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THE MODEL TO EXPRESS DYADS FOR ROBOTS USING COLORS SUITABLE FOR JAPANESE PEOPLE: PART 1 ORDER OF BASIC EMOTIONS AND PRIMARY DYAD

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Abstract. *Several methods have been proposed for using color to express emotion. The most commonly used model of emotion is Plutchik's model of emotion. However, this model may not suit Japanese people. In addition, emotions other than the basic emotion have not been well studied, especially the method to express the secondary dyad. In this paper, we propose a new method that places surprise between anger and expectation, and expresses primary dyads using two basic emotion patterns. Experimental results show that the primary dyad can be expressed using two different gradation methods. Furthermore, we find that the reordering method gives better results for Japanese people. It may be possible to apply these results to finding an even better sorting order for people in other countries, or to create a model that expresses all emotions in the future.*
Keywords: Robot, Emotion, LED, Color, Gradation

1. **Introduction.** Nowadays, Japan's population has been aging. As a result, there is a problem of a worker shortage. In order to solve this problem, robots are used in various fields. One of these is the partner robot. For example, people with social anxiety tend to be unwilling to talk to humans. However, they are not unwilling to talk to a robot with a metal body [1]. Using these results, counseling methods using robotic bodies are discussed [2]. Additionally, the robot partner that helps improve elderly people's mental health instead of caregivers is proposed in [3, 4]. Robots are no longer focused only on physical functionality. They are required to have mental functions.

These partner robots can communicate with humans. Humans not only communicate through words, but also facial expressions and gestures. Through these actions, humans communicate their emotions to others. Equally, robots should express their emotions. The reason is that when a robot expresses emotions, humans can predict the robot's behavior and feel familiarity. Even chatbots that respond to product reviews focus on emotion for better responses [5]. These bring better communication on both human and robots [6].

When the robot is attempting to express emotions, most emotional expression methods make the robot complex. Therefore, various studies have focused on the relationship between color and emotion [9, 10, 11, 15, 16]. For example, Sugiyama and Kanoh examine

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whether the color of the clothing worn by the robot makes a difference in its emotional expression [9]. Thus, there is a close relationship between color and emotion.

The use of color as an emotional expression is also considered in [10, 11, 15, 16]. Sugano and Ogata propose a method using colors of the robot's head with other expressions. Their robot uses blue to express fear, red to express anger, and yellow to express anticipation and joy [10]. Gotoh et al. propose a method using color of the head and the cheek with facing expressions [11]. Their robot expresses anger by glowing red on its head, joy by glowing green on its head, and sadness by glowing its cheeks. However, their robots do not express emotions only through colors. Their robots use color as an assist to gesture and facial expression. Additionally, their robots can only express a small number of emotions. The models are required to express a various range of emotions. In order to make such a model, we must consider to classify emotions. There are various methods to classify emotions [12, 13]. One of them is Plutchik's method [12]. He first selects eight basic emotions, joy, acceptance (Later changed to trust [14]), fear, surprise, sadness, disgust, anger, and anticipation. In addition, these basic emotions can mix. A mixture of two of basic emotions is called a "dyad". This name is based on the mixture of two primary colors. In particular, he calls emotions that are a mixture of similar basic emotions primary dyads. The reason to focus on his model is that he focuses on the similarities between color and emotion. Therefore, studies using his model are being conducted on ways to express emotion using color [15, 16, 17]. Teshi et al. [15] propose the use of color to express emotion during readings. They use a robot named Nao from Aldebaran Robotics SAS to model eight basic emotions. They create the method of expressing emotion by changing the color of the robot's eyes. Yamauchi et al. [16] create the model expressing 24 emotions, including basic emotions and three levels of intensity. They use only dynamic color change. However, their method includes some problems. In their method, the colors that express the emotions belong to the same basic emotions. For example, joy is expressed by yellow, but serenity (strong emotion of joy) is expressed by green. Therefore, this method is not practical. Additionally, some of the relationship between the speed of cycle and the intensity of the emotion are not accurate.

On the other hand, Tanaka et al. create and evaluate a model to solve the problems of Yamauchi et al.'s model [17]. They base their model on rules. Their models use the same colors for the same basic emotions. The difference in intensity is expressed by the speed of blinking. The colors are determined to be as easy to distinguish as possible.

As shown above, there are several researches that have attempted to express the basic emotions. In addition, Tanaka et al. use the model that can express primary dyads [18]. They propose methods of expressing the primary dyad by combining two basic emotional patterns. In their model, aggressiveness (anger + anticipation), optimism (anticipation + joy) can be accurately expressed. However, love (joy + trust) can be confused with optimism, remorse (sadness + disgust) can be confused with awe, and awe (fear + surprise) can be confused with aggressiveness, remorse, and contempt. Moreover, submission (trust + fear), disappointment (surprise + sadness) and contempt (disgust + anger) cannot express exactly. This research shows that primary dyads may be expressed as two-color gradients and that the order of Plutchik's model may not be appropriate for the Japanese. In other words, it was considered that the dyads that could not be expressed may not have a bad model, but rather a problem with the pairing of basic emotions. In Plutchik's model, surprise places between fear and sadness. However, according to their experiments, surprise is easily confused with anger, anticipation, and joy. Therefore, they raise the possibility that it would be better to reposition surprise between anger and anticipation.

