# Electromyography Focused on Passiveness and Activeness in Embodied Interaction: Toward a Novel Interface for Co-creating Expressive Body Movement

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**Abstract.** In expressive body movement created by one person and his/her partner, a sense of nonseparation, as if one's body and his/her partner's body are united, is experienced. For such a relationship between the two, a process to feel passiveness and activeness physically is important. The objective of this study is to capture passiveness and activeness in bodily interaction. We focused on myoelectric (ME) potential from which time of generation and amplitude differ in voluntary and reaction movements. A measurement system was developed using ME potential in bodily interaction. This technique was validated by our data.

**Keywords:** embodied interaction, expressive body movement, passiveness and activeness, surface EMG.

## 1 Introduction

Since the embodiment plays a very important role for the communication, both participants' bodies need to be on the common actual field [1]. Through such embodied interactions, various expressions are co-created while each decides his/her own role extemporaneously. For example, in extemporaneous bodily expression activities performed by two or more persons as typified by "contact improvisation [2]", performers create one bodily expression with a new image while reading their partner's weight or movement and also their mind through physical contact. If the boundary between one's own body and the others' body is opened, a nonseparable relationship such as a sense of unity between oneself and others sometimes realized by both.

Nishi, who is one of authors, has investigated phenomenologically the above-mentioned relationship created by interactive communication through bodies [3-4]. This was based on her experience in the field of bodily expression activity with people of different age, sex, or bodily features. An outline of the process is described below.

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In bodily expression activity with others who have a physical difference, somesthetic difference as well as visual difference is vividly realized. In the wake of the sense of gap, consciousness accepting a partner's motion and feeling are mutually strengthened. Active movement for sustaining bodily expression and spontaneous response to others' activity are generated continuously. "Sympathetic body awareness," synchronizing one's own and others' mind and body, is developed, and the person's and partner's minds are united.

On the basis of the study mentioned above, in the process of developing a nonseparable relationship between oneself and others, sympathetic body awareness generated from passiveness and activeness has a significant role. If we capture objectively how the passive–active state changes dynamically in each other and how sympathetic body awareness is generated, the generation mechanism of the nonseparable relationship may be elucidated. This knowledge may contribute to the interface technology that supports co-creating bodily expression.

We attempted to measure the passive–active state in mutual bodies. Specifically paying attention to myoelectric (ME) potential, from which time of generating timing and amplitude differ in voluntary and reaction movements, we proposed a ME potential measurement system in bodily interaction. Based on the measurements using this system, this technique was validated by employing ME potential.

## 2 Measurement Method Focused on ME

Taking contact improvisation as a typical example of creation of each other's expression by communication through embodied interaction, the passive–active state was measured during this period. We initially selected bodily expression in which two people touch each other's palm, and the united palm was considered to be a measurement object. Movement of the palm is limited to one DOF (back and forth) to simplify the measurement object. For limiting DOF, a slidable board is used, as shown in Fig. 1. Two subjects hold this board between their palms and push or pull it.

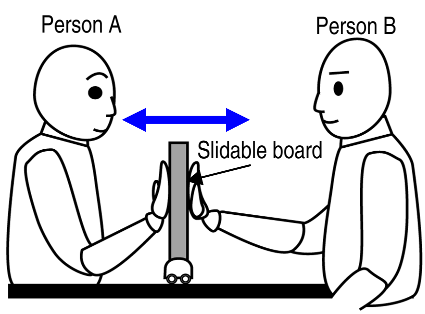


**Fig. 1.** Slidable-board-mediated bodily interaction

The measurement method and its principle are described. Whether it is active movement or passive movement cannot be distinguished only from information on movement of their bodies (e.g., position, speed, acceleration). For example, when one side moves the hand to a previous position, it is difficult to judge if one pushed the hand actively or if it is pulled by one's partner. We therefore focused on the force generated in each body. We proposed a method utilizing ME potential, which can measure generating force simply. It has been noted that the ME potential in voluntary movement increases several tens of milliseconds earlier than the start of body movement. This phenomenon is called "electro mechanical delay" (EMD). When movement is in response to one's partner, it is expected that force is reactive to a movement. If these expectations are correct, it is believed that increase in ME potential of active movement precedes body movement, and increase in ME potential of passive movement lag body movement. It is also believed that the amplitude of force generated by active movement is larger than that generated by passive movement, and ME potential also increases according to it.

We attempted to judge and measure passive–active status based on the observations mentioned above. Although research on brain activity in passive movement with respect to restriction of body has been conducted [5-6], applying it to the present study, which deals with communication in bodily expression, is difficult.

