sensor (Fujikura, XFPM-115KPAR).

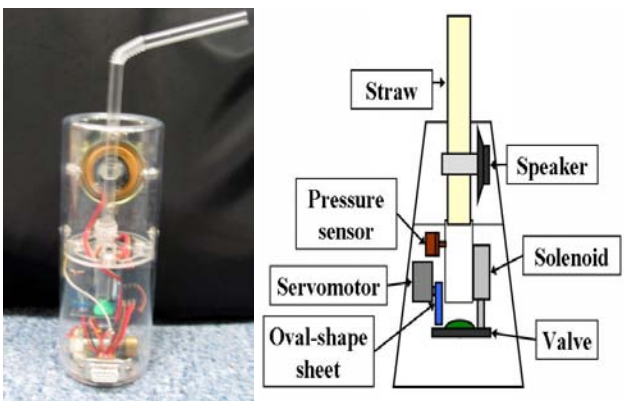

Figure 2. Structure of SUI

This pressure change is created by an appropriate control of the opening and closing of a valve installed in the SUI. While drinking, if the valve is closed, the pressure inside the straw will decrease. If the valve is opened, the pressure will rise. For this reason, by appropriate control of the valve, we can produce various changes in pressure. The solenoid and the R/C servomotor were used for the control of the valve. The solenoid is used to completely open and close the valve. The opening and closing of the valve is controlled with the solenoid at high speed, and a high frequency wave of pressure change is generated. The R/C servomotor is used to generate the low frequency waves of the pressure changes. The R/C servomotor with a cam is rotated, and the cam pushes the valve. The valve then makes the space between the valve and the straw. By minutely controlling the rotation angle of the R/C servomotor, a low frequency pressure change is smoothly generated. In the SUI, various pressure changes are produced by controlling these two actuators.

Following from this, when the speaker inside the SUI vibrates, the straw adhered to it will also receive the vibration and transmit it to the lips. Further, the SUI is operating by detecting the act of "drinking" using a value in a pressure sensor as the trigger. So a player can experience using the SUI without a complex operation using buttons.

2.3 Whole System Configuration

The basic system consists of the SUI, a motor control circuit, a microcomputer board, an external speaker, amplifier and a PC.

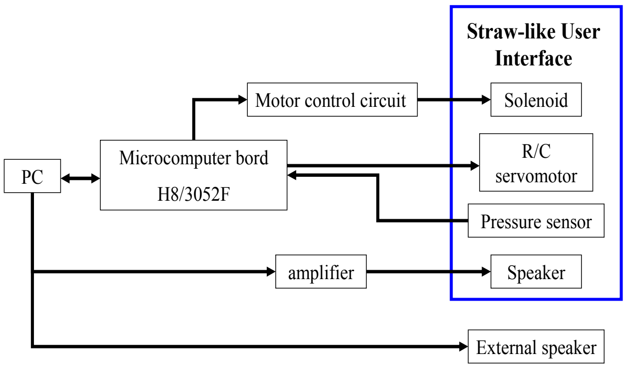

Figure 3. Overview of this system

H8/3052F are used to control the SUI. TA8429H was used as a drive for the solenoid, which together with a R/C servomotor are controlled by the microcomputer board. The pressure in the straw is measured with the pressure sensor. For vibration, the voice response from a PC was amplified and output to the speaker in the SUI. Moreover, the voice response from the PC is distributed and the sound is simultaneously given out from the external speaker. Synchronization between the PC and a microcomputer board was performed by serial communication.

2.4 Data Recording

For the data to be used for the operation of the SUI, we recorded pressure changes and sounds in a straw pipe. To record these data, a pressure sensor (Fujikura, XFPM-115KPAR) and a microphone were attached to a straw and we drank actual food. To keep individual differences from being a factor, the food was drunk as vertically as was possible.

