A study on the applicability of facial expression chart for display systems

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Abstract

Existing display systems are sometimes insufficient to display the information to be conveyed. For example, a room temperature meter displays the room temperature as a bar graph or numerical value, but the sensible temperature differs depending on the season: the same 20 degrees centigrade can be cold in summer but warm in winter. Additionally, elderly people may have a dull sense of temperature and hence not notice the room temperature even if the change is significant. A display system showing not only the temperature but also the four seasons in the year, level of comfort and color code for danger (red: dangerous, yellow: caution, green: safe) can be easier for users to understand. However, displaying various information simultaneously can overburden the users since it requires intensive and swift processing of incoming information. To address these problems, this paper considers a display system with facial expressions: information to be displayed are translated to part and condition of the face to construct a face chart. The shape, size, position, color or movement of the chart are determined by the information. Morphological visual data transmission is superior in speed, recognizability, accuracy and multiple data transmissions. For human beings, faces are the most significant clue for identifying others. Facial expressions are mainly expressed by the muscles around the eyes. Eyes often shows the emotional state of the person. This paper aims to evaluate the effect of the display system using the features of facial expression. We first examine the accuracy of facial expressions of taste and emotion and their recognition by conducting questionnaire experiments. In the next step, we evaluate the ability of facial expression in simultaneous information transmission and its impact to observers. Finally, we propose an indoor environment display system using face expression as its application. Main results are as follows: as for taste, sweetness (76.5 %) and acidity (72.8 %) had high recognition rates; as for emotion, joy (96.3 %) and surprise (76.5 %) had high recognition rates; taste and joy matching experiments showed high matching rate between sweetness and joy (94.3 %); an experiment to evaluate a Japanese sweetshop showed sufficient simultaneous information transmission result (74.8 %); an experiment for time indication showed the facial expression method had the highest impact ability. These results show the effectiveness of facial expression system.

Key words

face information processing, facial expressions, display methods, simultaneous information transmission through facial expression, impact of facial expressions

1. Introduction

Numerous methods are used to display various information in daily life. In household, a table clock displays the time by the angle of the hands. A microwave oven numerically indicates the amount of dielectric heating by high frequency. In factories and offices, various indicator lamps are used to notify operational state of devices and machines. These indicators are easy to understand, but sometimes do not have sufficient capacity to signal various patters. In public space, traffic signals employ three-color scheme, which is easy for drivers and pedestrians to make accurate and prompt judgements; but sun light or its reflection make these signals difficult to see. Recently, as one of the measures to fight against the spread of new corona virus, numerous notices for keeping social distancing are posted everywhere, but they are saturated and do not have sufficient impact for behavioral change. Current display methods are useful but have room for improvement. By the way, the patent application for the display means can be viewed from (Astamuse, 2021).

In our daily lives, the face plays an important role in social interactions. By looking at the face, one can promptly grasp a wide range of information. These include gender, age, facial expression, relationship, and the mood of that person. This prompt and multiple information transmission function shows the importance and necessity of studying the face and its function through more academic approach (Shibui et al., 2011). In this respect, the activities of the Japan Face Society (Jface, 1995), established in 1995, can be used as a starting point for the study in face information processing. Several studies have shown a multifaceted nature of information transmitted by face: structural and morphological information in dentistry and medicine; engineering coded information in facial recognition and synthesis; and socio-cultural and psychological aspects (Calder et al., 2000; Campanella et al., 2001; Haxby et al., 2000: Matsuzaki and Sato, 2008; Newell and Bulthoff, 2002; Tanaka et al., 2010; Turk and Pentland, 1991; Zhao et al., 2003).

Previous studies using facial expression chart include route decision systems associating with facial expression (Iwata and Anisawa, 1996), taste-elicited facial expressions and recognition (Hakoda et al., 2001), and trends and prospects in psychology of facial impressions (Nakamura, 2021), all of which offer insightful findings but do not analyze the prompt and various information transmission feature of the face expression chart.

In this paper, we first examine the accuracy of facial expressions to show the subjective taste of the participants. In the next step, the ability to transmit multiple data simultaneously by a facial expression display system is examined to determine the impact of facial expressions. Finally, face expression chart is applied to propose an indoor environment display system.

