Relations between Body Motion and Emotion: Analysis based on Laban Movement Analysis

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Abstract

This study examined the relationship between human body movements and emotion based on Laban Movement Analysis (LMA). Ten participants participated in the experiment in which they stayed at a small resting room while hearing pleasant or unpleasant sounds. After the stay at the room, the participants rated their subjective emotional states. Participants' body movement were also recorded with four video cameras. The movement analysis based on LMA reveled significant differences in movement features between experimental conditions. In addition, significant correlations between movement features and subjective mood ratings were observed. These results suggest a strong relationship between human body movements and emotion.

Keywords: Emotion; Body motion; LMA

Introduction

The English word "emotion" comes from the Latin word "emovere," meaning to "move out." This derivation suggests a close relationship between emotion and body movements. In fact, this relationship, which we will refer to as *the motion-emotion relationship* in this paper, has been repeatedly discussed (Damasio, 1994; Darwin, 1890; James, 1892). Researchers have attempted to reveal causal relationships between emotion and body movements or the evolutionary advantages of emotion. This work has also described how emotion is expressed in body movements. However quantitative relationships between body movements and emotion categories have yet to be fully clarified.

Experimental studies on the motion-emotion relationship have so far, been conducted in the field of emotion perception (Atkinson, Dittrich, Germmell, & Young, 2004; Dittrich, Troscianko, Lea, & Morgan, 1996; Field, Hampson, & Rose, 2005; Kaiser & Keller, 2011; Pollick, Paterson, Bruderlin, & Sanford, 2001). For example, in Dittrich et al. (1996) presented participants with stimuli that expressed human body movements, and participants rated their impressions of those movements on basic emotional category scales. The results showed that participants could judge the emotional states even from biological motion produced by point-light displays.

Pollick et al. (2001) also conducted experiments that followed the paradigm proposed by Dittrich et al. (1996). Unlike the other previous studies, Pollick and colleagues quantified features of body movements as a way to reveal the motion-emotion relationship. The results showed that motions with strong velocity tended to be perceived as anger or happiness, while motions with weak velocity tended to be perceived as sadness or tired.

The movement stimuli used in emotion perception studies are usually created from performances of expert dancers or actors. On the basis of this method, several body movement theories have been proposed in the field of drama and dance.

Laban Movement Analysis (LMA) is one of the most famous theories of body expressions in dance (Laban, 1980). This theory assumes two basic opposing forms of body movement: fighting form and indulging form. Fighting form involves active, prominent, brisk body movements, while indulging form is unsteady weak body movements.

LMA assumes that such forms of body movement reflect subjective inner attitudes, refered to as *efforts*. The theory classifies effort into the following three axes:

- Weight effort that stands for the vigorousness of body movement.
- Space effort that stands for the degree of directional deflection.
- Time effort stands for the hurriedness in the changes of movement.

The terms fighting and indulging refer to opposing or enhancing the characteristics of a type of effort defined in the above three axes. Fighting form has strong weight, space, and time efforts. Indulging form has weak weight, space and time efforts.

LMA does not directly explain the motion-emotion relationship. Instead, this theory was proposed to describe body movements in dance. Laban (1980) did not mention any correspondence between the efforts and emotion categories. However, several researchers have applied LMA to emotion expressions programmed in robots (Hachimura, Takashina, & Yoshimura, 2005; Masuda & Kato, 2009; Nakata & Mori, 2002). For example, Nakata and Mori (2002) defined the three effort axes based on Euclidean vector operations. Here, participants rated impressions of robot motions that manipulated the three efforts based on LMA. The results indicated correlations between emotion ratings and the efforts based on LMA.

Studies using robots are useful in being able to produce precise manipulations of body movement. Researchers can freely create robot's movements, and these movements are easily quantified. However, studies using robots have the same limitations as studies assessing emotion perception. Both fields have only examined intentionally expressed emotion. Ekman and Friesen (1975) pointed out that there are uncontrolled, involuntary, true emotion expressions, as well as qualified, modulated, or false expressions. Past studies have examined Ekman's second type of emotion expressions. Few studies have challenged the first type of emotion expressions. For a deeper understanding of the motion-emotion relationship, the first type of emotion expressions needed to be examined.

The present study aimed to apply past findings of the motion-emotion relationship from uncontrolled experimental situations (Ekman's first type). To achieve this goal, we quantified involuntarily body movements using LMA. The motion-emotion relationship was explored by calculating correlations between quantitative features of body movements and subjective ratings of emotional states. In addition, this study explored how the environment influences on the motion-emotion relationship. It can be reasonably assumed that the motion-emotion relation will be affected by environment. We prepared two experimental conditions that were expected to arouse different emotional states.