Furthermore, Huyen et al. [19] perform experiments on Vietnamese participants based on the study by Tanaka et al. They perform two experiments. The first is on the relationship between the intensity of each basic emotion and blinking speed. Through this experiment, they conclude that fear, surprise, sadness, and disgust can express strong emotions at high speed and weak emotions at low speed, while anger, anticipation, joy, and trust cannot express by this way. The second is about the primary dyad. Their experiments show that they could express aggressiveness (anger + anticipation), optimism (anticipation + joy) and love (joy + trust), but not much about the rest.

In this paper, we propose a new model which places surprise between anger and anticipation and then propose a model to express primary dyads. Specifically, models of the primary dyads are created for the re-ordered basic emotions, presented to the participants, and evaluated. If good results are obtained by this method, then this ordering is considered to be appropriate for the Japanese. This paper is organized as follows. In Section 2, we describe the basic emotions and dyads. In Section 3, we explain the model used in experiment. Section 4 gives experimental method. In Section 5, we summarize experimental results. In Section 6, we give some discussions from result in Section 5. Finally, Section 7 gives concluding remarks.

2. **Basic Emotions and Dyads.**

In this section, we summarize the emotions proposed by Plutchik [12, 14].

Plutchik considers that emotions have characters similar to colors [12]. Specifically, he considers that emotions are not independent from each other but are related, and one emotion is made from some basic emotions. Thus, he selects eight basic emotions corresponding to primary colors and places them in a circle as hue circle. He concludes that the order of emotions on the emotion circle is joy, acceptance (Later changed to trust [14]), fear, surprise, sadness, disgust, anger, and anticipation. However, this order is not absolute and is subject to change depending on the measure used and other factors.

As with colors, basic emotions can be mixed to make new emotion. For color circle, mixture of any two primaries is called a dyad. For this reason, mixture of any two basic emotions is called dyads. Primary dyads are mixtures of two adjacent basic emotions. Dyads are mixtures of two emotions that are once removed on the circle, and tertiary dyads are mixtures of two emotions that are twice removed on the circle. Table 1 shows the list of dyads. Note that the mixture of surprise and disgust is not decided. However, a mixture of two emotions that are more widely apart on the emotion circle is harder to imagine than the one that is closer together. For this reason, secondary and tertiary dyads will be more inaccurate than primary dyads.

3. **New Model of Emotions.**

In this section, we propose a new model of emotions.

3.1. **Robot.**

Figure 1 shows the robot that is used for the experiment. There exists color development mechanism in the robot made of acrylic. USB cable connects the microcomputer and the external PC. Light Emitting Diodes (LEDs) are controlled by operating the PC. The target of this experiment is the robot that does not have a shape of creatures. Therefore, unnecessary parts are not attached to the robot in order to pay attention to the colors and blinks. There is color development mechanism consisting of RGB LEDs and microcomputer in the inside of the robot. RGB LEDs (OSTA5131A) are common cathode type that red, green, and blue are united. When an electrical current of 20 [mA] flowed in one LED, red, green, and blue emit wavelength 635 [nm], 525 [nm] and 470 [nm]. Microcomputer (Arduino UNO) carries out Pulse Width Modulation (PWM) control. Each three colors can change 256 grades between 0 [V] and 5 [V].

TABLE 1. List of dyads [12]

Primary dyads	Secondary dyads
joy + acceptance = love	joy + fear = guilt
acceptance + fear = submission	acceptance + surprise = curiosity
fear + surprise = awe	fear + sadness = despair
surprise + sadness = disappointment	surprise + disgust = ?
sadness + disgust = remorse	sadness + anger = envy
disgust + anger = contempt	disgust + anticipation = cynicism
anger + anticipation = aggressiveness	anger + joy = prise
anticipation + joy = optimism	anticipation + acceptance = fatalism
Tertiary dyads	
joy + surprise = delight	
acceptance + sadness = resignarion	
fear + disgust = shame	
surprise + anger = resentment	
sadness + anticipation = pessimism	
disgust + joy = morbidness	
anger + acceptance = dominance	
anticipation + fear = anxiety	

FIGURE 1. Robot appearance [17]

Two types of color development mechanisms are created. The first one is the mechanism that blights five LEDs at the same time. PNP type transistors (2SA1015) are used in order to control five LEDs connected in series. The other is the mechanism that blights two colors. This mechanism is connected with four LEDs. Two of these are connected to the same control terminal. To control one LED, three terminals are required for red, green, and blue. Therefore, a total of six terminals are used.

Microcomputer and PC are connected by serial communication. Each pattern can be chosen by using Graphical User Interface (GUI) on the PC. Pushing the buttons, the values that are assigned to emotions convey to the microcomputer. According to the value, parameters set in microcomputer are called and LEDs blink. By selecting the first and second colors, two colors can be presented. If "1 color (OFF)" is selected the second color, single color can also display. Figure 2 shows GUI for color control.