We conducted six experiments. In Experiments 1, 2, 4 and 5, participants were required to judge the indicated facial expression carefully. In order to secure reliable data, we formed a focus group composed of nine students.

2. Facial expressions and recognition accuracy

There are four basic tastes: sweetness, saltiness, acidity, and bitterness. Taste is also influenced by odor, texture and temperature. Emotions are the feelings animals including humans have toward objects surrounding them. These feelings are joy, sadness, anger, surprise, disgust, and fear.

In this chapter, a participant (a sender) is asked to imagine the taste or emotion and then facially express that imaginary taste or emotion. From this facial expression, another participant (a receiver) is asked to judge the taste or emotion expressed by the sender. By comparing senders' intentions and receivers' judgements, recognition rates of facial expressions for various tastes and feelings are analyzed. In addition, the relationship between facial expressions of taste and feeling is investigated.

2.1 Experiment 1: Accuracy of taste facial expression

9 participants were asked to imagine to eat sweet, salty, acid, and bitter foods. Their facial expressions were captured by a camera (color, front image above the chest). 36 photos

Table 1: Recognitions of facial expressions: sweetness (SW)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	SW	SW	SW	SW	SW	SW	SW	SW	SW
	B	SW	SW	SW	SW	SW	SW	SW	SW	AC
	C	SW	SW	SW	SW	SL	AC	SL	SW	AC
	D	SW	SW	BT	SW	SW	SW	SW	SL	SW
	E	AC	SW	SW	SW	SW	SW	SW	SW	SL
	F	SL	SW	SW	SW	SL	SW	SL	SW	BT
	G	SL	SW	SW	SW	SW	SW	SW	SW	BT
	H	SW	SW	SW	SW	SW	SW	SW	SW	SW
	I	SW	SW	SL	SW	BT	SW	BT	SW	SL

Note: SW: sweet, AC: acid, BT: bitter, SL: salty.

Table 2: Recognitions of facial expressions: saltiness (SL)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	SL	BT	SL	BT	SL	SL	SL	BT	BT
	B	SL	SL	SL	SL	AC	SL	SL	SL	BT
	C	SW	BT	SL	SL	SW	BT	BT	BT	SW
	D	SW	SW	AC	SL	SW	SW	SW	SL	SL
	E	SL	SL	BT	SL	AC	BT	AC	AC	SL
	F	SL	SL	BT	SL	SL	SL	SW	SL	SW
	G	BT	SW	SL	SL	SW	BT	BT	SL	SW
	H	SL	BT	SL	SL	BT	BT	SL	SL	AC
	I	BT	SL	SL	BT	BT	BT	SL	BT	SL

Note: SW: sweet, AC: acid, BT: bitter, SL: salty.

Table 3: Recognitions of facial expressions: acidity (AC)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	AC	AC	AC	AC	AC	AC	AC	BT	AC
	B	AC	AC	SL	AC	AC	AC	AC	AC	AC
	C	BT	BT	BT	BT	AC	SL	BT	SL	BT
	D	AC	AC	AC	AC	AC	AC	AC	AC	AC
	E	AC	AC	AC	AC	AC	AC	AC	AC	AC
	F	AC	AC	AC	AC	AC	AC	AC	AC	AC
	G	SL	SL	SW	SW	BT	SL	AC	BT	AC
	H	BT	BT	AC	BT	AC	AC	BT	AC	AC
	I	BT	AC	AC	AC	AC	AC	AC	AC	AC

Note: SW: sweet, AC: acid, BT: bitter, SL: salty.

Table 4: Recognitions of facial expressions: bitterness (BT)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	BT	AC	AC	BT	AC	AC	AC	AC	AC
	B	BT	BT	AC	BT	BT	BT	BT	BT	SL
	C	AC	AC	SL	AC	AC	AC	SL	BT	SL
	D	SL	SL	BT	BT	BT	BT	BT	BT	BT
	E	BT	BT	BT	BT	BT	SL	BT	BT	SL
	F	SL	BT	BT	SL	SL	SL	SL	SL	BT
	G	SW	SW	SW	SW	SW	BT	SL	SW	BT
	H	SL	SL	SW	SL	BT	SW	BT	BT	BT
	I	SW	BT	AC	SL	SL	SW	SW	AC	AC

Note: SW: sweet, AC: acid, BT: bitter, SL: salty.