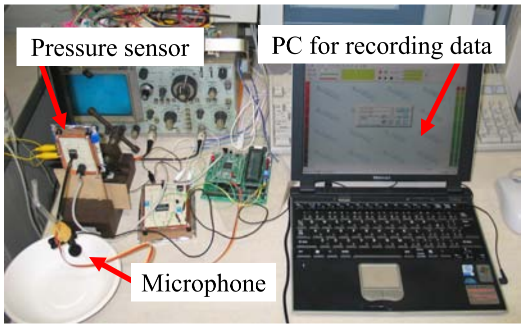

Figure 4. Experimental recording

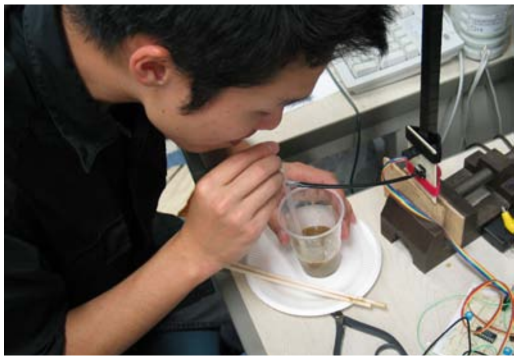

Figure 5. Drinking through a straw

2.5 Recorded Results

We recorded data relating to about 60 kinds of food. We recorded any type of food that it was possible to drink like liquids, solids, gels, and soluble and gooey etc. When the pressure value data was observed, we noticed that there were similarities in the shapes among the graphs. Then, we classified graphs with similar features and from this postulated that it was possible to roughly classify the data into three food groups. Graphs of the pressure of representative foods in each of the three classifications are shown in Figures 6, 7 and 8.

The amount of pressure changes for the shake were dramatically large (Figure 6). The resistance at the time of drinking appeared to be very strong, as did the tendency to attempt to drink repeatedly. Whipped cream, rice cake, cheese, etc. were foods with similar features to this. The feature of curry and rice is that there were high frequency waves of pressure change (Figure 7). This is thought to be because of the mixture of a liquid and a solid. Fermented soybeans, fresh egg, ramen noodles, etc. have similar features to this. The waveform for caviar showed the least changes (Figure 8). This is thought to be because caviar is small and does not tend to block the straw. Sesame, salmon flakes, juice, etc. were foods with similar features to this.

Therefore, it was assumed that the drinking sensation can be shown with some reality by undertaking controls based on the feature of the pressure changes caused by drinking food.

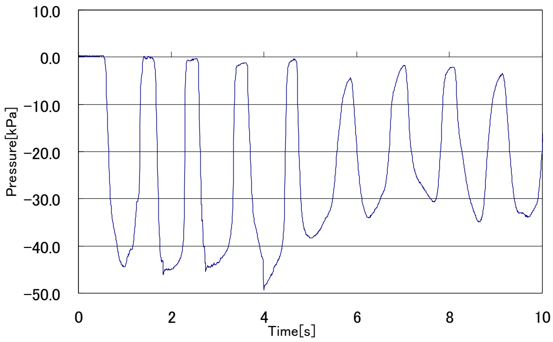

Figure 6. Recorded data (Shake)

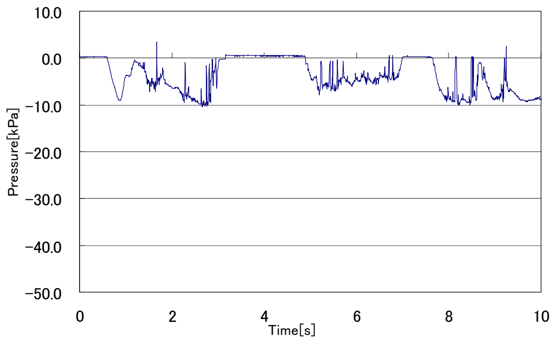

Figure 7. Recorded data (Curry and rice)

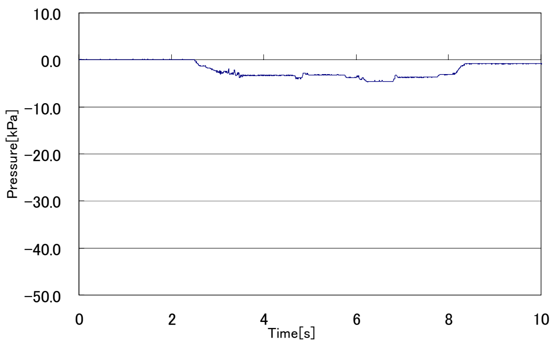

Figure 8. Recorded data (Caviar)

3. EXPERIMENT

3.1 Reproducibility of the Pressure Changes

To verify the reproducibility of the pressure changes in a SUI, we conducted an experiment to compare pressure changes when drinking actual food with those when using the SUI. We assumed that the sensation was presented during a fixed time regardless of the strength of drinking when a subject drank using the SUI. Data is shown in Figure 9.

