A visual-taste interference model and the EEG measurement

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Abstract: Taste cognition is interfered by visual information; however the mechanism has not been clarified. We assumed the interference model in the process of taste and visual information. The model was tested with frequency analysis on EEG and the button response time. The tasks were matched/miss-matched between taste and visual information of orange or apple juice. There were changes in α waves that originated in visual processing of a juice package and changes in β waves that originated in taste processing. There was the possibility with the parallel processing mechanism in the visual-taste interference.

Keywords: taste cognition, visual information, interference, EEG

I. Introduction

There are studies using facial expressions [1] or skin temperature on the nasal area [2] as a method to give an objective evaluation on taste. There are also various papers that handled taste and the brain [3] [4]. However, those papers that handled the brain and taste have not reached an objective evaluation of products. In this paper, therefore, a method to give an objective evaluation on taste as well as products presented was reviewed based on the relationship between taste and the brain. Spontaneous brain waves were measured in order to develop the taste processing model in this paper, by focusing on integrated processing of vision and taste. The taste processing model was designed to measure the interaction of visual information and taste, including whether information obtained from people's eyes influences taste cognition, or only taste influences taste cognition.

II. Interference between taste and vision

1. Proposal of taste processing model

The process to reach taste cognition in interdependence between vision and taste was proposed as the "taste processing model" in this experiment. Information received from two sensory organs, i.e., eyes for vision and the tongue for taste, is communicated to the nerve center. Images entered through eyes are recognized in the vision area, the information is sent to the temporal association cortex, and the images seen are interpreted as meaningful. Taste entered from the tongue transmits from the receptor called the taste buds on the tongue onto sensory nerve fibers, and the five-taste (sweet, salty, delicious, bitter and sour) information is taken over to the taste area in the brain. These two kinds of information in the above are integrated in the brain and the integrated information is related to memory, leading to taste cognition (Fig.1).

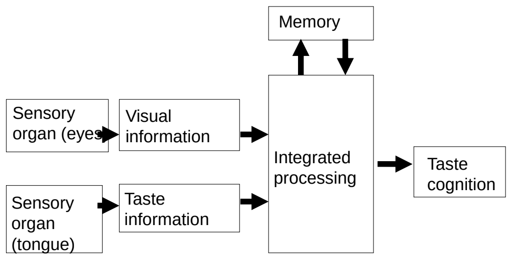

Fig.1. Proposed taste processing model

2. Verification of hypotheses with brain waves

The following three hypotheses are considered based on the taste processing model. If responses of spontaneous brain waves are successfully obtained in accordance with these hypotheses, it will be useful to support development of the taste processing model. Spontaneous brain waves can be divided into three bands including α waves (8-13Hz), β waves (14-30Hz) and θ waves (4-7Hz). α waves appear when eyes are closed, when relaxed or not nervous, or when brain activities are calm. β waves appear when stress is accepted or during calculation. θ waves appear in the course from awakening to onset of sleep. It is also known that α waves decrease when visual information is given, in comparison with the time at rest [4]. In addition to the above, we considered that the volume of thoughts occurring in the brain when taste is given (difficulty in relating short-term memory from vision or long-term memory to taste) was involved in the increase/decrease of α waves and β waves in this paper. If these three hypotheses are verified with experiments, the taste processing model will be successfully developed. Hypotheses at this time were prepared based on brain waves including α, β and θ waves when taste information of water was given.