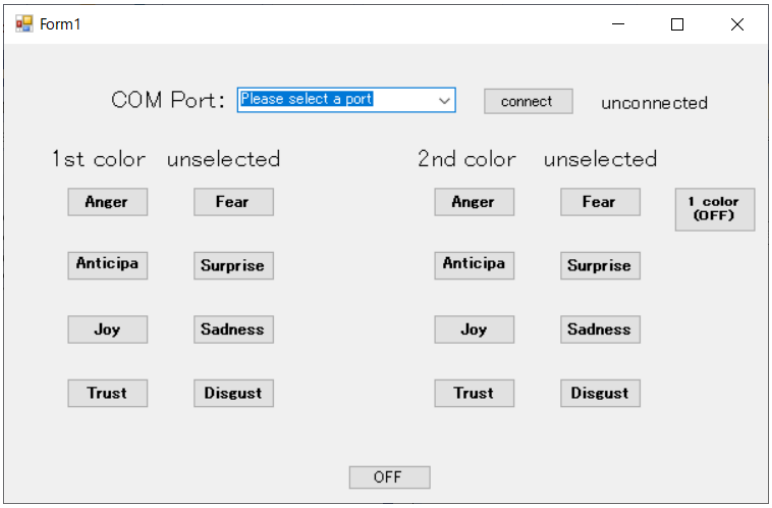

FIGURE 2. GUI for color control

3.2. **Model of basic emotions.** The model of basic emotions used in this paper is summarized in Table 2. This model is the same as the model proposed in [17]. The model of basic emotions proposed in [17] is summarized in Figure 3. However, the order of this model is not considered appropriate for the Japanese. Therefore, we reposition surprise between anger and anticipation. The pattern of each emotion is not changed. In other words, the proposed model assumes that the order of emotions is as follows: Anger (R), surprise (YR), anticipation (YR), joy (Y), trust (G), fear (PB), sadness (B) and disgust (RP).

TABLE 2. The model of basic emotions [17]

Basic emotion	Color (R, G, B)	Color name	Period [ms]
Anger	(0, 255, 255)	R(Red)	550
Anticipation	(50, 220, 255)	YR(Yellow Red)	1300
Joy	(0, 150, 255)	Y(Yellow)	1100
Trust	(150, 0, 255)	G(Green)	2100
Fear	(150, 255, 100)	PB(Purple Blue)	1800
Surprise	(0, 230, 255)	YR(Yellow Red)	625
Sadness	(255, 255, 0)	B(Blue)	3500
Disgust	(50, 255, 150)	RP(Red Purple)	2450

3.3. **Primary dyads.** In this paper, the names of the dyads are not used in the experiment, but are expressed as a combination of the basic emotions. In other words, the experiment is performed on the dyads in Table 3.

In the paper in [17], each of the dyads has a name. For example, the primary dyad consisting of anger and anticipation has the name aggressiveness. However, considering the use of the model as a robot's emotion expression, it is not necessary for the dyad to have a name. For example, aggressiveness can be expressed as

$$\text{aggressiveness} = x_1 \cdot \text{anger} + x_2 \cdot \text{anticipation}, \tag{1}$$

where x_1, x_2 is an arbitrary value, but $x_1 = x_2$ in these studies. It is possible to express it in this way, which is why it makes sense to set up basic emotions. The superiority of this method is that any emotion can be expressed by a mix of basic emotions. In other words,

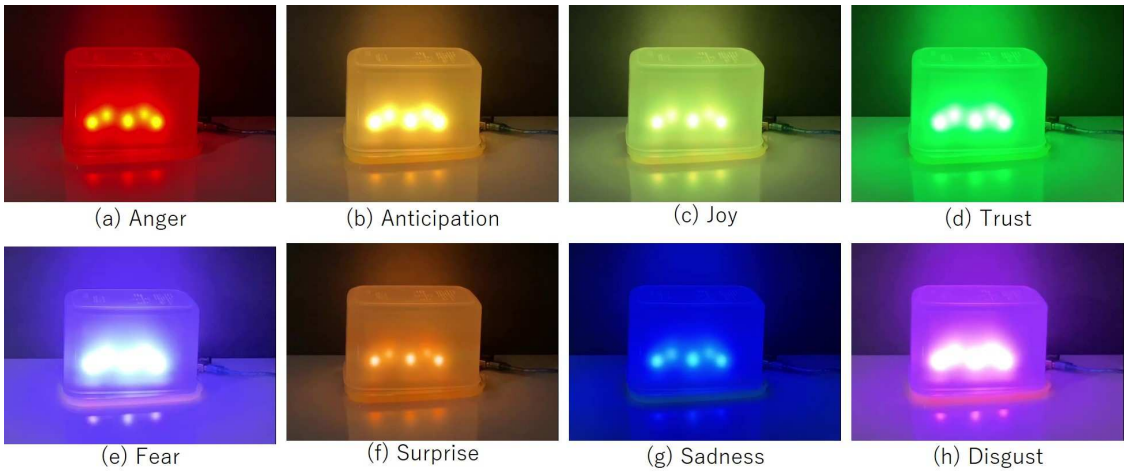

FIGURE 3. The model of basic emotions in [17]

TABLE 3. Primary dyads used in this paper

Primary dyads
anger + surprise
surprise + anticipation
anticipation + joy
joy + trust
trust + fear
fear + sadness
sadness + disgust
disgust + anger

the essential meaning of the dyad experiment is to confirm that multiple basic emotions can be used to express emotions other than the basic emotions. Therefore, we conduct the experiment without naming the dyad in this time.