From the graphs, the maximum value of the real activity was 11.6 [kPa]; the maximum reproduced value was 10.7 [kPa]. Therefore, it can be said that the pressure changes mostly matched. Moreover, the envelopes for the graphs almost match each other. Consequently, it can be said that the SUI can reproduce the pressure changes seen in the real activity.

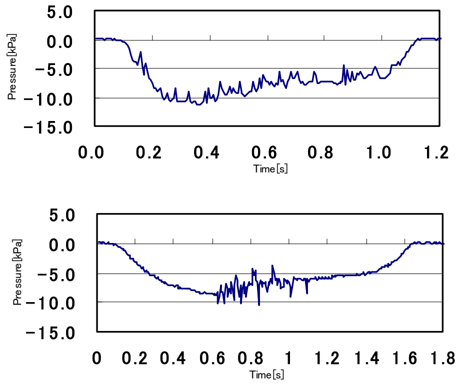

Figure 9.

Original values (above) and reproduced values (below)

3.2 Food Discrimination by SUI

To investigate the effectivity of category division and the possibility of discriminating food through the drinking sensation, we did discriminate experiments of food by using drinking sensations. The outline of experiments is as follows.

- The feeling of foods is presented to test subjects at random.
- Test subjects answer the food name thought to have been presented.

There were three kinds of experimental conditions.

Condition 1: Presentation of the pressure and vibration

Condition 2: Presentation of sound

Condition 3: Presentation of pressure, vibration and sound

3.2.1 Discrimination of Six Kinds of Food

First, we selected two foods respectively from among the three classifications shown in Chapter 2.5, and performed the presentation of the feeling at random for six kinds of food. The selected foods were respectively, “Chinese noodle and raw egg”, “cola and popcorn”, and “shake and rice cake”. Each condition was presented 20 times. The results are shown in Table 1, and Figures 10, 11 and 12. Table 1 shows the number of correct answers, the average number of correct answers, and the correct answer rate of each condition. Figures 10, 11 and 12 show the ratio of the food responded to that presented.

Table 1. Experimental results (6 kinds of foods)

	condition 1	condirion 2	condition 3
Examinee A	8	16	19
Examinee B	5	15	16
Examinee C	3	6	10
Examinee D	5	6	6
Examinee E	3	14	6
Number of correct answers (average)	4.8	11.4	11.4
Correct answer rate (average)	24[%]	57[%]	57[%]

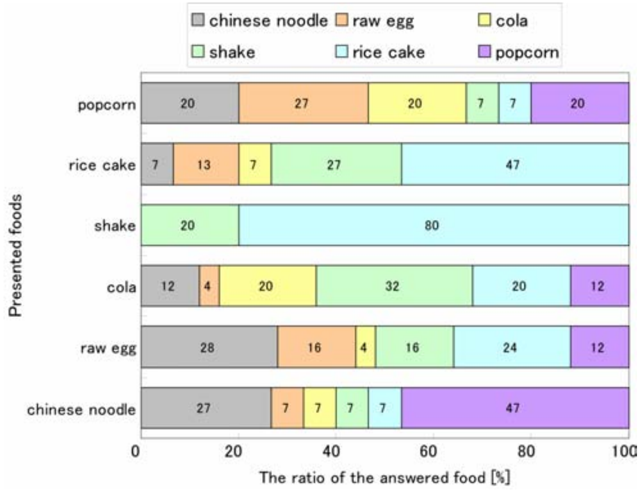

Figure 10. Response rate (condition 1)