Table 5: Recognition rates of taste facial expressions

Taste	SW	SL	AC	BT
Recognition rate	76.5 %	48.1 %	72.8 %	42.0 %

Note: SW: sweet, AC: acid, BT: bitter, SL: salty.

(4 tastes by 9 participants) were randomly shown to each participant to judge the taste which the expression in the photo was trying to convey. In total, 324 judgements were conducted (9 participants by 36 photos). After taking a photo, the participant could check the result and request to retake another until he/she was satisfied with.

2.1.1 Results

Tables 1 to 4 respectively show the results of each taste. Participant (I) is a receiver and judges the taste expressed by a sender, Participant (II). The participants are all university students aged between 21 and 22. D, F and G are female and the rest are male. Table 5 shows the accurate recognition rate of each taste facial expression (rounded to the first decimal point).

The tastes with high accuracy are sweetness (76.5 %) and acidity (72.8 %); with low accuracy are saltiness (48.1 %) and bitterness (42.0 %), both of which are below 50 %.

For the sweetness, no specific patters can be found for inaccurate judgements. Accuracies of each participants are between 56 % and 100 % and none of them was extremely low in judgement.

In the case of saltiness, many inaccurate judgements were made for bitterness expression, which account for 55 % of inaccurate judgments. There were few cases where salty faces were mistaken for those of acidity (14 %). Inaccurate judgements for bitterness or sweetness depended on the participants.

Regarding the acidity, numerous inaccurate judgements were made for bitterness expression, accounting for 64 % of inaccurate judgements. There were few cases to misjudge acidity faces for those of sweetness (9 %).

In the bitterness face judgements, inaccurate judgements were evenly distributed among sweetness (23 %), saltiness (43 %) and acidity (34 %), which were subject to the participants.

In all of the four tastes, there were no clear differences in

accuracy between male and female students.

From Experiment 1, sweetness and acidity were shown to be recognized with a certain level of accuracy by the facial expression.

2.2 Experiment 2: Accuracy of feeling facial expression

9 participants (same as in experiment 1) were asked to imagine situations where they feel joy, sadness, anger, surprise, disgust and fear. Their facial expressions were captured by a camera (color front image above the chest). 54 photos (6 feelings by 9 participants) were randomly shown to each participant to judge the emotion which the expression in the photo was intended to convey. In total, 486 judgements were conducted (9 participants by 54 photos). After taking a photo, the participant could check the result and request to retake another until he/she was satisfied with.

2.2.1 Results

Tables 6 to 11 respectively show the results of each emotion. Participant (I) is a receiver and judges the emotion expressed by a sender, Participant (II). The participants are all university students aged between 21 and 22. D, F and G are female and the rest are male. Table 12 shows the recognition rate of each emotion facial expression (rounded to the first decimal point).

The emotions with high accurate recognition rate are joy (96.3 %) and surprise (76.5 %); with significantly low accurate rate is fear (17.3 %).

For joy, no specific patters can be found for inaccurate judgement. Regarding sadness, many inaccurate judgements were made for disgust (59 %). No cases were found for misjudging the face for anger or surprise. In the case of anger, there were many inaccurate judgements for disgust (63 %). Inaccurate judgments for joy, fear or sadness were small in number. In the case of surprise, 52 % misjudgments were made for fear. Inaccurate judgement for other emotions were evenly distributed. Regarding disgust, 46 % misjudgments were made for anger. There were few inaccurate judgements for joy or surprise. In the case of fear, many inaccurate judgements were made for anger (34 %) and surprise (31 %). Except for joy, inaccurate judgements were dependent on the participants.