3.4. **Model of dyads in previous research [18].** Based on our paper in [18], dyads have been expressed by gradation expression of two colors. The RGB values between the first and second color are varied to become a sinusoidal wave. Specifically, RED is calculated by

$$\mathrm{RED} = \frac{\mathrm{RED1} - \mathrm{RED2}}{2} \sin\left(\frac{\pi i}{180}\right) + \left(\mathrm{RED1} - \frac{\mathrm{RED1} - \mathrm{RED2}}{2}\right), \tag{2}$$

where RED1 is the red parameter of the first pattern, and RED2 is the red parameter of the second pattern. Here, "i" moves from 0 to 360. To express the period, delay WAIT [ms] before proceeding to the next i. WAIT is calculated by

$$\mathrm{WAIT} = \frac{\mathrm{PERIOD1} - \mathrm{PERIOD2}}{360}, \tag{3}$$

where PERIOD1 is the period of the first pattern, and PERIOD2 is the period of the second pattern.

However, this model has the problem that if the two colors are separated from each other, the gradation may go through various colors in the middle of the gradation. This may result in poor visibility.

3.5. **New model of dyads.** While the model described in Section 3.4 is valuable, it has a problem. The problem is that mixing two basic emotions that are far apart in color results in a lot of colors being passed through, making it difficult to express them. Therefore, we propose a new model.

The proposed model alternates between the first and second color. First, the first color is turned on and off. Next, the second color is turned on and off. This process is repeated. Specifically, RED is calculated by

$$\mathrm{RED} = \begin{cases} \dfrac{\mathrm{RED1}-255}{2}\sin\left(\dfrac{\pi i}{180}\right)+\left(\mathrm{RED1}-\dfrac{\mathrm{RED1}-255}{2}\right) & (i \le 90,\ 270 < i \le 360) \\ \dfrac{\mathrm{RED2}-255}{2}\sin\left(\dfrac{\pi i}{180}\right)+\left(\mathrm{RED2}-\dfrac{\mathrm{RED2}-255}{2}\right) & (90 < i \le 270) \end{cases}, \quad (4)$$

where RED1 is the red parameter of the first pattern, RED2 is the red parameter of the second pattern and "i" moves from 0 to 360. WAIT is the same as the old pattern and written by (3).

For example, the case of creating a pattern that expresses emotions between emotion1 and emotion2 is shown in Table 4. Emotion1 is red with a period of 500 [ms], and emotion2 is bluish-purple with a period of 1300 [ms].

Table 4. Patterns of example

Emotion	Red	Green	Blue	Period
Emotion1	0	255	255	500
Emotion2	150	0	255	1300

Figure 4 shows the parameters of the model used in the previous research (old model) in [18] and that proposed in this paper (new model). In Figure 4, the solid line shows red, the dotted line shows green, and the dashed-and-dotted line shows blue. The period is 900 [ms], which is the average of the emotion1 and emotion2 period. In the old model, emotion1 is first presented at 0 [ms]. Next, each parameter is changed gradually, and emotion2 is presented at 450 [ms]. Then, the parameters are changed to emotion1 by 900 [ms]. In this case, a reddish-purple color would be presented around 225 [ms]. In the new pattern, emotion1 is presented at 0 [ms]. Next, the light is completely turned off by 450 [ms]. In other words, all RGB parameters are set to 255. After that, emotion2 is presented by 900 [ms]. The two colors are now presented independently, without mixing in the middle.

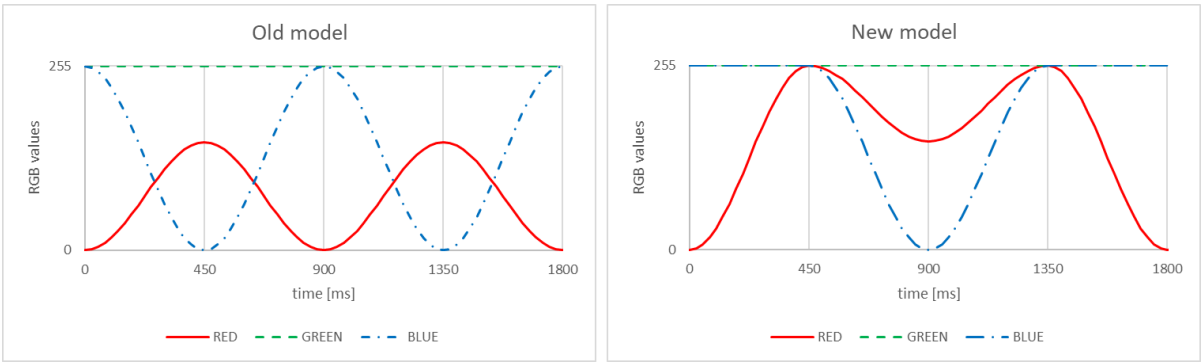

Figure 4. The model of dyad emotions

4. **Experimental Method.** In this section, we explain experimental method in order to clarify the effectiveness of the proposed model.

Participants are 15 Japanese students aged 21-24. Two experiments conduct to them and evaluate.

Experiment 1: Research using old model in [18]
Experiment 2: Research using new model

Experiment 1 uses the old model described in Section 3.4, and Experiment 2 uses the new model described in Section 3.5. In each experiment, primary dyads are presented and evaluated. These are conducted in the order of Experiment 1, and Experiment 2.

Both experiments are performed according to the following procedure.

1) First, one pattern of the patterns of primary or secondary dyad is shown. The patterns are shown at random.
2) The participants evaluate it as 8 basic emotions with five grades (5. Very-suited, 4. Suited, 3. Not-sure, 2. Not-very-suited, 1. Not-suited).
3) After they evaluate, next pattern is shown.
4) The experiment finishes when all 8 patterns are shown.

