Development of a facial expression training system using muscle potential measurement and image processing

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Abstract. Communication in daily life deepens relationships among human beings. Such communication is conducted not only verbally but also by using physical cues such as facial expressions. People such as senior citizens and others who have acquired physical limitations as well as those with congenital challenges often face resulting deficits in communication that in turn impacts their relationship with others. These individuals present a clear need for rehabilitation such as that provided by speech–language–hearing therapists (ST) active in the medical field, who can offer guidance and training with respect to facial expressions, vocalization, and speech. Often, the demand for such therapy is greater than the supply of therapists. In addition, the therapy itself can be highly subjective. Therefore, in this study, we focused on developing a facial expression training system to support ST. Our system quantifies training by means of muscle potential measurement and image processing.

Keywords: facial expression, speech–language–hearing therapists, facial action unit, electromyography

1. INTRODUCTION

Communicating with others is socially important. Human communication comprises verbal and non-verbal communication. Non-verbal communication includes use of gestures and eye and body movements, which are used in all cultures.

Mehrabian reported on the role of communication channels for conveying emotions that demonstrate agreement or disagreement with others. In humans, there are differences between verbal and non-verbal communication of emotions. Facial expressions convey 55% of information; vocal expression conveys 38% and verbal expression conveys 7% of information (A. Mehrabian, 1981).

Humans are also known to empathize with each other, which is called emotion propagation behavior. An example of this is the expression of a happy face when someone else is talking; the human recipient tends to have happy feelings and a similar facial expression as others. It is considered extremely important for humans to empathize with others (H. Ichikawa et al., 2004).

In Japan, rehabilitation training is important to achieve smooth communication.

For example, language auditory training is needed for people with disabilities in hearing and vocal organs, due to language delay from stroke, aphasia, or disease, as well as for people who have disabilities in language due to accident. Against this backdrop, to attain previous vocalization abilities, professional speech training from a medically trained speech–language–hearing therapist (ST) is necessary.

The leadership of the ST, the improvement of the communication failure is also included, early becomes correspondence has been desired in the nursing field. However, currently, there is an insufficient number of trained ST, and because of the differences in skill and experience among ST, a system training system to improve ST skills, as well as increased support of ST, is needed (Japan speech-language-hearing therapists Association official website, K. Yamazaki, 2000).

Therefore, we aim to provide communication training with respect to facial expression by developing a computer-assisted support system. We hope to support ST training using a computer system, as well as reduce the burden on the ST; this aims to ensure the voluntary training time of the trainee.

In addition, we aim to provide highly diagnostic information of objectivity by quantifying the data on the training results in the computer.

In this study, a prototype system of facial expression training creates a training menu to richly express facial expressions of happy and angry. The trainee training results (facial expressions and evaluation results) are presented on-screen, with feedback and the easy-to-understand information, and the training results are saved in the database.

In this paper, we report on the background and preliminary experiments of the developed system.

2. FACIAL EXPRESSIONS

In this chapter, we discuss the six basic facial expressions, the action unit (AU), and facial muscles. Furthermore, we describe the muscle potential measurement method.

2.1 Six basic facial expressions

When people from different cultures are communicating, their body language may have different meanings, and information may be misunderstood. People express emotions differently among cultures.

However, Ekman (P. Ekman et al., 1987) reported that ix emotions (happy, surprise, angry, sadness, disgust, fear) can be recognized on facial expressions from a photograph of a face. These facial expressions have been determined to have a universal commonality that goes beyond nationality and culture.

2.2 Action unit

Ekman and colleagues have proposed the AU as the smallest unit of facial expression operating in the Facial Action Coding System (FACS) [6]. The AU provides a detailed breakdown of how facial expressions are created. There are 62 AU in total; for example “raise the inside of the eyebrow” is AU1. There are AU44 units (AU01–46) related to facial expression, AU8 units (AU51–58) on the neck, AU6 units (AU61–66) on the eyeball and exception 4 units (AU70–72, 80). Facial expressions can be represented by a combination of AU as demonstrated in Table 2-1.