Table 6: Recognitions of facial expressions: joy (JY)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	JY	JY	SR	JY	JY	JY	JY	JY	JY
	B	JY	JY	JY	JY	JY	JY	JY	JY	JY
	C	JY	JY	JY	JY	JY	JY	JY	JY	JY
	D	JY	JY	JY	JY	JY	JY	JY	JY	JY
	E	JY	JY	JY	JY	JY	JY	JY	JY	JY
	F	JY	JY	JY	JY	JY	JY	JY	JY	JY
	G	JY	JY	JY	JY	JY	JY	JY	JY	JY
	H	JY	JY	JY	JY	JY	JY	JY	JY	JY
	I	JY	JY	SD	JY	DS	JY	JY	JY	JY

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear.

Table 7: Recognitions of facial expressions: sadness (SD)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	SD	SD	SD	SD	DS	DS	SD	DS	DS
	B	SD	SD	SD	SD	DS	DS	SD	SD	SD
	C	SD	SD	SD	SD	SD	SD	SD	SD	SD
	D	SD	SD	SD	SD	SD	DS	SD	SD	SD
	E	DS	FR	DS	DS	DS	DS	SD	DS	SD
	F	SD	SD	SD	SD	SD	SD	SD	SD	SD
	G	JY	JY	DS	JY	JY	JY	JY	JY	JY
	H	JY	FR	DS	SD	SD	FR	FR	DS	JY
	I	SD	SD	SD	SD	DS	DS	SD	DS	DS

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear.

Table 8: Recognitions of facial expressions: anger (AN)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	AN	SR	SR	SR	SR	SR	SR	SR	AN
	B	AN	AN	DS	SD	AN	DS	AN	AN	AN
	C	AN	AN	AN	DS	AN	FR	AN	AN	AN
	D	AN	AN	AN	AN	AN	AN	AN	AN	DS
	E	DS	AN	AN	AN	AN	AN	AN	AN	AN
	F	AN	DS	DS	DS	DS	AN	AN	AN	DS
	G	JY	AN	SD	FR	DS	FR	DS	DS	DS
	H	DS	DS	AN	DS	AN	DS	AN	AN	DS
	I	SD	DS	SD	DS	DS	AN	DS	DS	DS

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear.

Table 9: Recognitions of facial expressions: surprise (SR)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	FR	FR	FR	AN	SR	DS	FR	SR	SR
	B	SR	SR	SR	SR	SR	SR	SR	SR	SR
	C	SR	SR	SR	SR	SR	SR	SR	SR	SR
	D	SR	SR	SR	SR	SR	SR	SR	SR	SR
	E	SR	SR	SR	SR	SR	SR	SR	SR	SR
	F	JY	SR	JY	SR	SR	SR	JY	SR	SR
	G	FR	AN	SR	FR	FR	DS	DS	SR	DS
	H	FR	SR	SR	SR	FR	SR	SR	SR	FR
	I	SR	SR	SR	SR	SR	SR	SR	SR	SR

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear.

Table 10: Recognitions of facial expressions: disgust (DS)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	DS	SD	DS	DS	DS	SD	SD	AN	DS
	B	DS	DS	AN	DS	DS	AN	DS	DS	DS
	C	AN	DS	AN	AN	AN	AN	FR	SR	DS
	D	SD	DS	DS	DS	SD	DS	DS	DS	SD
	E	SD	SD	DS	SD	DS	AN	DS	AN	DS
	F	DS	DS	DS	DS	DS	DS	AN	SD	SD
	G	DS	FR	DS	AN	DS	FR	AN	DS	DS
	H	AN	DS	DS	AN	DS	DS	AN	DS	DS
	I	DS	DS	DS	FR	FR	FR	FR	DS	DS

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear.

In all the six emotions, there were no clear differences in accuracy between male and female students.

From Experiment 2, joy and surprise were shown to be recognized with a certain level of accuracy by the facial expression.