## 3 Development of Measurement System

An overview of the developed system is shown in Fig. 2.

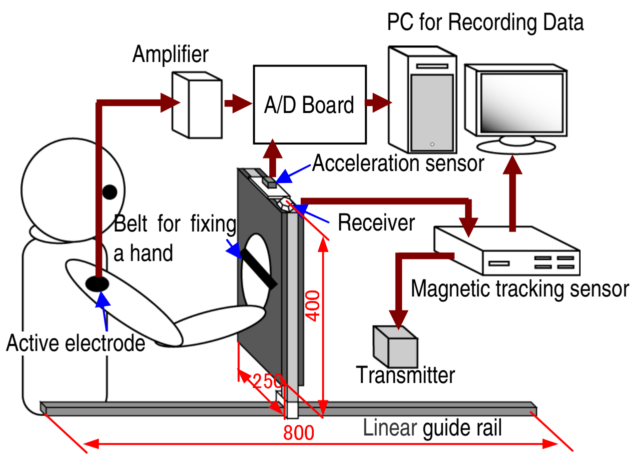


**Fig. 2.** Bodily movement and EMG measurement system

This system comprises a slidable board only in the front–back direction, an acceleration sensor, a magnetic tracking sensor, active electrodes for surface EMG and an amplifier, an A/D board, and a personal computer for data recording. In consideration of acceleration measurement, the slidable board must deaden the vibrations and must be highly stiff. The aluminum frame was therefore fixed to an iron linear guide (length, 800 ms) with screws and an acrylic board (400 × 250), which was pushed or pulled by the subject's hand while fixed to this aluminum frame.

A belt was attached for fixing the palm to the acrylic board. The EMG measurement system needed >1 kHz sampling frequency due to the properties of the ME signal. Activity electrodes (4 ch) attached to an arm and amplifiers (Delsys, Bagnoli-2) were connected to the PC using an AD board (Interface, PCI-3135). Differential amplification (80 dB of profits) was possible using a reference electrode for this amplifier. To acquire ME signals and the signal from the acceleration sensor synchronously, these signals were recorded from the same A/D board. Data logging can be carried out in about 1800 Hz when ME signals (4 ch) and the acceleration sensor's signal are measured simultaneously.

In addition to the above, the position of a slidable board was also measured using a magnetic tracking sensor. Because positional data from the magnetic tracking sensor is transmitted using RS-232C, a time gap between positional data and ME potential signals or acceleration data arises due to the difference in the transfer rate. To compensate for the time gap, the time gaps of acquisition by the A/D board and magnetic tracking sensor were measured beforehand, and compensation was applied using them (an A/D board acquires about 19 ms earlier than the magnetic tracking sensor.).

## 4 Measurement of ME Potential during Embodied Interaction

### 4.1 Embodied Interaction with Fixing the Relationship between Passive and Active

The difference between the ME potential of passive movement and the ME potential of active movement has been confirmed. Either subject was directed to move the slidable board always actively, or the other subject was directed to move it always passively. Subjects repeatedly pushed and pulled the slidable board for 30 s three times in total while changing the speed of movement. In addition, an active electrode was put on the center of the deltoid muscle (which is used to pull the board) and another was put by the armpit in the pectoralis major muscle (which is used to push the board) using double-faced tape (Fig. 3). A reference electrode for differential amplification was placed on the left elbow (which has few muscles). A situation of an experiment is shown in a Fig. 4.

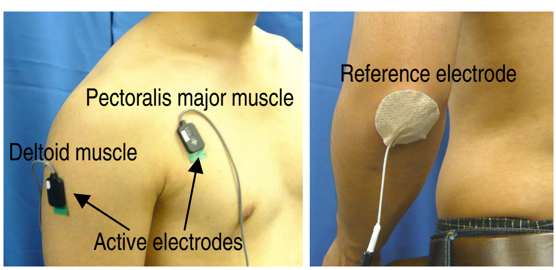


**Fig. 3.** Pasting Positions of active and reference electrodes

A part of the measured data is shown in Fig. 5. To clarify the rising point of ME potential and acceleration, original waveforms were filtered by a one-order Butterworth low-pass filter (time constant, 0.01 s). ME potentials changed according to the change in position and acceleration of the slidable board (Fig. 5). Increase in ME potential of the active side tended to occur earlier than that of the passive side. Repeated pushing and pulling by a certain subject in 30 s enabled the mean time lag to be ascertained. The rising time of ME potential minus that of acceleration between increase in ME potential and increase in acceleration for 30 s was computed (Table 1). The rising time of ME potential of active movements I was about 170 ms earlier than that of passive movements. When the slidable board was moved forward, an EMD was confirmed but, if it was moved backward, EMD was not confirmed. This is partly because the slidable board may have started to move using the arm or waist before activation of the deltoid muscle.

