Motion Capture of Emotional Expression Features in the Walking Posture

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Abstract: Studies investigating the association between emotions and biological information, such as breathing, pulse wave, heartbeat, voice, and facial expression, have suggested that many of them can estimate emotions. However, few studies have linked walking to emotions. In this study, we used optical motion capture to evaluate walking in humans in four emotional states, namely happy, angry, sad, and relaxed, and examined differences for each emotion. We found that walking in happy and sad states had unique features; whereas that in angry and relaxed states, which had few unique features. In other words, happy and sad states are easy to interpret, whereas angry, and relaxed states are a challenge. However, humans can distinguish between angry and relaxed walking. Therefore, in addition to gait, humans may observing other factors, such as how force is applied and the center of gravity.

Keywords: Emotions, Walking, Motion capture, Stride and span of both wrists, Walking speed, Elbow and neck angles

1. INTRODUCTION

Although technological advances have improved lives. Stress has increased. In 2020 COVID-19 increased global stress further. According to the Ministry of Health, Labor and Welfare, approximately half the people experienced anxiety regardless of the period. From April to May 2020 [1]. 63.9% of the population reported being anxious. A goal of SDGs includes “Good health and well-being”. Health depends not only on physical but also psychological factors. Therefore, the Ministry of Health, Labor and Welfare has promoted stress checks for companies [2]. The number of companies engaged in stress checks increased from 47.2% in 2012 to 59.2% in 2018 [3]. Thus, research on emotions will be extremely useful in the future. Studies on evaluating emotions have been actively conducted; many have focused on respiration, heartbeat, and EEG [4] [5]. In addition to those on voice and facial expressions; however, we have focused on walking. We classified emotions from walking into positive or negative states and found that 80% were correctly classified at best and 20% at worst, with the average of all five individuals being 36%. Gait analysis revealed that the five participants could be divided into “people who easily express emotions when walking”, and “people who do not easily express emotions when walking”. From this, categorizing emotions further and investigating characteristics of walking for each emotion was challenge.

In this study, we used motion capture to evaluate walking in happy, angry, sad, and relaxed states. Studies on emotional gaits include physical distances. Such as stride and span of both wrists, walking speed, and elbow and neck angles [6][7][8]. Therefore, we focused on these characteristics. The goal of this study was to classify emotions with high accuracy using machine learning.

2. ANALYSIS METHODS

2.1 Optical motion capture

We measured gait using the MAC3D System (Motion analysis Inc.), which uses optical motion capture technology. Figure 1 shows the studio used. We used 12 infrared cameras for measurements, and evaluated a walk of approximately 5 m length. We used Cortex (Motion analysis Inc.), which is the control software for MAC3D System, for subsequent analysis. Table 1 shows the specifications of the infrared camera. The tracker shown in Figure 2 is photographed by the camera and can be used to obtain three-dimensional coordinates. The acquired 3D coordinates were fed into Microsoft Excel for gait analysis.

Figure 1: MAC3D System
Table 1: Infrared camera specifications

| Specification               | Value                      |
|-----------------------------|----------------------------|
| Number of pixels            | 2.2 million pixels          |
| Resolution                  | 2,048 × 1,088 pixel        |
| Shooting speed at full resolution | 300fps                  |
| Effective shooting speed    | 1 – 600fps                 |
| Lens length                 | 8 mm                       |

Table 2: Walking patterns and features

| Gait | Tracker to use          |
|------|-------------------------|
| Stride[mm] | R.heel and L.heel      |
| Span of both wrists [mm] | R. wrist and L. wrist |
| Walking speed[m/s]       | Chest                   |
| Neck angle[°]            | Head, Neck, and Back    |
| Elbow angle[°]           | Shoulder, Elbow, and Wrist|

Two participants were included in the study; heights of participants 1 and 2 were 172cm and 174cm, respectively. This experiment was conducted based on the research ethics examination for humans “Gait analysis in virtual living environment 2019-A-16” at Kogakuin University.

3. RESULTS OF ANALYSIS

Results for participants 1 and 2 are shown in Figures 4 and 5, respectively.

Figure 2: Tracker position

Figure 3: Schematic diagram of gait

Figure 4: Emotional expression features (mean ± SD, participant 1)

2.2 Gait analysis method

Table 2 shows measured gaits, and figure 3 shows a schematic diagram of the gait. A stride defined as is the three-dimensional distance between the left and right heels. Wrist span for both wrists is the three-dimensional distance between left and right wrists. For these, the average of maximum values, which appeared several times during walking, was calculated using Microsoft Excel. Walking speed was calculated by dividing distance walked, which was measured using a chest tracker, by the elapsed time. Neck and elbow angles were calculated from the three joints shown in Table 2.

2.3 Experiment

We conducted experiments using the following procedures;
1) The participant was instructed to walk while expressing emotions. The walking order was happy, angry, sad, and relaxed. We asked the participant not to skip or walk exaggeratedly.
2) Data lost was interpolated by Cortex.
3) Gait analysis (section 2.2) was performed using Excel.