2.3 Experiment 3: Relationship between taste and emotional facial expression

For each taste, the photo with the highest accurate recognition rate was selected and presented to 53 participants (all third-year students), who made a judgement for emotions of

Table 11: Recognitions of facial expressions: fear (FR)

		Participant (II)								
		A	B	C	D	E	F	G	H	I
Participant (I)	A	SR	SR	FR	SR	SR	SR	SR	SR	SR
	B	AN	SR	AN	SR	AN	AN	DS	AN	AN
	C	JY	SR	SR	SR	SR	SR	SR	SR	FR
	D	DS	FR	DS	FR	FR	FR	FR	FR	FR
	E	JY	JY	JY	SR	JY	FR	FR	JY	JY
	F	AN	SD	FR	FR	DS	FR	SD	DS	SD
	G	SR	AN	SR	SR	AN	DS	AN	AN	AN
	H	AN	AN	AN	AN	DS	DS	DS	DS	SD
	I	AN	DS	AN	AN	AN	AN	AN	AN	DS

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear.

Table 12: Recognition rates of each emotion

Emotion	JY	SD	AN	SR	DS	FR
Recognition rate	96.3 %	58.0 %	50.6 %	76.5 %	56.8 %	17.3 %

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear.

joy, sadness, anger, surprise, disgust or fear. Multiple judgements were allowed when applicable.

2.3.1 Results

Figures 1 to 4 show the photos used in the experiment. The results are shown in Table 13.

The emotion that was strongly linked to the sweet facial expression was joy (94.3 %); for the salty facial expression, disgust (68.8 %) and sadness (23 %) were highly related; for the acid facial expression, many participants related it to surprise (39.5 %); and for the bitter facial expression, disgust (60.4 %) was strongly linked. These results suggest the possibility of one facial expression to convey both taste and emotion.

For the cases in which participants could not choose one emotion, 6 participants selected disgust and sadness when presented with the salty facial expression.

Instead of imagining four tastes as in our study, Hakoda (2001) conducted experiments by asking participants to actually intake sweet or salty foods. It concluded that although salty and bitter facial expressions could respectively convey sadness and disgust / sadness, there were no significant pattern for sweet and acid facial expressions.

In contrast to this conclusion, our experiments have shown that salty facial expression correspond with disgust (66.8 %) or sadness (22.3 %) and bitter facial expression correspond with disgust (60.4 %). In our experiments, participants (senders) were allowed to check the image taken and to retake one until they were satisfied with. This step may play a part for participants to create facial image which matches as closely as possible with their imaginary taste experience.

From Experiment 3, it was shown that facial expressions of sweetness and joy were highly related. Also, facial expressions of salty and bitterness were highly related to disgust.

3. Simultaneous information transmission through facial expression

Using facial expressions, we conducted two experiments to analyze their ability to simultaneously transmit information. 9 students (same as in Experiment 1) participated in the experiments.

Table 13: Matching rate of taste facial expressions to emotions

	JY	SD	AN	SR	DS	FR	Total
SW	94.3 %	1.9 %	1.9 %	0.0 %	1.9 %	0.0 %	100.0 %
SL	1.6 %	23.0 %	3.3 %	0.0 %	68.8 %	3.3 %	100.0 %
AC	7.3 %	20.0 %	21.8 %	39.9 %	5.5 %	5.5 %	100.0 %
BT	3.4 %	13.9 %	10.3 %	8.6 %	60.4 %	3.4 %	100.0 %

Note: JY: joy, SD: sadness, AN: anger, SR: surprise, DS: disgust, FR: fear, SW: sweet, AC: acid, BT: bitter, SL: salty.

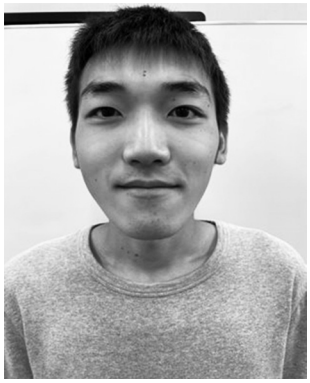

Figure 1: Face image: sweetness

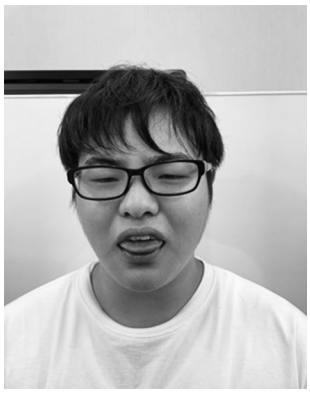

Figure 2: Face image: saltiness

Figure 3: Face image: acidity

Figure 4: Face image: bitterness

In Experiment 4, information is assigned to facial parts and expressions to analyze the number of information that can be transmitted simultaneously. Success or failure of the transmission is judged by the number of facial parts and expressions accurately constructed by the participants. Inaccurate constructions were judged to be failed transmissions.