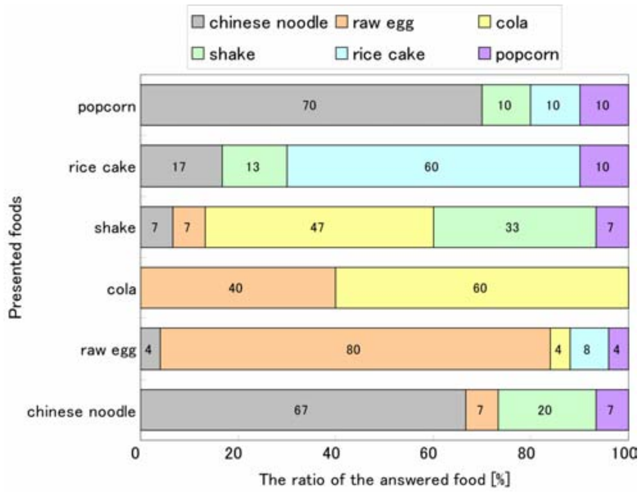

Figure 11. Response rate (condition 2)

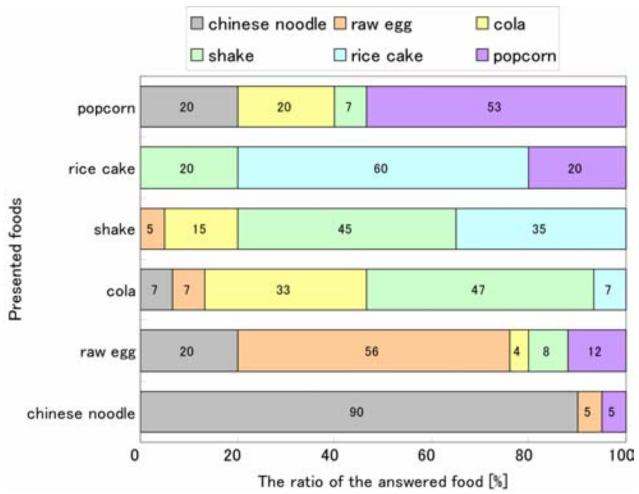

Figure 12. Response rate (condition 3)

From table 1, the average rate of correct answers was less than 60 percent in every condition. Particularly, the rate of correct answers for condition 1 was half of rate of condition 2. Pressure and vibration were presented in condition 1, and sound was presented in condition 2. Thus it is thought that sound can assist in feeling food more than pressure and vibration. Indeed, it seems that we are seldom conscious of pressure and vibration under the usual conditions of eating. On the other hand, we always clearly hear the sound of food when eating and consider it. Therefore, it seems that it was difficult to correctly determine food from only pressure or vibration, among the several foods presented.

The rate of correct answers did not go up under condition 3, though it had more information available than condition 2. We selected two foods respectively from each classification in this experiment. It was thought that the test subjects were confused by too much information in condition 3, since the similarity of food would be a cause. Actually, the dispersion of the responding rate of the food under condition 3 was a little larger than under condition 2 (Figures 11 and 12). However, when the response rate for food under condition 3 is considered, the correct answer rate is the highest in five food items from among the six (condition 2: four items, condition 1: one item). For the remaining one item, the correct answer rate was the second highest.

From this, it was determined that the easiest condition for correctly recognizing food was condition 3.

Next, we investigated the rate of familiarity between two foods from the results of condition 3. The response rate for food was used for calculations of familiarity. For example, if the response rate of the shake when presenting the drinking sensation of rice cake was 20%, and if the response rate of rice cake when presenting a drinking sensation of shake was 35%, the rate of these two foods is calculated in the following way.

(20+35) / 2= 27.5 [%]

Calculation results are shown below.