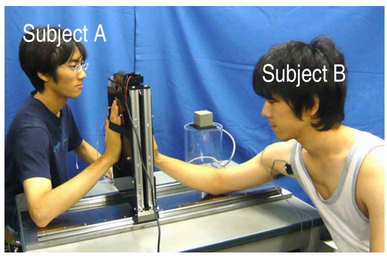


**Fig. 4.** A situation of an expriment during slidable-board-mediated bodily interaction

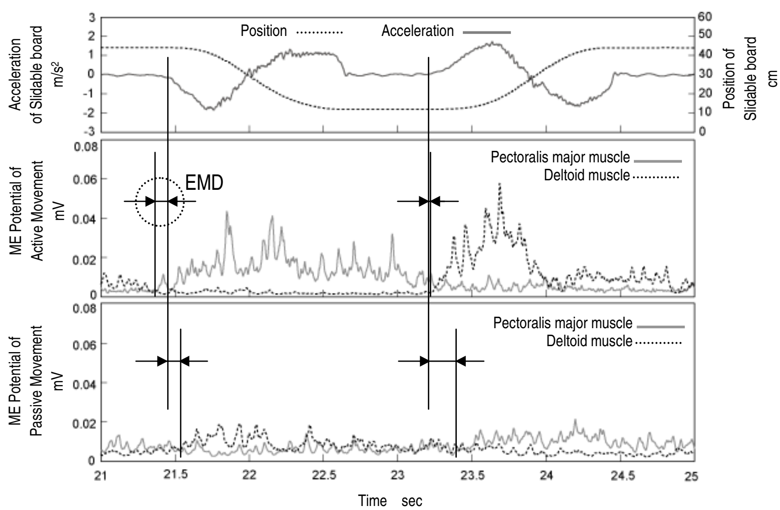


**Fig. 5.** A part of result of measurement during Embodied Interaction with fixing relationship between passive and active

**Table 1.** Time lags between rising of ME potential and rising of acceleration

| Active movement | | Passive movement | |
|---|---|---|---|
| Moving forward sec | Moving Backward sec | Moving forward sec | Moving Backward sec |
| -0.06±0.03 | 0.125±0.06 | 0.18±0.07 | 0.23±0.06 |
| **Average** sec | | **Average** sec | |
| 0.04±0.11 | | 0.21±0.07 | |

Amplitudes of the ME potential of active and passive movements were compared. In general, it is thought that the ME potential increases proportionally to the amplitude of generated power in its muscle. If a large force is applied to a slidable board, the acceleration of the board also becomes large. As shown in Fig. 6, the peak value of the acceleration of one operation was plotted on the horizontal axis, and the amplitude of the peak of ME potential at the time was plotted on the vertical axis. The ME potential generated by active movement was larger than that generated by passive movement when the slidable board was moving at a certain acceleration. This suggested that distinguishing active movement from passive movement was possible by determining increase in ME potential.

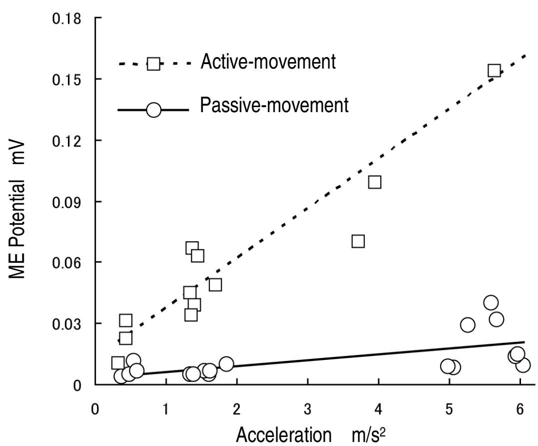


**Fig. 6.** Relationship between ME potential of passive/active movement and acceleration

## 4.2 Embodied Interaction without Fixing the Relationship between Passive and Active

When a subject interacted with his partner freely without deciding their passive–active state, we attempted to distinguish active movement from passive movement using the waveform of the ME potential based on the result of Section 4.1. Two subjects moved the slidable board freely for 1 min and their ME potentials were measured. To investigate how much their passive–active state was judged by a ME potential comprising a subjective sense of "I lead" or "I am led," subjects reported it in real time during the experiment by pushing buttons assigned "I lead" or "I am led," respectively.