Experiment 5 studies how much information the other participants (receivers) can receive. Additional analysis was conducted to investigate the parts and facial expressions that were easy to convey accurate information.

3.1 Experiment 4: The number of information that can be transmitted by facial expression

Using the evaluation score of a Japanese sweet shop, experiments were conducted to analyze how many evaluation items can be transmitted by facial expression.

The experiment was conducted as follows for each participant:

(1) The evaluation score of the shop is handed to a participant. Consulting the sheet corresponding the evaluating items and facial parts (Table 14), the participant is asked to imagine the facial parts corresponding to that evaluation.
(2) The participant is asked to draw a face based on a blank paper. When drawing, the corresponding sheet is turned over to prevent consultation. The participant can consult the evaluation score of the shop if necessary.
(3) From the face constructed in step (2), count the facial parts drawn according to the evaluation score and corresponding sheet. This count is the number of information that can be sent out by facial expression.

3.1.1 Results

Table 15 shows the evaluation score of the shop handed to the participants. When drawn accurately based on the table, a face would look like those in Figure 5.

Tables 16 and 17 show the experiment results. From Table 16, the ratio of the evaluation items that can be sent out by facial expression for this Japanese sweets shop is 92.2 % (average value) *1. From Table 17, the facial parts that are frequently used in facial expressions are ear size, smile/crying face, wink / no wink, earrings, glasses, and hair band. On the contrary, although there was no significant tendency for infrequent usage, eye size, nose height and eyebrow thickness were comparatively less used. Since the face is drawn front facing, recreating nose height may be difficult.

From Experiment 4, it was confirmed that the facial expression was able to express the information contained in the evaluation items.

Table 14: Corresponding sheet for evaluation items and facial parts

Items	Value	Part
For gift	Yes/No	Face width (large/small)
For personal use	Yes/No	Ear size (large/small)
Experience of gift giving	Yes/No	Happy face/unhappy face
Experience of personal use	Yes/No	With wink/without wink
Recognition	High/Medium/Low	Eye size (large/medium/small)
Taste	Good/Normal/Bad	Nose height (high/normal/low)
Reasonable price	Yes/No	With earing/without earing
Preference	Yes/No	With eyeglasses/without eye glasses
Attractive appearance	Yes/No	With hair band/without hair band
Shop with long history	Yes/No	Eyebrow thickness (thick/thin)

Table 15: Evaluation score of a Japanese sweet shop

Items	Response
For gift	No
For personal use	Yes
Experience of gift giving	Yes
Experience of personal use	No
Recognition	High
Taste	Good
Reasonable price	No
Preference	Yes
Attractive appearance	No
Shop with long history	Yes

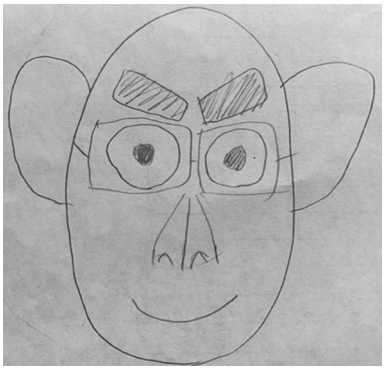

Figure 5: A correct hand-drawn face based on Table 15

3.2 Experiment 5: The number of information that can be received by facial expressions

Using the evaluation items of the Japanese sweet shops, experiments were conducted to analyze how many evaluation values can be received from the facial expressions.