Table 2. The rate of familiarity between two foods

pairing	rate of familiarity [%]
chinese noodle – raw egg	12.5
chinese noodle – cola	3.3
chinese noodle – shake	0.0
chinese noodle – rice cake	0.0
chinese noodle – popcorn	12.5
raw egg – cola	5.3
raw egg – shake	6.5
raw egg – rice cake	0.0
raw egg – popcorn	6.0
cola – shake	30.8
cola – rice cake	3.3
cola – popcorn	10.0
shake – rice cake	27.5
shake – popcorn	3.3
rice cake – popcorn	10.0

From table.2, it can be seen that it is possible to roughly divide the foods used into “Chinese noodle, raw egg and popcorn” and “rice cake and shake cola” groups. Additionally, “Chinese noodle and raw egg” and “rice cake and shake” have relatively high familiarities. In respect to popcorn, the rate of familiarity with Chinese noodle is the highest. However, the value is almost the same as the rate of familiarity with cola. Moreover, popcorn has some familiarity with all the foods. Cola has the high rate of familiarity with shake; probably because both are drinks. Actually, the example of mistaking the presented sensation of cola for the shake was seen until the sensation of the shake was presented. However, the rate of familiarity between cola and popcorn is high in the second. In addition, cola has some familiarity with all foods used as did popcorn. So, it can be said that cola and popcorn, with similar features, constitute a group. As a consequence, classifications according to the features of the food obtained from the experimental results were in agreement with the category divisions postulated in Chapter 2. However, it was understood that the food genre of drink influences the distinction of the drinking sensations. Therefore, it will be necessary to examine the difference of the drinking sensations by food genre in the future.

3.2.2 Discrimination by Three Kinds of Food

It was shown that the division of food into categories in Chapter *3.2.1* was effective. Next, we selected one food respectively from among the three classifications shown in Chapter 2.5, and investigated the rate of correct answers. The selected foods were “raw egg”, “popcorn”, and “shake”. These foods are the extractions of each category from among 6 kinds of foods used in Chapter *3.2.1*. We experimented 10 times under each condition. The results are shown in table 3, which gives the number of correct answers and the correct answer rate for each condition.

Table 3. Experimental results (3 kinds of foods)

	condition 1	condition 2	condition 3
Examinee A	7	7	9
Examinee B	4	4	9
Examinee C	5	7	7
Examinee D	7	9	9
Examinee E	6	6	8
Examinee F	9	9	7
Examinee G	0	0	9
Examinee H	8	7	9
Examinee I	5	5	5
Examinee J	4	5	0
Examinee K	5	8	7
Correct answer rate (average)	55[%]	61[%]	72[%]

From table 3, it turned out that the average rate of correct answers under each of the conditions increases compared with Table 1. Moreover, it was confirmed that selected foods have an original feature of the drinking sensation. These results also validated the division into classifications. In particular, the increasing rate of correct answers under condition 1 was large, and became twice that of the last experimental results. It is thought that this is reason that the test subjects could distinguish food by pressure and vibration with ease, since there was no food with a similar feature. Thus, it is shown that a test subject can clearly recognize the difference in the pressure change or vibration. That is, it was shown that pressure changes and vibrations are important essentials for determining the drinking sensation. The order of the percentage of correct answers became “condition 1 < condition 2 < condition 3”. As noted above, it was shown that pressure change, vibration, and sound are sensational and important elements for ascertaining the drinking sensation.

4. INSTALLATION USING A SUI

4.1 Installation Outline

We made and exhibited an installation using the SUI so that many people could experience and evaluate the drinking sensation. An outline of the installation is as follows.

- Choose favorite food from two or more food groups.
- Drink using the SUI and experience the drinking sensation of the selected food.

Three kinds of formats were created for the presentation; the situation of the exhibition, the available equipment, space, and the target age group, etc.

4.2 Work format 1

4.2.1 Outline

Work format 1 mainly targeted a young age group and pursued the pleasure of the experience. The content is that the player catches with the SUI and drinks a moving character that carries food on its back. The character is always moving about the screen. This format has the nature of a game of pursuing and catching. This format was exhibited as a presentation at International Collegiate Virtual Reality Contest (IVRC) 2004 and ARS Electronica 2005 (annual permanent exhibition).

Figure 13.

Appearance (format 1) and a subject of experiencing

4.2.2 System

The features of this system are a large rear projection screen to project the image with the projector and a tracking system to be operated to catch a character with the SUI.