Figure 7 shows the waveforms of the position and acceleration of the slidable board, and the ME potentials of the pectoralis major muscle and deltoid muscle. The motion of pushing and pulling changed continuously, as noted from the waveform of the position of the slidable board. The pectoralis major muscle and deltoid muscle are often both activated, so increase in ME potential was not clear at the start of moving. We therefore tried to judge the passive–active state by the amplitude of ME potential. The peak ME potential during one movement was assumed to be a representative value of ME potential according to the movement. The mean of a few dozen representative values obtained during the experiment for 1 min was calculated. When the peak ME potential was larger than this mean value, it was judged to be active movement, and when it was smaller, it was judged to be passive movement. Figure 8 shows the results of judgment by ME potential and report by pushing buttons. Judgment by ME potential corresponded well with reports of subjective sense. The concordance rate was 73%, and validity of this method was suggested.

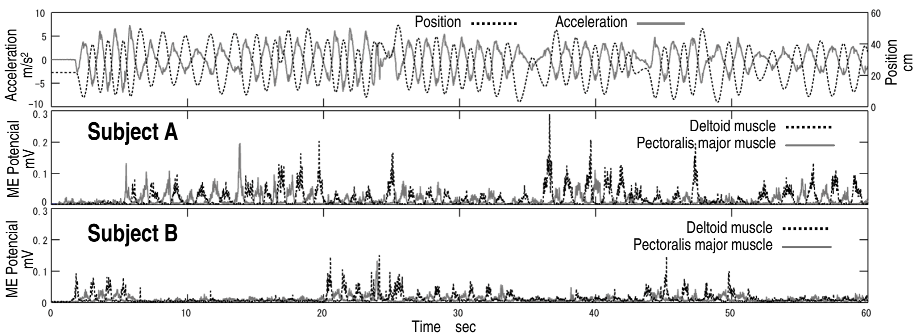


**Fig. 7.** Result of measurement during Embodied Interaction without fixing relationship between passive and active

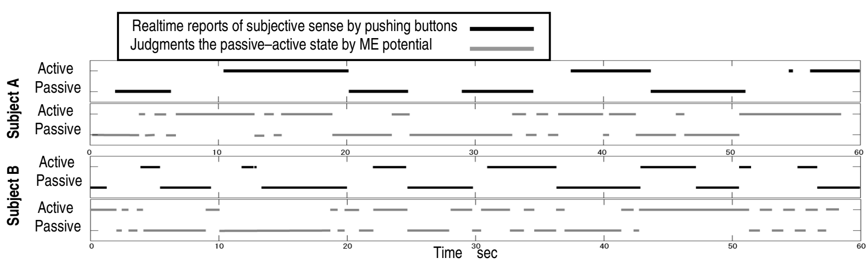


**Fig. 8.** Result of realtime reports of subjective sense by pushing buttons and judgments the passive–active state by ME potential

As a threshold value for dividing passive from active, the mean value of peaks of line potential is used. If a subject is inclined only toward activity or passivity in one side during an experiment, this method fails. If the relationship between peak ME potential of active movement or passive movement to acceleration of a slidable board is investigated beforehand for each person, obtaining a correspondence rate by calibration using the relationship is possible. Realtime reports of subjective sense were obtained in this experiment, but the meaning of these reports relates only to the conscious mind. Unconscious bodily movements or responses could not be measured, so there was a discrepancy between judgments by ME potential and reports of subjective sense. From another standpoint, this measurement method goes far beyond investigating simple correspondence of judgments by ME potential with reports of subjective sense. It can concurrently measure subjective sense surfacing in consciousness and ME potential because bodily information can handle two types of information (cognition and action). As mentioned above, this method can measure dynamics of the passive–active state, which are expected to involve embodied duality. This research can be developed further.

## 5 Conclusions

To study the generation mechanism of a nonseparable relationship as if your body and your partner's body are united, we measured the dynamism of the passive–active state in a mutual body during expressive body movement. Paying attention to ME potential, from which a generating timing and amplitude differ in a voluntary movement and reaction movement, we proposed and developed a measurement system for ME potential in bodily interaction. The effectiveness of this method was suggested by our data.

In the future, we will study the method of analysis to judge the passive–active state and dynamics of cognitive information by reporting subjective sense and embodied information (including unconscious factors).

## Acknowledgment

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