The experiment procedure is as follows for each participant:

(1) Have them check the correspondence table in Table 14. After that, turn it over so that it cannot be consulted during the experiment.
(2) Ask the participant to obtain the score of each evaluation item from the hand-drawn face expression (Figure 15), which can be consulted during the experiment. The participant filled out an answer sheet on which the evaluation items were printed.
(3) The result of step (2) is compared with the evaluation

Table 16: Number of evaluation items able to be transmitted through facial expressions

Subjects	Number of items
A	10
B	9
C	10
D	10
E	10
F	9
G	8
H	9
I	8

Table 17: Frequency of parts used in facial expression (sender = 9)

Part	Frequency	Percentage
Face width	8	88.9
Ear size	9	100
Smile/cry	9	100
With or without wink	9	100
Eye size	7	77.8
Nose height	7	77.8
Earrings	9	100
Eyeglasses	9	100
Hair band	9	100
Eyebrow thickness	7	77.8

score in Table 15. The number of evaluation items (the number of correct answers) in which both have the same value is output. This is the number of evaluation values that the receiver can obtain accurate information from the facial expression.

3.2.1 Results

Figure 5 shows the face expression of the hand-drawn face used in the experiment. Tables 18 and 19 show the results of the experiment. From Table 18, the ratio of the number of evaluation items of this Japanese sweet shop, where accurate information can be obtained from the facial expression, is 81.1 % (average value) *2. Most of the participants had high evaluation values, but students C and H had about half of the evaluation values. From Table 19, it was found that the part where the receiver can easily remember the evaluation value is the size of the ear, while the part where it is difficult to remember was related to winks.

From *1 and *2 , facial expressions were able to transmit 74.8 % of evaluation value of the Japanese sweet shop. This result shows that the ability to transmit the evaluation value table by facial expression was high.

Table 18: Number of evaluation values obtained by the receiver by facial expression

Subjects	Number of items
A	8
B	8
C	6
D	9
E	7
F	10
G	10
H	5
I	10

Table 19: Frequency of parts used in facial expression (receiver = 9)

Part	Frequency	Percentage
Face width	8	88.9
Ear size	9	100
Smile/cry	7	77.8
With or without wink	5	55.6
Eye size	7	77.8
Nose height	6	66.7
Earrings	8	88.9
Eyeglasses	8	88.9
Hair band	7	77.8
Eyebrow thickness	8	88.9

4. Impact of facial expression

The impact of facial expression is examined and compared with the conventional display method using a questionnaire method. Conventional display methods include analog and digital types such as thermometers and hygrometers; color-only type such as traffic lights; and photographs showing the state of morning, noon, evening, and night; blinking type for underlining important information; and the text only type.

4.1 Experiment 6: Impact degree of each display methods

Following eight types were used for the experiment: (1) simple analog type, (2) digital type, (3) color schematic of morning, noon, evening, and midnight, (4) symbolic photos for morning, noon, evening, and midnight, (5) decorated analog type, (6) analog type with a blink signal for current time, (7) text type, and (8) face expression proposed in this study.

After being explained for each of above 8 types by PowerPoint slides, 65 undergraduate students (all in second-year) filled out a questionnaire to evaluate the impact level of each display method. The evaluation scale is 1 to 10, with 10 the highest impact. Standard value is 5.

4.1.1 Results

Figure 6 shows the eight types of display methods used in the questionnaire. The results of the questionnaire are shown