5. **Experimental Results.** In this section, experimental results are summarized.

5.1. **Experiment 1.** Experimental results for Experiment 1 are summarized in Figure 5. The abscissa of the graph is the evaluation emotions, and the ordinate represents the average of the evaluation value of presentment emotions. Namely, when the evaluation value is almost 5, many people felt that the presentment emotions expressed the evaluation emotions. Conversely, when the evaluation value is almost 1, many people feel that the presentment emotions are not expressed the evaluation emotions.

According to Figure 5, dyads other than trust + fear have higher values of the basic emotions they compose. Therefore, it seems possible that these primary dyads can be expressed. In many dyads, the most confusing emotions are those similar to the emotions that compose the presented dyad. However, fear is higher for anger + surprise and disgust + anger.

In order to analyze the results more accurately, multiple comparisons are performed. The method used in this paper is the Dunnet test, using the "multcomp" library of the R language. The Dunnett test is performed for each of the two basic emotions contained in the presenting emotion. For example, in the case of anger + surprise, the comparison is made for anger and the other seven emotions, followed by a comparison for surprise and the other seven emotions. The results are shown in Table 5. The first row lists the presented emotions and the first column lists the evaluated emotions. In Table 5, "***" is written if the p-value is smaller than 0.001, "**" if it is smaller than 0.01, and "*" if it is smaller than 0.05. In other words, the above three symbols are written when there is a significant difference. Especially, when "***" is written, no one can assume that it is expressing evaluation emotion. When "**" and "*" are written, many people can distinguish between evaluation and presentment emotions. Conversely, when * is not written, the evaluation emotion can be confused with the presentment emotion.

According to Table 5, primary dyads can be expressed except for trust + fear. Most dyads are mostly accurately expressed, but trust + fear is not expressed at all. In addition, in the fear + sadness, the value of sadness is much higher than that of fear, causing a significant difference. There are some problems, but overall, it is possible to express primary dyads in this way.