Methods

Design

This study utilized audio stimuli that were assumed to arouse participants' emotion. A series of studies have previously examined environmental sounds related to pleasant or unpleasant emotion (Shimai, Tanaka, & Terasaki, 1990). From this work, we set up an experiment to examine the motion-emotion relationship using different environmental sound settings.

A between subjects design was used in the experiment. One group heard a pleasant environmental sound (pleasant sound group), and the other group heard an unpleasant environmental sound (unpleasant sound group).

Participants

Twenty graduate students from Japan Advanced Institute of Science and Technology participated in the experiment; they were divided into two groups of 10 participants each; all participants were in their 20s and naive to the purpose of the study.

Apparatus

We did not prepare any specific tasks for the participants because we wanted to examine emotion elicitation and body movement in uncontrolled situations. The participants were just asked to relax in a resting room while hearing the environmental sounds. We prepared the following resting room and environmental sounds:

- Resting room

  The resting room was designed like a Japanese teahouse (2m $\times$ 2m $\times$ 2m). The room had two tatami on the floor, and one small window on the wall. The participants' body movements were recorded with four video cameras affixed to the ceiling (Panasonic BB-HCM515).

- Environmental sound

  The environmental sounds were prepared using free sound libraries on the web. The pleasant sound was selected from "pdsounds" (http://www.pdsounds.org/). The unpleasant sound was created at "sound 101" (http://www.sound101.org/). Ten sound files were arbitrarily downloaded from these two web sites. Three raters, who were naive to the purpose of the study, assessed the pleasantness of these sounds. The sound that had the highest rating was chosen as the pleasant sound, and the sound that had the lowest rating was selected as the unpleasant sound. The selected pleasant sound was the sound of a brook (17 seconds), while the unpleasant sound was composed of several noises, such as sirens, microphone feedback, and scratching noises (20 seconds). Each environmental sound was looped during the experiment. The participants heard the sound through wireless headphones (Sony DRBT50). The maximum output sound level was kept below 70 db for both groups.

Procedure

The procedure for the experiment was composed of the following three steps:

1. Instructions

   The participants were told that this experiment was conducted to evaluate the resting room with environmental sound. They were asked to rest while hearing the environmental sound. They were not told that their movements would be recorded while in the room.

2. Resting room

   The participants entered the resting room alone, and took off their shoes. They put on a set of wireless headphones and an orange jump suit. The jump suit was used to analyze body movements with more ease. The participants could not bring any personal items into the room, including their mobile phone. After 30 minutes, the experimenter announced the end of the experiment.

3. Subjective emotional state ratings

   Immediately after being in the resting room, the participants rated their emotional states using the POMS (Profile of Mood States) brief test (Pollock, Cho, Reker, & Volavka, 1979). This test is usually used to assess transient and distinct mood states, which includes 30 questions classified into six factors: tension (anxiety), depression (dejection), anger (hostility), vigor (activity), fatigue (inertia), and confusion (bewilderment). This test outputs standardized scores with an average of 50 points.

The Ethics Committee of Japan Advanced Institute of Science and Technology approved the study.

Analysis

We analyzed the video data by applying LMA. Although the LMA effort axes were quantified by Nakata and Mori (2002), their method targeted pre-programed movements with parameters such as joint torque or angles of movement. Since our study obtained data in uncontrolled situations, the method from this previous study could not be directly applied. To quantify the efforts of Weight, Space and Time, we used optical flows estimated by image processing.

Weight effort is defined as the following equation.

$$Weight = \sum_{n=1}^{t} \sum_{i=1}^{x} \sum_{j=1}^{y} \frac{||v_{nij}||}{t \times x \times y} \quad (1)$$

where t, x, and y indicates the number of frames (25 fps), the width of the frame (240px), and the height of the frame (320px), respectively. $||v_{njk}||$ indicates the strength of the optical flow at pixel ij of frame n. Weight indicates the time space average of the vector strength. If the participants moved actively, this index would increase.

The following equation defines Space effort.

$$Space = \sum_{n=1}^{t} \sum_{i=1}^{x} \sum_{j=1}^{y} \frac{\mu_n \cdot v_{nij}}{t \times x \times y} \quad (2)$$

where μ_n is a mean vector (by-center) of optical flows in frame n, which indicates overall direction of body movements in the frame. Space is calculated as the time space average of dot products between a mean vector and individual optical flows. This value would increase when optical flows in the frame had consistent direction. Conversely, the value would decrease if direction of optical flows diverged.