III. EXPERIMENTS

1. Experiment method

Subjects were four healthy males (age: 21-22). The experiment was conducted in a lab which was not a shielded room, and lights were turned off during the experiment, i.e., the condition of a dark room. First of all, subjects sat on chairs, the experimenter presented a table with the names of six samples (water, apple, orange, strawberry, banana and pear) to ensure taste cognition, and indicated one of them would be put into the mouth. The subjects were instructed to identify which sample was put into the mouth. They were to push down the switch at hand immediately after they knew what sample it was (considered that taste was recognized). The reason for pushing down the button is that the time from completion to integrate vision with taste until taste cognition as shown in Fig.1 is considered to be interrelated with the time until pushing down the button by the subjects. Therefore, after explaining about the experiment, we asked them to avoid movements except pushing down the button or teeth grinding during the experiment. After full explanation, subjects were instructed to put on an electrode cap to measure brain waves. They were also asked to hold the hose (φ5×7 mm) connected to the One Shot Measure 30ml (Sentec D-19002BK) in the mouth using the lips, to enable input of a fixed amount. (The hose was not sticking to the face, and the sample was not visible.) Since the photo of the package is shown before giving the sample (taste stimulation) in this experiment, the task is in the order of visual stimulation and taste stimulation. Eyes were opened when visual stimulation was given, and closed when it ended. Visual stimulation was given for five seconds, and another five seconds were provided for the time to close the eyes. Then, input of taste began. The sample was input without notifying the subject of the timing of input. The timeline of the experiment is indicated in Fig.2.

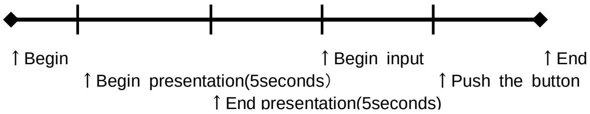

Fig.2: Timetable for the experiment

Table 1 includes Tasks 1 to 11. Enough time was maintained between task and task in the experiment, and the oral cavity was rinsed with water after and immediately before taste stimulation. To avoid the same sample to be input in a row, Tasks 1 to 5 and Tasks 6 to 11 in the experiment were conducted at least with one-week interval.

Table 1: Tasks in the experiment

Task No.	1	2	3	4	5	6	7	8	9	10	11
Visual presentation	O	A	x	x	x	O	A	O	A	O	A
Experiment samples	x	x	W	O	A	O	A	A	O	W	W

In regards to symbols in Table 1, O represents orange juice, A represents apple juice and x represents no stimulation. Orange juice and apple juice used in the experiment was "Tropicana 100% Orange Juice" and "Tropicana 100% Apple Juice." Packages for these two kinds of juice were photographed with a digital camera for presentation. With the response time like in Tasks 3, 4 and 5 as the reference where only the sample was given, Tasks 8, 9, 10 and 11 were considered to take longer for integrated processing when the subjects respond, leading to a long button response time. On the other hand, the button response time was considered to be shorter for tasks which seem to take less time for integrated processing.

2. Measurement method

Neurofax EEG1100 (Nihon Kohden) was used to measure brain waves, and FOCUS (Nihon Kohden) was used for analysis. 31 exploring electrodes in accordance with the International 10-20 method are arranged on the electrode cap (Electro Cap) (refer to Fig.3). Unipolar induction was used for measurement with both earlobes (A1 and A2) as reference electrodes. Experiments were completed within 60 minutes after the electrode cap was worn (Fig.3). In regards to brain waves extracted, the band with α waves was at 8-13Hz, β waves at 14-30Hz and θ waves at 4-7Hz. The intervals to analyze brain waves included from the beginning of visual stimulation presentation to the completion of visual stimulation presentation, and from the beginning of taste stimulation presentation to button pushing by a subject. The FFT was applied to these intervals and the content of brain waves in all channels were averaged to obtain the content rate for these three bands.