- Screen

The image is projected on the large-sized screen by the rear projector. To exhibit the work in a 2[m] x 2[m] space, we reflected the projection light of the projector using three mirrors, and the screen size of 60 inches was realized by securing the projection distance. By implementing like this, space-saving and a large screen were realized.

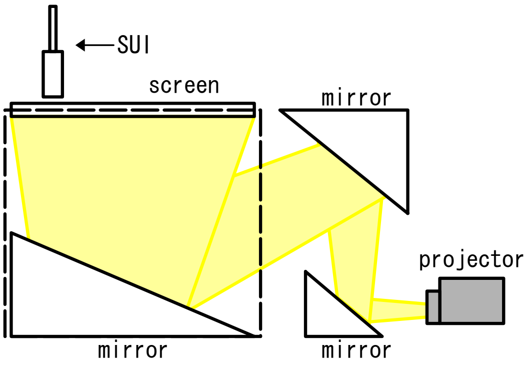

Figure 14. Method of projection

- Tracking

To realize the component of catching the character CG by placing the SUI on it, we devised a tracking system that used infrared LEDs and a CCD camera. This tracking system was modeled after HoloWall [4]. First, an infrared LED was attached to each of the four corners of the rear projection screen, and the bottom of SUI, respectively. And the CCD camera was installed under the screen. A filter that allows the penetration of only an infrared light is attached to the CCD camera. Next, the image in the CCD camera was captured with a PC and the coordinates on the screen were calculated image processing.

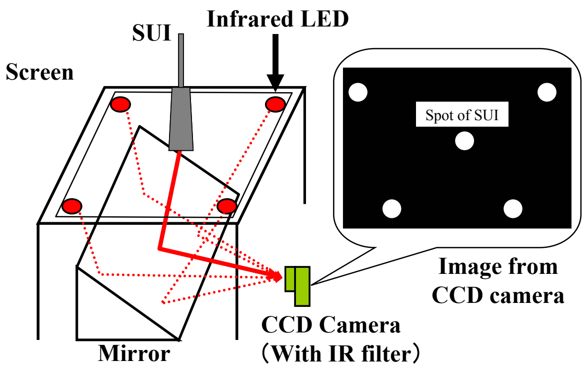

Figure 15. Method of tracking

4.3 Work Format 2

4.3.1 Outline

Work format 2 focuses on intuitive operation and the experience of the drinking sensation. In this format, the selection of a favorite food was enabled by touching a picture of the food displayed on a touch-sensitive liquid crystal display monitor (Touch Panel Systems K.K., 1416TD17/U2-1). This format was exhibited as a presentation at Laval Virtual 2005, ARS Electronica 2005 (annual permanent exhibition), Digital Art Festival Tokyo 2005 and Japan Media Arts Festival 2005.

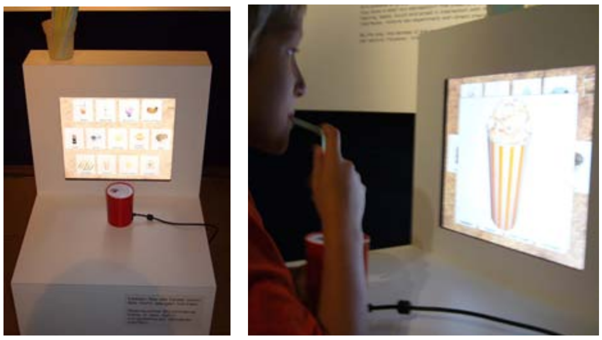

Figure 16.

Appearance (format 2) and a subject of experiencing

4.3.2 System

The feature of this system is the interface that enables the experiencing person intuitive food selection. The adoption of a touch-sensitive panel made it possible to intuitively and smoothly choose the food to be experienced. A displayed image consists of only some pictures of food and so it clearly a simple operation. Moreover, since the monitor is arranged in front, a player can continue to see the picture of food while experiencing this work. For this reason, when experiencing this work, it is possible for the person to be highly conscious of the food.

4.4 Work Format 3

4.4.1 Outline

Work format 3 was modeled on the present-day meal structure. No image display devices, such as a monitor or a projector, were used. We used only a plate, several disks with the picture of a food and the SUI system. A player chooses food by putting the disk on a plate, then puts the SUI on it, and experiences the sensation of drinking the selected food. This format was exhibited as the presentation at Emerging Technologies section of SIGGRAPH2005 and Interactive Tokyo 2005.