Based on the above two feature quantities, Time (W) and Time (S) are defined as hurriedness in the changes of movement.

$$Time(W) = \sum_{n=2}^{t} \frac{|Weight_(n) - Weight_(n-1)|}{t} \quad (3)$$

$$Time(S) = \sum_{n=2}^{t} \frac{\mu_n \cdot \mu_{n-1}}{t} \quad (4)$$

Time (W) and Time (S) represent the difference of Weight and Space between two continuous frames respectively. Time (W) represents the degree of changes of movement strength. Time (S) indicates the degree of changes of movement direction.

These feature quantities were averaged over the four video cameras. Optical flows were determined by Lucas and Kanade (1981)'s gradient method. The frames were preprocessed by gray-scale processing and background differencing technique. For all steps of the above analysis, we used OpenCV that is an open-source library for image processing.

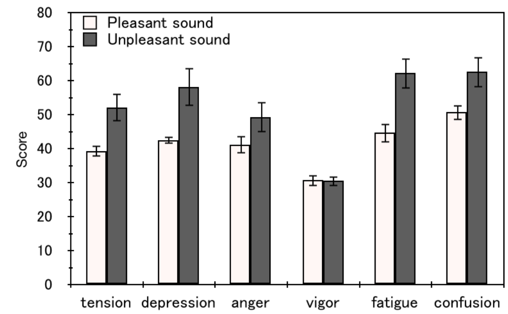

Figure 1: Subjective rating of emotional states after staying in the resting room.

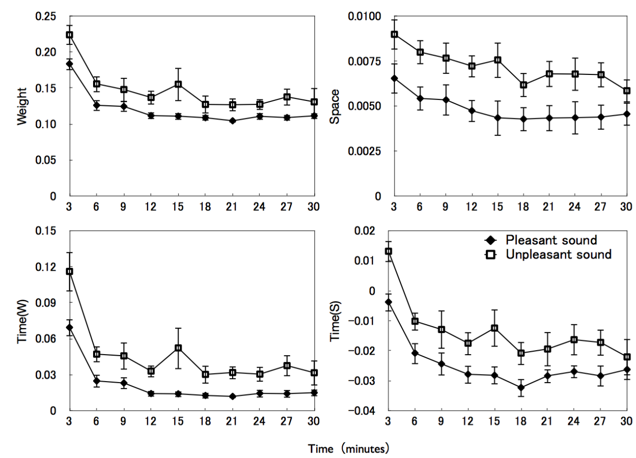

Figure 2: Changes in the features of body movements while in the resting room.

Results

Subjective ratings on emotional states

Figure 1 shows the average rating scores on the POMS after staying in the resting room. A 2 (group: pleasant sound vs. unpleasant sound) by 6 (emotion categories: tension, depression, anger, vigor, fatigue, confusion) mixed design Analysis of Variance (ANOVA) revealed a significant interaction between the environmental sounds and the emotion categories ($F(5,90) = 3.80, p < .01$). Simple main effects of the environmental sounds were significant for tension, depression, fatigue, and confusion (tension: $F(1,18) = 8.97, p < .01$, depression: $F(1,18) = 7.89, p < .05$, anger: $F(1,18) = 2.64, n.s.$, vigor: $F(1,18) = 0.01, n.s.$, fatigue: $F(1,18) = 11.12, p < .01$, confusion: $F(1,18) = 5.74, p < .05$). These results indicate changes in emotional states influenced by the environmental sounds.

Table 1: Correlations between the subjective ratings of emotional states and features of body movements (Overall).

	Weight	Space	Time(W)	Time(S)
tension	0.632*	0.543*	0.655*	0.691*
depression	0.436	0.275	0.405	0.560*
anger	0.589*	0.372	0.560*	0.610*
vigor	-0.072	0.056	-0.036	-0.023
fatigue	0.601*	0.473*	0.601*	0.520*
confusion	0.473*	0.327	0.435	0.468*

Note. * $p < .05$.

Feature quantities of body movement

Figure 2 shows the feature quantities of body while the participants were in the resting room. Four separete 10 (time: 3-30) by 2 (environmental sounds: pleasant vs. unpleasant) mixed design ANOVAs were conducted for the feature quantities. The analysis did not reveal significant interactions between time and the environmental sounds (Weight: $F(9,162) = 0.38, n.s.$, Space: $F(9,162) = 0.59, n.s.$, Time(W): $F(9,162) = 0.49, n.s.$, Time(S): $F(9,162) = 0.85, n.s.$). We obtained significant main effects of the environmental sounds (Weight: $F(1,18) = 12.77, p < .01$. Space: $F(1,18) = 11.64, p < .01$. Time(W): $F(1,18) = 8.54, p < .01$. Time(S): $F(1,18) = 23.92, p < .01$), and significant main effects of time for the four feature quantities (Weight: $F(9,162) = 12.17, p < .01$. Space: $F(9,162) = 6.22, p < .01$, Time(W): $F(9,162) = 12.89, p < .01$. Time(S): $F(9,162) = 15.30, p < .01$).