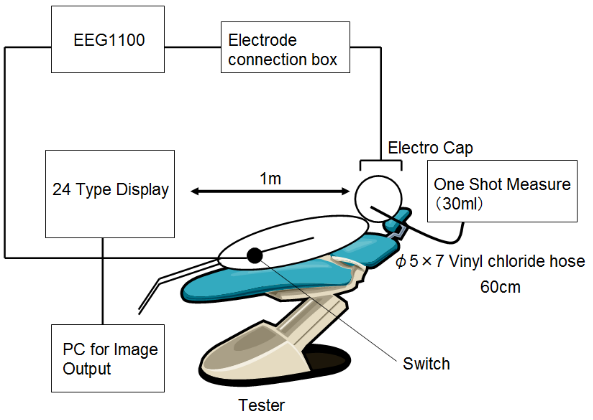

Fig.3: Measurement system

IV. RESULTS

1. Hypothesis 1: Taste and electroencephalographic response

Tasks with taste presentation only are compared. For Hypothesis 1, it was considered in the cases of samples with and without taste that α waves decrease and β waves increase because the burden of taste integration increases for the sample with taste, as a result of the load from the work to relate to long-term memory. As a result of experiment, the content rate of α waves tended to decrease and the content rate of β waves tended to increase for samples with taste in comparison with samples without taste, when Tasks 3 and 4 as well as Tasks 3 and 5 were compared, and the content rate of θ waves decreased. This is because the volume of thoughts increased more for the process to screen orange or apple out of the given hints (water, apple, orange, strawberry, banana and pear) than the case of water. Significant difference was not recognized in Student's t-test (significance level=0.05; two-sided test) of brain waves for either Tasks 3 and 4 or Tasks 3 and 5. Based on the above, the tendency of the hypothesis was observed but statistically significant differences were not recognized (Fig.4).

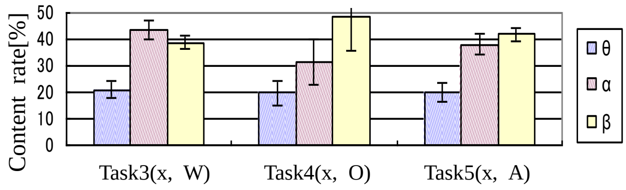

Fig.4: Taste and electroencephalographic response (average ± standard deviation)

2. Hypothesis 2: Presence of visual presentation and electroencephalographic response

Next, tasks with taste information only are compared with tasks where the same visual and taste information are presented such as visual information of apple and taste information of apple (Tasks 6 and 7). For Hypothesis 2, the volume of thoughts decreases upon taste cognition, since integrated processing of vision and taste goes easier with tasks with visual information. Thus, we considered that α waves increase and β waves decrease in comparison with brain waves when only taste is presented. As a result of the experiment, the content rate for α waves and β waves decreased when Tasks 4 and 6 were compared, and increased when Tasks 5 and 7 were compared. θ waves have a tendency to increase when vision is presented rather than presenting taste only. A significant difference was not recognized in Student's t-test (significance level=0.05; two-sided test) for Tasks 4 and 6 as well as Tasks 5 and 7. Based on the above results, it is assumed that in the case of Tasks 4 and 6, α waves decreased and β waves increased as a result of relating to long-term memory, and in the case of Tasks 5 and 7, α waves increased and β waves decreased as a result of relating to short-term memory (Fig.5).

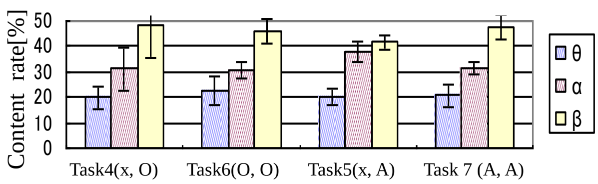

Fig.5: Presence of visual presentation and electroencephalographic response (average ± standard deviation)

3. Hypothesis 3: Electroencephalographic response to match/mismatch of taste and visual presentations

Next, tasks where the same vision and taste are presented are compared with tasks where different vision and taste are presented (Tasks 8 and 9). For Hypothesis 3, we considered the case where taste information does not match vision information given, e.g., visual information of apple and taste information of orange. In this case, integrated processing becomes extremely difficult and the volume of thoughts increases; therefore we considered that α waves decrease and β waves increase compared with the case where the same visual and taste information is given. First of all, the content rate of α waves decreased, the content rate of β waves increased and θ waves also increased in the case of Task 8 (A, O) compared with Task 7 (O, O). On the other hand, the content rate of α waves and β waves decreased and θ waves increased in the case of Task 9 (O, A) compared with Task 6 (A, A). Significant difference was not recognized in Student's t-test (significance level=0.05; two-sided test) of brain waves for Tasks 7 and 8 as well as Tasks 6 and 9. It is considered that α waves decreased with short-term memory in regards to the mismatch (Fig.6).