Table 2-1: Combination example of the AU of the six basic emotions

	The movement of the AU
Happiness	6+11+12 or 13
Surprise	1+2+5
Anger	4+7+17+23
Sorrow	1+4+15 or 17
Aversion	4+6+9+10+17+22
Fear	1+5+25 or 26

2.3 Mimic muscle

In this chapter, “facial muscle” is used as the general name for muscles in the face. Contraction of these muscles changes the facial expression, and each of the facial muscles play a role. Skillful movements of the facial muscles create myriad facial expressions. Ekman’s AU are based on the contraction of the facial muscles. Therefore, to make a specific facial expression, it is necessary to contract the specific expression muscles. The name and location of each facial muscle is shown in Figure 2-1.

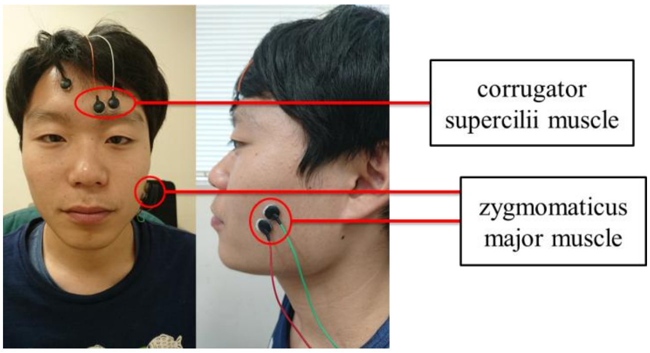

Figure 2-1: Muscles used in the experiments

As shown in Figure 2-1, the human face has a large number of facial muscles. The combination of these muscle contractions results in complex facial expressions.

2.4 Mimic muscle potential measuring method

In this section, surface muscle potential measurement, facial muscles potential measurement, muscle potential measurement method, electrode, and electromyography (EMG) analysis method are described.

2.4.1 EMG measurement

Muscle fibers receive electrical signals from the brain or spinal cord; the potential change occurs when the muscle performs contraction. This potential change is referred to as a muscle potential. Potential is measured in subcutaneous muscle by electrodes attached to the surface skin, when the muscle is activated. The measurement of the potential change is referred to as EMG. Instead, of a surface electrode, muscle potential may be measured using a needle electrode, which is referred to as needle muscle potential measuring (T. Kizuka et al., 2006).

2.4.2 Mimic muscle potential measurement

Facial expression is created by the activity of facial (mimic) muscles. Like other muscles, muscle potential is generated at the time of activity. To measure muscle potential, the measurement electrode is applied to the skin surface of the facial muscles. The presence or absence of activity of the facial muscles enables the muscle strength to be measured.

2.4.3 Muscle potential measurement method

Myoelectric potential generated by the activity of the muscle is said to be attenuated to 1/1000 or less to reach the measurement electrode on the skin surface, and the measured potentials range from μV to mV. These signals are uploaded to a computer for analysis and amplified after the voltage value has been converted into a digital signal by the A/D converter.

2.4.4 Electrode

EMG signals are measured by a bipolar differential derivation [8]. Electrodes are applied to the skin in the following procedure:

(1) Mark pasting position
(2) Degrease with alcohol on cotton
(3) Apply a skin treatment agent to remove dead skin cells
(4) Remove excess skin treatment agent
(5) Attach the electrode with the electrode paste
(6) Insure the electrode is fixed in place with surgical tape

With this method, it is possible to perform a stable muscle potential measurement that reduces the skin impedance.

2.4.5 EMG analysis method

Direct observation of the original EMG waveform by myoelectric potential measurement is referred to as a qualitative analysis method. The EMG in Figure 2-2 is an example.

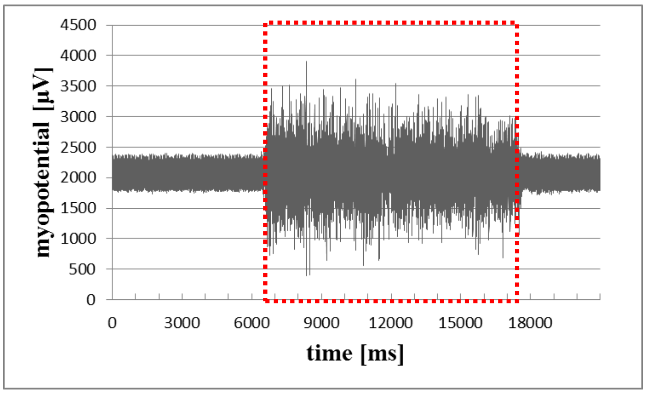

Figure 2-2: Electromyogram

The zygomaticus major muscle activity was observed when a subject exhibited a happiness facial expression (portion enveloped with dotted line in Figure 2-2).