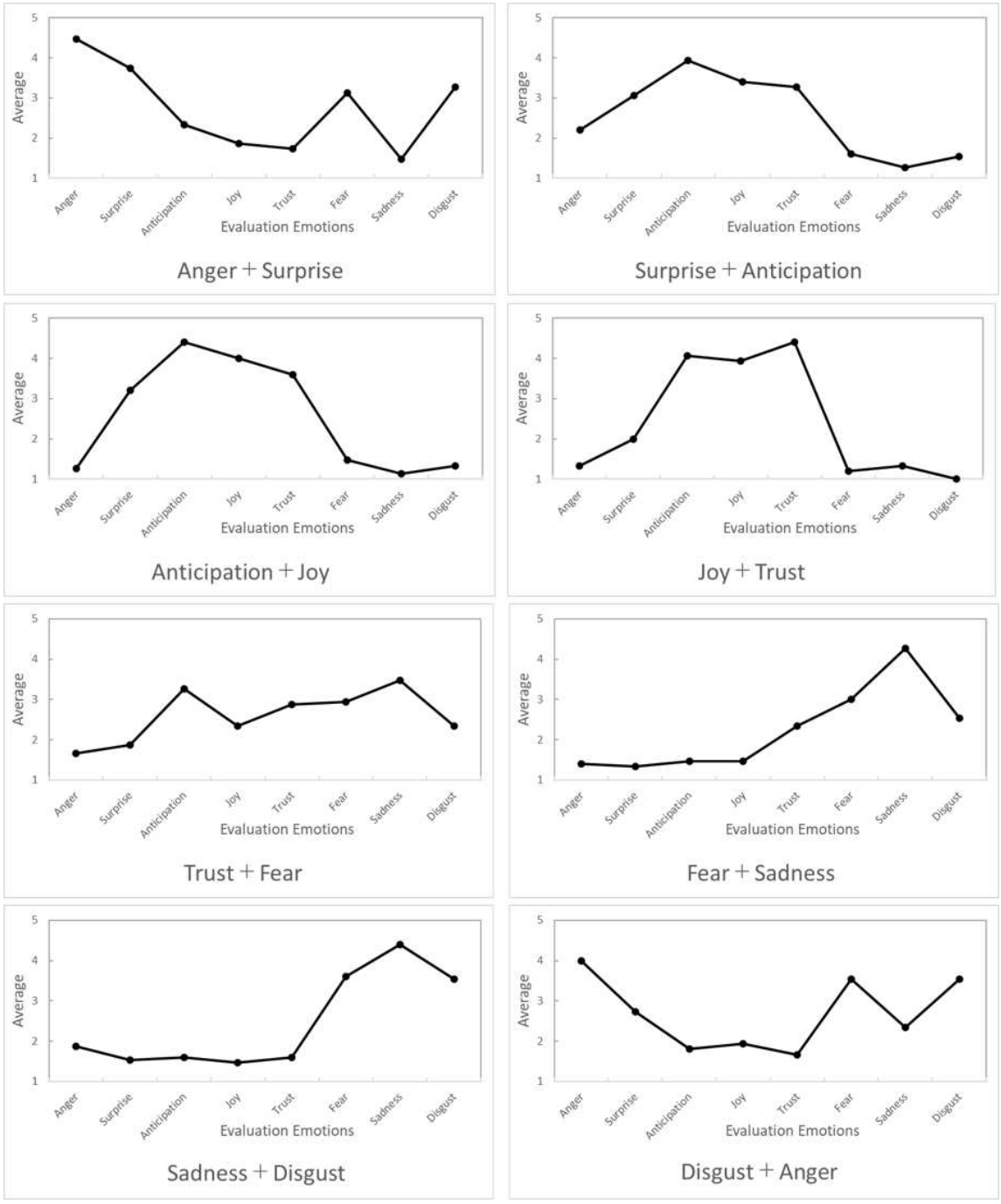

FIGURE 5. The result of Experiment 1

5.2. **Experiment 2.** Experimental results for Experiment 2 are summarized in Figure 6. The results shown by Figure 6 have almost no difference from result of Experiment 1 expressed in 5.1. The shape of the graph is almost the same as in Experiment 1. Therefore, it seems possible that primary dyads except for trust + fear can be expressed. Similarly to Experiment 1, fear is higher for anger + surprise and disgust + anger.

In the same way as Experiment 1, Dunnet test is performed. The results are summarized in Table 6. Table 6 shows that some results are better than that in Experiment 1, but in most cases there is no change. Thus, primary dyads can be expressed except for trust + fear. Regarding presenting fear + sadness, the fear value was higher in Experiment 2

TABLE 5. Results of multiple comparisons (Experiment 1)

	Evaluation emotions							
Presentation	Anger + Surprise		Surprise + Anticipation		Anticipation + Joy		Joy + Trust	
emotions	anger	surprise	surprise	anticipation	anticipation	joy	joy	trust
Anger	–			***	***	***	***	***
Surprise		–	–		**		***	***
Anticipation	***	*		–	–			
Joy	***	***				–	–	
Trust	***	***						–
Fear	*		**	***	***	***	***	***
Sadness	***	***	***	***	***	***	***	***
Disgust			***	***	***	***	***	***

Presentation	Trust + Fear		Fear + Sadness		Sadness + Disgust		Disgust + Anger	
emotions	trust	fear	fear	sadness	sadness	disgust	disgust	anger
Anger			**	***	***	***		–
Surprise			***	***	***	***		
Anticipation			**	***	***	***	**	***
Joy			**	***	***	***	**	***
Trust	–			***	***	***	**	***
Fear		–	–	*				
Sadness			*	–	–			**
Disgust				***		–	–	

Note: "***" indicates $p < 0.001$, "**" indicates $p < 0.01$, "*" indicates $p < 0.05$.

than in Experiment 1. This caused no significant difference between fear and sadness. In other words, Experiment 2 seemed to be able to express both fear and sadness better.

Overall, Experiment 2 results are slightly better than Experiment 1, but when expressing the primary dyads, the new model and the old model are almost the same.

6. **Discussion.** From the preceding section, we will discuss on the experimental results in Section 5.

According to result of Experiments 1 and 2, primary dyads except of trust + fear able to be expressed. Therefore, we find that it is possible to express the primary dyad in both the old and new patterns. Experiment 2 results are slightly better than Experiment 1, but this difference is little. Accordingly, either method may be used. However, this is an experiment conducted on Japanese, and different results may be obtained for different groups. However, while the basic emotional values that compose the presented dyad are high, the shapes of the graphs of surprise + expectation, expectation + joy, and joy + trust are similar. Therefore, they may be confused with each other. Equally, the shape of the graphs of fear + sadness and sadness + disgust are similar, so they may be confused. Thus, different models are necessary when these need to be clearly distinguished.

Regarding anger + surprise and disgust + anger, they have some problem. Fear and disgust values are high for anger + surprise, and fear values are high for disgust + anger. One possible reason for this could be the confusion between the emotions the robot wants to express and the emotions felt by the participants. In other words, participants may have felt fear or disgust when they saw a robot expressing anger or surprise, and fear when they saw a robot expressing disgust or anger. Therefore, when conducting such experiments, it is necessary to constantly remind participants to answer the emotion that the robot is expressing. For example, if the format is such that the participants answer