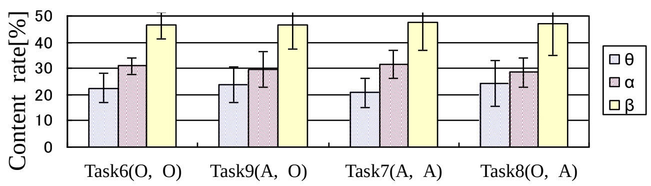

Fig.6: Electroencephalographic response (average ± standard deviation) in match/mismatch of taste and visual presentations

V. DISCUSSIONS

Based on the results of experiments at this time, visual information as well as specific work in integrated processing is added to the taste processing model (Fig.1).

The model under Hypotheses 1was indicated in the taste-vision processing model in Fig.7. The decrease of α waves and increase of β waves can be explained with the increase in the volume of thoughts at the time of screening taste. Based on this, the model was restructured.

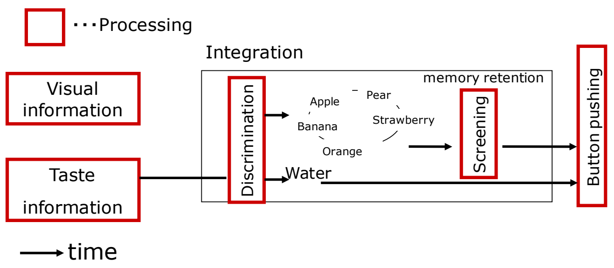

Fig.7: Restructured taste-vision processing model (in the case of Hypothesis 1)

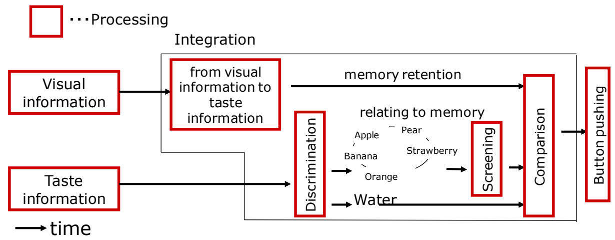

Fig.8: Restructured taste-vision processing model (in the cases of Hypotheses 2 and 3)

The model under Hypotheses 2 and 3 was indicated in Fig.8. Increase/decrease of α waves and β waves was considered to change depending on long-term memory and short-term memory used to relate to memory when the same taste information as visual information is given. On the other hand, when taste information different from visual information is given, α waves decreased while β waves did not increase, by relating to long-term memory without using short-term memory; therefore the model was restructured.

VI. CONCLUSION

We measured spontaneous brain waves for the taste processing model. In these experiments, a tendency of α wave decrease and β wave increase was observed for tasks with taste information only in comparison with tasks where taste information of water only was presented under "4.1 Taste and electroencephalographic response." Based on these results, the vision-taste processing model was developed. It is possible to explain from this model that integrated processing is conducted in the interaction of vision and taste. We hope to carry out statistical review by increasing the number of subjects as well as the number of trials in the future.

We had assumed that β waves of brain waves covered at this time increase/decrease as a result of relating taste to memory; however a significant difference was not recognized in any task. We will confirm whether or not a significant difference is recognized by calculating brain waves with the content rate. Higher brain activities might not be occurring when taste is obtained if there is no difference in β waves; therefore review is desired. In this paper, a model was developed by focusing on vision and taste and conducting experiments. It is needless to say that when an object is tasted, not only vision and taste but also smell is an important sense, and we plan to review the influence of smell on the brain in our future studies.

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