Figure 17.

Appearance (format 3) and a subject of experiencing

4.4.2 System

A feature of this system is that it almost represents today's structure of a meal, especially by using actual tableware. We used the technology of Radio Frequency Identification (RFID) to realize this. A RFID reader (Phidgets, PhidgetRFID) is stationed under a plate, and the RFID tag is embedded in the disk. By implementing in this way, if a disk is placed on a plate, the RFID reader under a plate can read the ID of the RFID tag, and the data that identifies what kind of food it is can be obtained. Consequently, if this system was set on a table, a comforting appearance is maintained that enables simultaneously intuitive food selection.

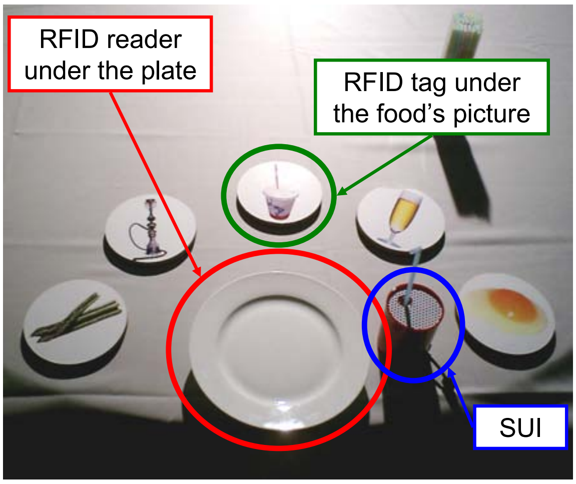

Figure 18. System overview (format 3)

4.5 EXHIBITION

We have exhibited this work in various countries around the world. From the results of the exhibitions, the uniqueness and novelty both of the presentation of the drinking sensation were evaluated in every country. Accordingly, we were able to check if this sensation was internationally acceptable. Moreover, in formats 2 and 3, we succeeded in making the drinking sensation a smooth experience. We also established that format 1 was useful as entertainment.

While evaluation of the work was very high, we received many questions about whether it could also realize presentations of smell, taste, and temperature. Questions about smell were the most common. Smell is such an important feeling, equal to taste as a component for determining food. Much research has been published about smell presentation [7-11]. However, as an aspect of this work is that it separates taste and the sense of smell, and that it enables the presentation of a new feeling by extracting only the drinking sensation. However, we think that it will be important to clarify this point regarding smell in the future; especially since it is an important ingredient of a meal. Thus, we should also consider taking in the essence of a smell.

5. FUTURE WORK

The SUI can possibly be proposed for various entertainment applications using the drinking sensation. In the gaming area, an SUI can be used in many kinds of games. The player will be able to experience a high level of reality in drinking the item, with the technique of using the mouth, and that the situation is that the player should vacuum up (drinking the potion or special food that exists only in game, draining the enemy's magic power, bonus or penalty in games vacuuming up enemies, etc). In the field of communication, an SUI could present many feelings (comfortable, evocative, yucky, etc.). Then, along with Edible Bits [6], the drinking sensation can be converted into some information because lips and mouth are very sensitive. So if this sensation is converted into words and emotions, we can get the content of all messages from a unique drinking action and expand the width of communication. Moreover, it is possible to add new texture to a drink by basing it on this system. We want to propose and produce the above-mentioned applications.

6. CONCLUSION

In this research, we developed a device that presents the drinking sensation and validated it experimentally. Moreover, by making and exhibiting our installation using the SUI, we showed that the drinking sensation is one that is accepted internationally. Further, we could also realize its entertainment value. We will improve the SUI to enable an even better presentation of the reality of the drinking feeling. We also want to apply this device to various fields, such as medical treatment of diseases related to the mouth and lips and to facilitate improvements in liquid foods. In addition, we want to propose various applications using the drinking sensation, and will try to add smell, taste, and temperature to our sensation.

7. REFERENCES

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