Furthermore, it is possible to determine the average amplitude by obtaining the average of the amplitude of the myoelectric potential.

However, the magnitude of myoelectric potentials obtained by this type of measurement varies widely among muscles and individuals, and is susceptible to the electrode adhering paste. The impedance of the subcutaneous fat and skin is different. Therefore, it is necessary to normalize the signal to compare the magnitude of the activity of the muscle among different muscles or subjects.

3. EXPERIMENT 1: MUSCLE POTENTIAL SYSTEM BY THE MEASUREMENT

I present a facial expression training system of “angry” and “happy” using muscle potential measurement.

3.1 Overview of the system

A configuration diagram of the developed system is shown in Figure 3-1. The system consists of an analysis PC, a teacher PC, an EMG measuring device, and a vibration motor.

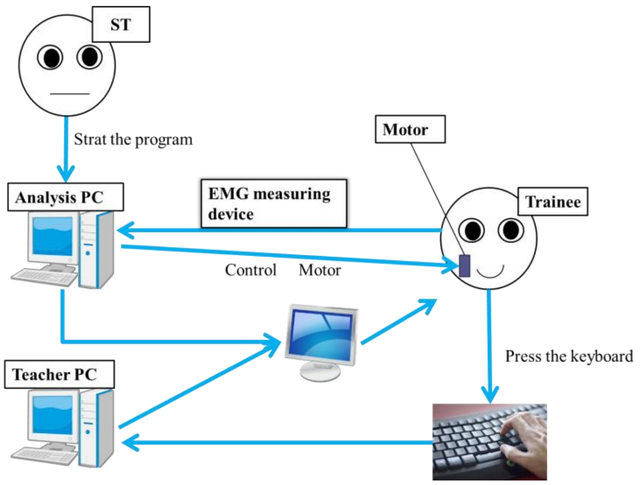

Figure 3-1: Structure of the system

The system is started by switching on the teacher PC equipped with a motor, and applying the electrode to the face of the trainee, in accordance with trainee indication of teacher PC in a state in which to start the analysis PC and EMG measuring device

3.2 Experimental apparatus and measurement points

3.2.1 Experimental conditions

- Electrode material: Ag/AgCl, Nihon Kohden Corp., Japan, NE-113A
- electrode geometry: discs
- Size: 7 mm in diameter
- Used paste, alcohol applied to cleanse skin, skin abrasion
- Inter-electrode distance: 13 mm apart
- Converter/amplifier: Biotop mini, East Medic Corp., Japan
- Sampling rate: 1000 Hz
- AD-card: 16 ch, 16 bits
- EMG band pass filter: 5.3–500 Hz

3.2.2 Measurement points

The system performs myoelectric potential measuring of the zygomatic major, corrugator, and orbicular muscles.

3.3 EMG analysis method

Each mimic muscle has a threshold to determine whether there is a reaction. It was considered that there was a response when the value of the potential exceeded the threshold value by 1000 or more. The threshold is used as the mean and standard deviation (SD) of the EMG during a 5 s rest period, and is obtained from the following equation:

$$\text{Threshold} = \text{average} + 2.5\text{SD}$$

The flow of the EMG analysis program is explained:

(1) Measurement begins when you receive the signal of the rest recording start from the teacher PC.
(2) EMG at rest to determine the 5 s measured threshold.
(3) Continue to measure EMG; a reaction is considered to be present if the value exceeds the threshold by 1000 or more (2).

We use the % maximum voluntary contraction (%MVC) measures of the muscle of the subject. Muscle activity is measured by the percentage of myoelectric potential measured for the value of the myoelectric potential is a method to examine how many % activities of the maximum.