The main effects of the environmental sounds indicate that the body movements in the unpleasant sound condition were active, directed, and rapid. This suggests that the unpleasant sound changed body movements toward fighting form. On the other hand, the pleasant sound changed the body movement toward indulging form.

The main effects of time indicate that the participants made more movements immediately after entering the resting room. We confirmed qualitative differences in behaviors between the early and latter stages of the experiment. During the first few minutes, several participants observed interiors of the resting room. Next, they tended to lie down on the tatami mats until the end of the experiment.

Correlations between emotional states and body movement

Table 1 shows correlation coefficients between the rated emotional states and the feature quantities of body movements. In this analysis, we used the feature quantities in the latter 12 minutes to examine body movements that strongly connected to the emotional states.

From the table, we can observe some significant correlations between body motion and the emotion ratings. The emotion categories other than vigor appear to be related to some of the body movements.

However, we cannot exclude the possibility that these correlations were caused by features of the environmental sound because the participants in the two groups heard different sounds. The body movements might have been influenced by acoustic features such as rhythm or tempo. To exclude this possibility and obtain stronger evidence of the motion-emotion relationship, we calculated correlations disaggregated by the environmental sound.

Table 2: Correlations between the subjective ratings of emotional states and features of body movements (pleasant sound condition).

	Weight	Space	Time(W)	Time(S)
tension	-0.136	0.113	-0.014	-0.181
depression	-0.028	0.129	0.267	-0.101
anger	-0.531	-0.405	-0.355	-0.657*
vigor	0.338	0.182	0.187	-0.005
fatigue	-0.610	-0.493	-0.436	-0.591
confusion	0.324	0.413	0.577	-0.259

Note. * $p < .05$.

Table 3: Correlations between the subjective ratings of emotional states and features of body movements (unpleasant sound condition).

	Weight	Space	Time(W)	Time(S)
tension	-0.616	0.389	0.580	0.798*
depression	0.291	-0.050	0.140	0.540
anger	0.731*	0.422	0.661*	0.892*
vigor	-0.232	0.039	-0.123	-0.020
fatigue	0.725*	0.451	0.621	0.719*
confusion	0.343	-0.001	0.158	0.510

Note. * $p < .05$.

Table 2 and 3 show correlation coefficients between the emotional states and the feature quantities of body movements in the pleasant and the unpleasant sound conditions, respectively. In the pleasant sound condition, anger was negatively correlated with time (S). In the unpleasant sound condition, anger was positively correlated with Weight, Time (W), and Time (S). There was a positive correlation between tension and Time (S) in the unpleasant sound condition. Fatigue in the unpleasant sound condition was also correlated with Weight and Time (S).

From these results, we confirmed a motion-emotion relationship in a situation where the same environmental sound was presented. However, there were large differences in the pattern of the motion-emotion relationship between the two groups. In the following section, we will try to explain each of the observed correlations.

Discussion

This study explored the motion-emotion relationship in uncontrolled experimental situations. We prepared two conditions that differed in the environmental sounds presented. The results confirmed that (1) changes in emotional states as a function of environmental sound occured, (2) differences in body movements between different environmental sound conditions emerged, and (3) correlations between emotional states and body movements in each environmental sound condition were observed. This following section provides an interpretation of these results and discusses implications and limitations of the current findings.

Changes in emotional states by environmental sound

This study confirmed that environmental sounds changed emotional states as assessed by the POMS test. Although this study does not focus on the relationship between environmental sounds and emotion, we consider this result useful for future experimental studies on emotional arousal. Presentation of environmental sounds is non-invasive and an easy way to manipulate emotional states.

However, Figure 1 also shows limitations of our emotional manipulation. The influence of the environmental sound was limited to specific emotion categories. There were no differences in anger and vigor between the two groups. It is difficult to interpret why these differences occured. To provide a more accurate emotion manipulation, we need to conduct further experiments that explore the mechanisms underlying the relationships between emotion categories in this context.