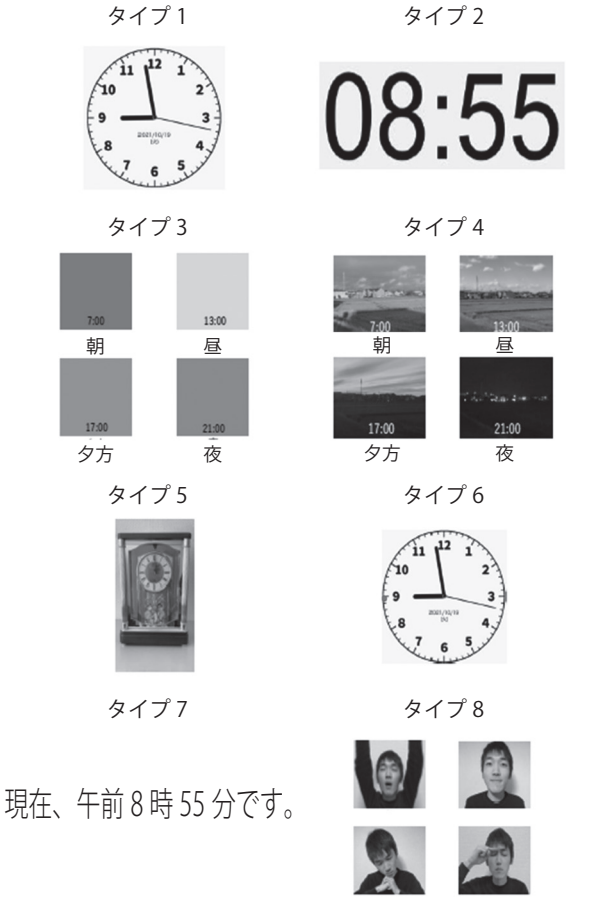

Figure 6: Eight display methods used in the experiments

Table 20: Impact of each display method

Type	1	2	3	4	5	6	7	8
M	3.8	5.3	4.7	6.1	4.7	4.5	4.4	6.3
SD	1.8	2.0	1.5	1.8	1.9	1.6	2.1	2.4

in Table 20. The degree of impact was calculated based on the average value of the respondents. Type (8) had the highest impact. The methods significantly exceeding the standard value of 5 were types (4) and (8). These two methods have images which are easy to comprehend. The result that type (8) has the highest mean value suggests the participants responded positively to the facial expressions.

From Experiment 6, it was shown that the information display method by facial expression had the highest impact among the eight methods used.

5. Application of face expression to Indoor environment display system

We propose a device that displays the indoor environment on the display screen using facial expressions. Environmental aspects to be considered are room temperature, humidity, comfort, weather forecast (atmospheric pressure), illuminance, indoor air pollution, season, odor and noise. These aspects are assigned to facial parts listed in Table 21. The parts of the face that do not correspond to these aspects measured by various sensors will not be shown so that users can concentrate easily on significant aspects. In this way, the indoor environment can be instantly visualized and transmitted from the face image displayed on the display screen.

Table 21: Assignment of environment to facial parts

Environment aspect	Part of the face
Room temperature	Cheek color
Humidity	Hair color
Comfort	Emotion (smile, normal, cry)
Air pressure (forecast)	Background color
Illumination?	Eye size
Cleanness of room air	Eye color (blue, green, purple, red)
Season	Upper body garment
Smell	Nose size
Noise	Ear size

6. Conclusion

Except for those who have been trained in facial expressions such as actors and comic storytellers, it is often difficult to express facial expressions just by imagining tastes and emotions. Therefore, in this study, the participants were allowed to check their facial expressions captured by a camera and to retake another until they were satisfied with.

With this high accurate representative facial expressions' images, we conducted five experiments. Experiment 1 showed that the recognition rate of sweet and sour facial expressions was high and Experiment 2 showed that the recognition rate for joy and surprise facial expressions was high. The relation between taste and emotion facial expressions was analyzed in Experiment 3, which showed a very high matching rate for sweet and joy facial expressions, followed by salty and disgust combination. In the literature (Hakoda 2001), experiments were conducted by asking participants to actually eat sweet or salty foods instead of just imagining the taste. They concluded while salty facial expressions were interpreted as sad and bitter facial expressions were interpreted as disgust or sad, sweet or acid facial expressions were interpreted to multiple emotions without any significant patterns.

In Experiments 4 and 5, the ability to simultaneously transmit and receive information by facial expressions were analyzed. While the results of the experiments proved satisfactory level of accuracy, the result could be dependent on which part of the face the evaluation item corresponds to. In developing a more accurate system, it is necessary to select a facial part that can be associated naturally with the evaluation item. This could lessen the burden for memorization. Experiment 6 showed the effectiveness of using facial expressions as the display means. Applying these findings, we proposed an indoor environment display system using facial expression in Chapter 5.

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