4. EXPERIMENT 1 OF THE EVALUATION EXPERIMENT

This time, facial expressions training and expression tuning training was conducted. The trainers comprised 10 people.

The experiment is to detect the facial expression using the developed training system. And the actual training to the trainee was evaluated.

4.1 Overview of the experiment

This training system was conducted for facial expression training and facial expression tuning training of “angry” and “happy.”

The flow of the training is shown in Figure 4-1.

(1) Carry out the facial expressions training of happy.
(2) Carry out the facial expressions training of angry.
(3) Carry out the facial expressions of happy tuning training.
(4) Carry out facial expressions tuning training of angry.
(5) Repeat steps 1–4 three times.

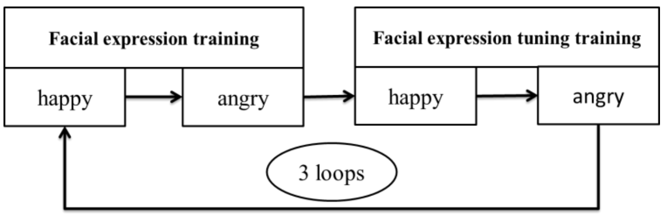

Figure 4-1: Flow of training

4.2 The elements of facial expression training

Performing training for correctly making a facial expression. The training details are shown in Figure 4-2.

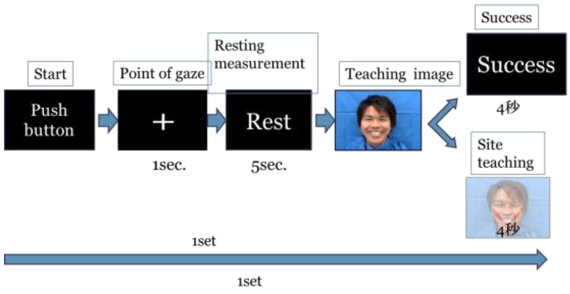

Figure 4-2: The contents of facial expression training

The training procedure is described below.

(1) Trainee initiates training start by pressing the button.
(2) Gazes at indicated point for 1 s.
(3) The muscle potential at rest is measured for 5 s.
(4) View the teaching image. Trainee to create the same facial expression and image.
(5) Measurement of the muscle potential of expression on the face.
(6) Training is successful when it does not exceed the threshold. In the opposite case, the teaching image is viewed for 4 s. The motor mounted on the teaching muscle site is vibrated for 2 s.

4.3 The elements of facial expression tuning training

Carry out the training of facial expression tuning. The training procedure is shown in Figure 4-3.

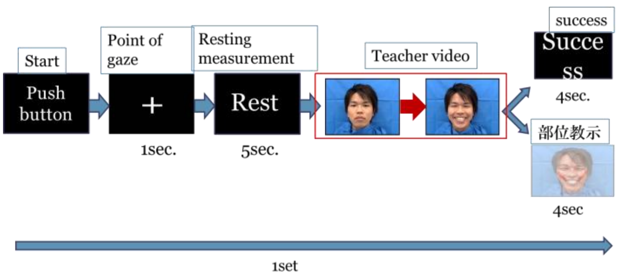

Figure 4-3: The elements of facial expression tuning training

The procedure of the training is explained as follows:

(1) Trainee initiates training start by pressing the button.
(2) Gazes at indicated point for 1 s.
(3) The muscle potential at rest is measured for 5 s.
(4) The teaching video is reproduced for 15 s.
(5) Training is successful when it does not exceed the threshold. In the opposite case, the teaching image is viewed for 4 s. The motor mounted on the teaching muscle site is vibrated for 2 s.

4.4 Trainee

Of the ten trainee students, nine were male and one was female. The trainees can correctly create the indicated facial expression.

4.5 Results of experiment 1

4.5.1 Result of facial expression training

Figure 4-4 shows the results in %MVC. Figure 4-4 is a representation of the average %MVC if they had changed what percent of mimic muscle of the trainee. In addition, average response time and the standard deviation of training 1 is shown in Figure 4-5.