Figure 4: Emotional expression features (mean ± SD, participant 1)
3) Walking speed
The walking speed in the happy state (1.78 m/s) was faster than that in the sad state (1.12 m/s). However, walking speed in the relaxed state (1.32 m/s) was slower than that in the angry state (1.64 m/s).

4) Neck angle
The neck angle in the sad state (152.31°) was the smallest and that in the relaxed (172.65°) was the largest. However, the neck angle was smaller in the happy state (160.14°) than that in the angry state (165.79°). The standard deviation of the neck angle in the angry state (11.08°) was the largest.

5) Elbow angle
The left-elbow angle was largest in the relaxed, state (138.19°), followed by that in the sad state (133.73°). At approximately 128°, the left-elbow angle was the smallest for both happy and angry states. The standard deviation of the left-elbow angle in the happy state (32.93°) was the largest, followed by that in angry (24.48°), relaxed (20.07°), and sad (11.98°) states. By contrast, right-elbow angles were not affected by emotions and were approximately 123°. A decreasing trend for standard deviation was observed for right-elbow angles, with happy (22.41°), angry (15.34°), relaxed (12.93°), and sad (9.28°), similar to that seen for the left elbow.

3.2 Participant 2
1) Stride
The stride in the happy state (633.87 mm) was larger than that in the sad state (562.49 mm). However, in the relaxed state (591.85 mm), it was smaller than that in the angry state (639.51 mm).

2) Span of both wrists
The span of both wrists in the happy state (724.25 mm) was larger than that in the sad state (657.55 mm). However, in the relaxed state (677.51 mm), it was smaller than that in the angry state (699.73 mm).

3) Walking speed
The walking speed in the happy state (1.18 m/s) was faster than that in the sad state (1.00 m/s). However, in the relaxed state (1.00 m/s), it was slower than that in the angry state (1.29 m/s).

4) Neck angle
The neck angle (157.07°) in the angry state was the smallest, with no difference in other states, at

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**Figure 5:** Emotional expression features (mean ± SD, participant 2)

3.1 Participant 1
1) Stride
In happy (920.83 mm) and relaxed (776.11 mm) states, strides were larger than those in angry (732.82 mm) and sad (680.70 mm) states. In other words, stride in positive states (happy, relaxed) were larger than those in negative states (angry, sad). The standard deviation of stride (42.87 mm) in the relaxed state was larger than that in other states.

2) Spans of both wrists
Spans of both wrists (965.35 mm) in happy and relaxed (820.06 mm) states were larger than those in angry (780.85 mm) and sad (646.26 mm) states. In other words, wrist spans in positive states (happy, relaxed) were larger than those in negative states (angry, sad). Moreover, the standard deviation of spans of both wrists (42.90 mm) in the relaxed state was larger than that in others.
approximately 165°. In addition, the standard deviation of the neck angle in the happy (9.38°) was the largest, followed by that in the sad state (5.19°).

5) Elbow angle
   The left-elbow angle did not differ depending on emotions, and were approximately 135° in the happy, relaxed, angry and sad state. The standard deviation of the left-elbow angle in happy or angry states (approximately 12°) was larger than that in relaxed or sad states (approximately 8°). The right-elbow angle showed the same tendency as the left elbow; no difference was observed (approximately 125°). The standard deviation of the right-elbow angle in happy or angry states (approximately 8°) was larger than that in relaxed or sad states (approximately 5°).

4. DISCUSSION
   For both participants, “The stride with happy is larger than it with sad (Figure 6(a))” “The span of both wrists with happy is larger than it with sad (Figure 6(b))” and “The walking speed with happy is faster than it with sad.” When a person feels happy, body movement increases. Therefore, the stride and span of both wrists are large, and walking speed is fast. These observations are likely common, suggesting that they are important clues in the classification of emotions. However, for participant 2, the stride and span of both wrists were smaller in the relaxed state than in the angry state. This was a different feature from participant 1. Happy and sad emotions are easy to distinguish, and relaxed and angry emotions are difficult to distinguish. By contrast, there was no commonality in the angles of the neck and elbow. However, each participant had the following common characteristics in right- and left-elbow angles. Standard deviations of left and right-elbow angles of participant 1 were all larger and in the order of happy, angry, relaxed, and sad. Standard deviations for left- and right-elbow angles of participant 2 were both large for happy and angry states and small for relaxed and sad states. When combined with results from stride, span of both wrists, and walking speed, classifying emotions of an individual may be possible.

5. CONCLUSION
   In this study, we measured gait using motion capture and investigated differences in gait for each emotion. We found that happy or sad emotions are easily characterized by stride, span of both wrists, and walking speed. By contrast, relaxed or angry emotions is challenging. Future studies, with a higher number of participants, will help discover more commonalities and features and realize emotion classification with high accuracy using machine learning.

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