Changes in body movements by environmental sound

In addition to the emotional states, the environmental sound influenced body movements. The feature quantities of body movements in the unpleasant sound condition were higher than those in the pleasant sound condition. The participants in the unpleasant sound condition exhibited active, directed, and rapid movement. Such body movements are consistent with fighting form of LMA. In contrast, body movements observed in the pleasant condition are consistent with indulging form. Considering the results of the POMS test, we can assume emotion categories like tension, depression, fatigue and confusion were related to fighting form.

However, this conclusion is not sufficient given that the environmental sounds in the two groups had different physical features. The difference between the two groups might be explained by certain mechanisms, such as sensory-motor coordination (Repp, 2005). This limitation can be addressed by examining correlations disaggregated by the environmental sounds.

Relationships between emotional states and body movement

Our study observed significant correlations between emotional states and body movements. This was especially the case when we consider that the correlations disaggregated by the environmental sounds are important. We provide an interpretation for the observed correlations in the following section.

Expressions of anger in response to the unpleasant sound In the unpleasant sound condition, anger was correlated with all of the features except Space. From this result, we can consider that anger is expressed as fighting form in LMA. This interpretation is consistent with past studies of emotion perception. As noted in the Introduction, Pollick et al. (2001) observed a correlation between anger perception and velocity of body movements. Masuda and Kato (2009), who analyzed robot motion based on LMA, also observed a strong correlation between anger perception and Time effort. The present study succeeded in extending these findings of emotion perception to an uncontrolled situation.

Expressions of tension in response to the unpleasant sound In the unpleasant sound condition, tension was correlated with Time (S), which quantifies the degree of hurriedness in movement changes. This result is consistent with the classic finding indicating that tension is often accompanied by muscle overactivity (Sainsbury & Gibson, 1954). Darwin (1890) also classified this action as an involuntary reflex movement. The present study described these relationships using the LMA framework.

Expressions of fatigue in response to the unpleasant sound Weight and Time (S) were correlated with fatigue in the unpleasant sound condition. POMS defines fatigue as decrease in motivation or energy. This result is inconsistent with our intuition that fatigue decreases body movements.

However, this result does not necessarily indicate a direct causal relationship between fatigue and these movement features. One possible explanation for this result might be that other emotion categories that covaried with fatigue caused an increase in the movement features.

In the unpleasant sound condition, fatigue was positively correlated with tension ($r = 0.738, p < .05$) and anger ($r = 0.698, p < .05$), which were also correlated with the movement features (Table 3). From these correlations, we can speculate that fatigue in the unpleasant sound condition was caused by strong and rapid movements accompanying these emotional states. However, our results cannot directly confirm this hypothesis. This possibility needs further study using more sophisticated methods such as path analysis.

Expressions of anger in response to the pleasant sound Compared to the unpleasant sound condition, the pleasant sound condition did not show many correlations between body movements and emotional states. In the pleasant sound condition, anger was negatively correlated with Time (S). This result is incontrast to the positive correlation observed in the unpleasant sound condition.

As in the above case, this contrasting finding might be explained by examining emotion categories that were negatively correlated with anger. In Pollick et al. (2001)'s experiment, both anger and happiness were expressed as active motion. Considering their finding, our negative correlation between anger and Time (S) is not too suprising. The increase in happiness might accompany a decrease in anger. However, we cannot confirm with the present results. Future studies that employ emotional ratings including happiness, should be conducted.

Summary

This study attempted to reveal motion-emotion relationships in uncontrolled situations. As a result, we observed that both motion and emotion were changed by environmental sounds. More importantly, we obtained correlations between emotion and body movements in each environmental sound condition. From these results, we confirmed the motion-emotion relationship from uncontrolled, involuntary emotional expressions.

Our study is characterized by a method of quantifying body movement features based on LMA. This quantitative method is useful for connecting motion and emotion in uncontrolled experimental situations. We consider that our approach can contribute not only to scientific studies of emotion but also to engineering applications. Automatic emotion assessment is applicable to various pragmatic situations, including dance, education and marketing. LMA is a useful tool for systematically describing body movements. Past studies using LMA have not included involuntary motion/emotion in uncontrolled situations. Our study extends the application fields of these past studies.

However, our results also revealed complexities in the motion-emotion relationship. As shown in Table 2 and 3, emotion is expressed differently in different situations. Additionally, there is no one-to-one correspondence between body movements and emotional states. A single emotion category can be connected to several body movements and vice versa. Furthermore, as speculated earlier, emotion categories are intricately intertwined. To reveal the deeper mechanisms of the motion-emotion relationship, studies with larger sample sizes will be needed.

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