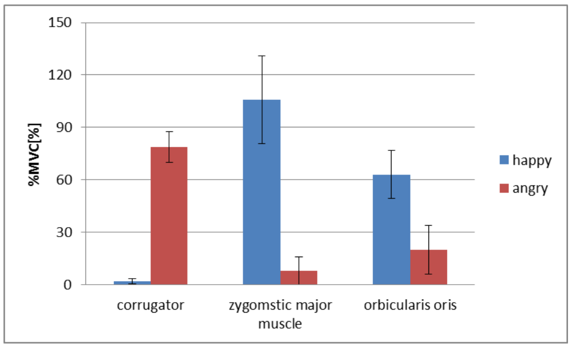

Figure 4-4: %MVC of the average result of facial expression training

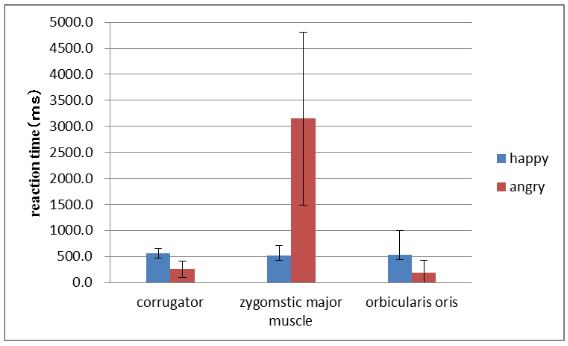

Figure 4-5: The average reaction time and the standard deviation of the facial expression training

As seen in Figure 4-4, when making a facial expression of “happy,” the zygomatic major muscle, which wrinkles the eyebrow muscles, has stronger activity than during the “angry” facial expression. In addition, the muscle activity of the orbicular muscle was confirmed to be higher during “happy” than “angry” emotions.

4.5.2 Result of facial expression tuning training

%MVC of the results is shown in Figure 4-6. Figure 4-6 is a representation of the average percent change of mimic muscle of the trainees. In addition, the average response time and the standard deviation of training 1 are shown in Figure 4-7.

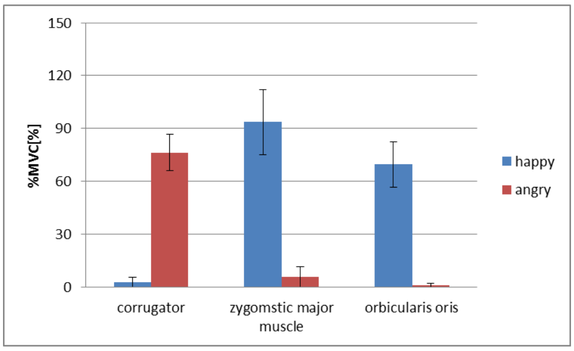

Figure 4-6: %MVC of the average result of facial expression tuning training

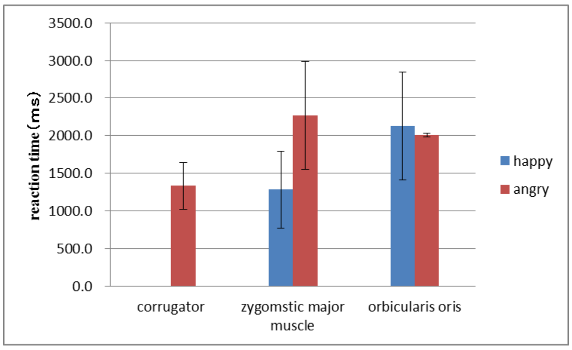

Figure 4-7: The average reaction time and the standard deviation of the facial expression training

As seen in Figure 4-5, when making a facial expression of "happy," the zygomatic major muscle, which wrinkles the eyebrow muscles, has stronger activity than during the "angry" facial expression. In addition, the muscle activity of the orbicular muscle was confirmed to be higher during "happy" than "angry" emotions. This is the same result as the facial expressions training.

5. EXPERIMENT 2: TRAINING SYSTEM BY IMAGE PROCESSING

This section details the facial expression training system by image processing of "angry" and "happy."

5.1 Overview of the system

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A configuration diagram of the system is shown in Figure 5-1. The system consists of a camera and an analysis PC.