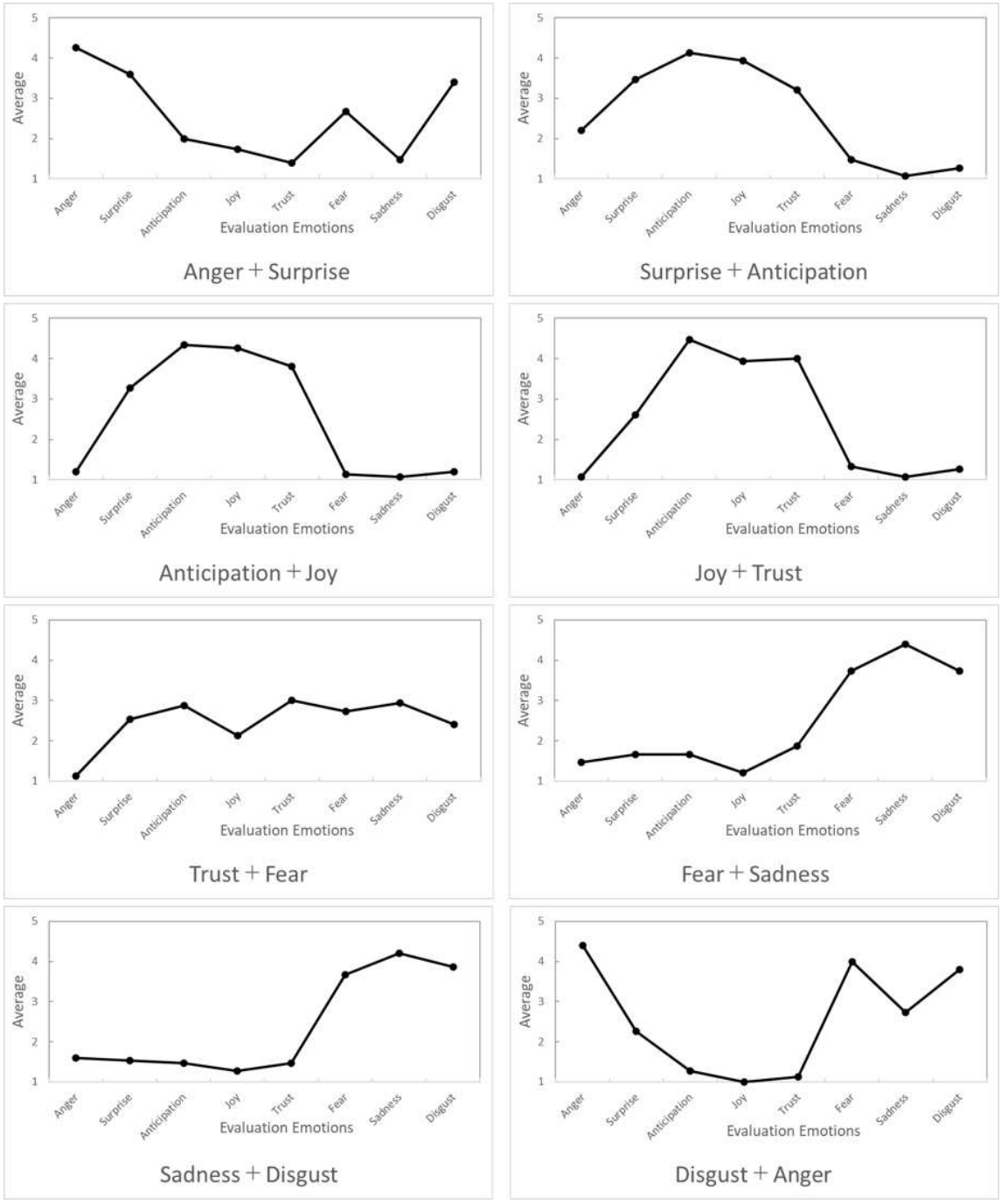

FIGURE 6. The result of Experiment 2

both the emotion expressed by the robot and the emotion felt by the participants, they may be able to answer without confusing these two emotions.

Additionally, compared with the result of previous research in [18], in this paper, the model can express anger + anticipation, anticipation + joy, joy + trust, sadness +disgust. Fear + surprise can be a little expressed. Conversely, trust + fear, surprise + sadness and disgust + anger cannot express. In this model, the dyads included surprise could be expressed little. However, by repositioning surprise between anger and anticipation, these dyads could be accurately expressed. Thus, for the Japanese, surprise is an emotion that places them between anger and anticipation. The reason may be that anger and anticipation are emotions that are closer to surprise, so it is easier to imagine the mixed

TABLE 6. Results of multiple comparisons (Experiment 2)

	Evaluation emotions							
Presentation	Anger + Surprise		Surprise + Anticipation		Anticipation + Joy		Joy + Trust	
emotions	anger	surprise	surprise	anticipation	anticipation	joy	joy	trust
Anger	–		**	***	***	***	***	***
Surprise		–	–		***	**	***	***
Anticipation	***	**		–	–			
Joy	***	**				–	–	
Trust	***	***						–
Fear	**		***	***	***	***	***	***
Sadness	***	***	***	***	***	***	***	***
Disgust			***	***	***	***	***	***

Presentation	Trust + Fear		Fear + Sadness		Sadness + Disgust		Disgust + Anger	
emotions	trust	fear	fear	sadness	sadness	disgust	disgust	anger
Anger	**	**	***	***	***	***		–
Surprise			***	***	***	***	***	***
Anticipation			***	***	***	***	***	***
Joy			***	***	***	***	***	***
Trust	–		***	***	***	***	***	***
Fear		–	–					
Sadness				–	–		*	***
Disgust						–	–	

Note: "***" indicates $p < 0.001$, "**" indicates $p < 0.01$, "*" indicates $p < 0.05$.

emotions in this experiment. Similarly, fear and sadness are not emotions that are close to surprise, and this may be because the mixed emotions were ambiguous in the previous model. In the study by Huyen et al. [19], aggressiveness (anger + anticipation), optimism (anticipation + joy), and love (joy + trust) were generally well expressed, while other dyads were less well expressed. For example, awe (fear + surprise) and disappointment (surprise + sadness) were not well expressed. This is similar to the study by Tanaka et al. [18]. Therefore, the original order of basic emotions did not express dyads including surprise very well. This result is similar to the results of the experiment with the Japanese; thus, it may be useful to move surprise even in an emotion model for the Vietnamese. In addition, we plan to study countries other than Japan and Vietnam, which may turn out to require similar operation for other than Japanese. Conversely, it may turn out that in other countries, it is better to move different emotions. As for trust + fear, it is difficult to express this dyad because neither study has been able to express it. Similarly, submission (trust + fear) is not well expressed in the experiment by Huyen et al. [19]. The reason why Disgust + anger could not be expressed in the previous research in [18] and is able to do in this study is considered to be due to the different evaluation methods. In the previous research, the method is to select five emotions that they thought applied. The result will be caused that they focused on fear and awe (fear + surprise). As discussed above, emotions including disgust and anger tend to have a high fear value. Therefore, the method used in this study is more suitable for evaluating dyads.