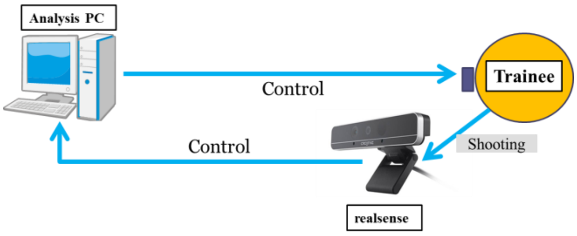

Figure 5-1: Structure of the system

5.2 Experimental apparatus and measurement method

5.2.1 Experimental device

Camera: Real Sense F200.

5.2.2Measurement points

The location to be measured was determined according to Ekman's AU. For "happy," looking at whether the mouth or is moving a zygomatic major muscle is open. For "angry," looking at whether the eyebrow is down.

5.3 Method of image processing

Use function is indicated by how much each part of the face has changed.

The flow of the program is as follows:

(1) It reads the image captured by the camera on the analysis PC.
(2) Identification of the face from the read image.
(3) See the change indexing where to measure this time from the identified face.

5.4 Preliminary experiment of Experiment 2

Preliminary facial expressions training was undertaken by two trainees. The experiment was tried to see whether the training system recognizes facial expressions of the trainees.

5.5 The contents of the experimental

The system was evaluated to determine whether it performed correctly.

This time, training related to facial expressions of "happy" and "angry" was conducted. The flow of the training is shown in Figure 5-2.

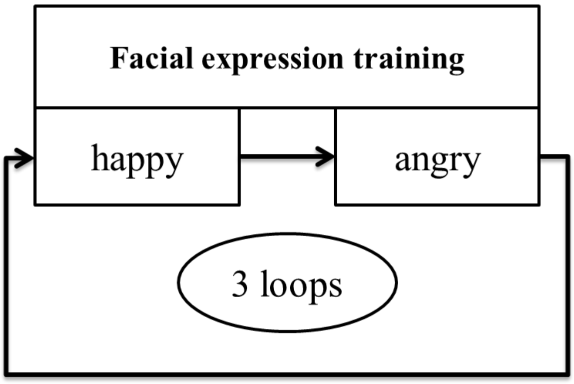

Figure 5-2: Flow of training

5.6 Result of the experiment

Using image processing, in most cases, it was possible to determine the facial expression. However, the eyebrows during the facial expression of "angry" as shown in experimental Fig. 5-3, there was a time when you do not it can be determined that the angry does not react.

Figure 5-3: Experimental image

In addition, movement of the mouth and zygomatic major muscle during the facial expression of "happy," but there was a case it is determined that the expression of "happy," without laughing eyes.

5.7 Discussion of Experiment 2

The determination of the expression "happy" is mainly detected by a change in the corner of the mouth, and, because the mouth is moving, the change of the zygomatic major muscle is recognized even without laughing eyes; incorporation of the facial expression of "happy" eye movements is planned in the future.

To detect the expression of "angry," it is necessary to make firm can trace the movement of the eyebrows.

Overall now it must be made allow the determination that a firm performs strict AU and determination to use because it does not can be done securely determined since no use only one or two AU.

6. CONCLUSION

In the facial expression training system shown in Experiment 1, during the training, EMG measurements are obtained of facial muscles during facial muscle activity and the results are fed back through vibrations from a motor that was affixed to the face. For the trainee, this feedback information makes it possible to grasp the position of the facial muscles to be trained; also, it becomes possible to know the activity level of the facial muscles. This feedback training is considered to become intuitively understandable.

The facial expression training system shown in Experiment 2 was based on image processing activities of facial expression muscles. Because the appearance of facial expression is very important, it is considered possible to set an objective indicator. Furthermore, it has become possible to record each of the training results with video.

In the future, we will provide the system to the trainees and ST. By advancing the verification experiment, we hope to improve the evaluation of facial expression using this system. In addition, we wish to implement the knowledge provided by more ST to the training menu.

ACKNOWLEDGMENTS

This work was supported by KAKENHI (Grant-in-Aid for Scientific Research (C): 15K01752, 15K04553), and SCOPE: 162305008.

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