In a detailed look at these results, primary dyads are often confused with close basic emotions. The reason might be that emotions are not independent of each other, as Plutchik proposed. In other words, humans may not perceive a single emotion as an emotion when it is expressed. When the participants looked at yellow and orange, they may have felt that the expressed emotion could be described as anticipation, and as

joy, for example, seeing a dog waiting for food, which could be described as anticipation or joy. However, the fact that "the dog wants to be fed" is perceived in either case. Therefore, if the emotions are close, there is no problem even if they are confused. Surprise + anticipation is confused with joy and trust, anticipation + joy is confused with trust, and joy + trust is confused with anticipation. Therefore, surprise, anticipation, joy and trust are confused with each other. Similarly, fear + sadness is confused with disgust, and sadness + disgust is confused with fear, so fear, sadness and disgust are confused with each other. Conversely, trust and fear are not confused with each other. This seems to be the reason why trust + fear could not be expressed in the research. In other words, trust and fear seems to be far apart.

There are several problems with the basic emotional circle by Plutchik [12]. For example, there is no logical basis for the order of basic emotions. For this reason, we place surprise between anger and anticipation. Other problems are that each emotion is not always evenly aligned. Moreover, assuming trust is positioned between joy and fear, the mixture of joy and fear is guilt according to him, not trust. Perhaps these vectors are not on a two-dimensional plane. However, it is not certain where they are located. For this reason, this model has some problems.

Altogether, there seems to be more distance between trust and fear than between other emotions. This distance makes trust and fear less confusing and mixed dyads cannot be accurately communicated. Thus, it proved difficult to use Plutchik's emotion model as it is for the basis of models of emotional expression. To make a better model, it would be necessary to re-order them according to the target group, and to increase or decrease the number of emotion types to equalize their width. All primary dyads could be expressed in these two models if this problem could be solved. One way to solve this problem is to use Russell's emotion model [13] together. Russell's model of emotion represents each emotion by the two axes of pleasure-misery and arousal-sleepiness. Applying an attempt to integrating this model with Plutchik's model may help to solve this problem.

Finally, this experiment was performed with a small number of people and is not a universal model. Therefore, it is not necessarily correct to place surprise between anger and expectation. However, the possibility was obtained that a better model of emotional expression could be created by re-ordering the basic emotions, which are easily confused, so that they are next to each other. Therefore, experiments on a larger scale may help to find a better order.

In summary, three expressions are proved in this paper.

1) The first is that both of the two models used in this paper can express primary dyads. Primary dyads except for trust + fear could be expressed using either model. However, surprise + expectation, expectation + joy, and joy + trust can be confused with each other. Similarly, fear + sadness and sadness + disgust can be confused.
2) The second expression is order of basic emotions. Comparing the results of the previous research [18] with the results of this experiment, there was a significant difference in the results of the dyad including surprise. Thus, for the Japanese, surprise is an emotion that places them between anger and anticipation. Moreover, fear and sadness should be switched in position.
3) Finally, the participants may confuse the emotions expressed by the robot with the emotions they felt. This seems to have resulted in high values of fear and disgust for anger + surprise, and high values of fear for disgust + anger. Therefore, when conducting such experiments, it is necessary to constantly remind participants to answer the emotion that the robot is expressing.

7. **Conclusion.** In this paper, we have proposed a new model that expresses the primary dyad by repositioning surprise between anger and anticipation for Japanese. We have presented two models to express primary dyads. The results show that both models can express dyads except for trust + fear. A new finding from these results is that Plutchik's emotional model has some problems. The problems are the order of the emotions and the width between them. For the Japanese, the final order is as follows: anger, surprise, anticipation, joy, trust, sadness, fear, and disgust. In addition, there may be more distance between trust and sadness than between other emotions. On this basis, it will be possible to create a better emotional model for the Japanese.

In this research, it was found that the order of the basic emotions can be interchanged. This result will be important for the construction of emotion models. For example, if we wanted to express various emotions by mixing fewer than eight basic emotions, a change in the position of surprise would not only change the mix for expressing surprise, but also the type of basic emotion to be chosen. Moreover, it may also impact other methods to express emotions other than color. For example, similar emotions might be expressed through similar motions.

In addition, this research shows the possibility that using two colors is usable as one of the methods of expressing primary dyads for the robots. In this way, robots of any shape could express more emotions and become more friendly. The results of this research could be used to create robots that are more human-friendly at a lower cost. As a result, communication robots would be able to provide better care to more depressed patients and others. In addition, the results could be used to create models that target people in other countries and that express all kinds of emotions.

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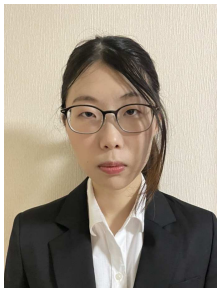

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