1. INTRODUCTION

Tourism is an event from which people can gain positive experiences [1-3]. The most positive experience is having a good time with friends, and communicating with others affords positive experiences in daily activities [4,5]. Sightseeing with a group offers both a good time and an experience with friends. However, people sometimes want to enjoy time with other group members more when they have visited a place of interest (POI). If a wearable or mobile device can detect their mood at the POI, it can provide advice and information for a more positive experience.

Previous studies have shown that people’s heart rate variability (HRV) is synchronized when they feel positive emotions by experiencing or seeing the same thing [6,7]. If a wearable sensor can determine the heart rate (HR) synchronicity of group members, it might estimate their mood on a tour and afford opportunities to provide support to ensure a positive experience.

The purpose of this study was to estimate a group’s mood based on the numbers of synchronized HR peaks in a group within each period of a tour. There are methods of using a wearable sensor to learn a person’s situation in tourism [8,9]. Studies have estimated happiness or excitement by measuring activity, movement, or biological signals using wearable sensors [10,11]. However, these studies have focused on one person’s context or mood and paid little attention to the group. Contrariwise, this study focuses on estimating the mood of a group using biological signals, especially HR.

Other studies suggest a relationship between a positive emotional connection with people and heart rate synchronization [6,7,12]. Some methods using the HR of multiple users have been proposed to estimate the mood or stress of a group in a laboratory or classroom [6,13,14]. However, this study differs from this previous research by focusing on group travel. In addition, this study dealt with the synchronicity numbers of HR peaks in a group using wearable devices and tried to estimate their mood during a tour.

This study formulated the hypothesis that group mood at a POI can be estimated from the synchronization of a group’s HR peaks as measured with wearable sensors. A previous study found that HRVs were highly synchronized between actors and audiences who had an emotional connection to each other. Viewers did not synchronize with actors’ HRV when they did not have an emotional attachment to them [7]. Thus, the group’s mood might be determined from HR peak synchronicity.

To test this hypothesis, this study designed a group mood estimation method based on the number of HR peak synchronizations of all members in each period on a tour. This study conducted a field experiment at nine POIs in Kyoto with 12 groups using a prototype system based on the proposed method. Each group had three members, all friends, who had measured their HR during tourism at one of the POIs and had completed a psychometric evaluation before, during, and after tourism at the POI. These results indicated that the proposed method might detect the mood of a group.

The novelty of this study is a novel algorithm for in-group mood estimation on a tour using synchronized data on the
HR peaks of group members collected by smartwatches. The contributions of this study are that the proposed method might detect a group mood using standard devices (i.e., Apple Watch) that everybody can use.

The remainder of this paper is organized as follows. In Section 2, this paper describes the method of estimating a group’s mood using the synchronicity of their HR peaks. This paper elaborates on the results of a field experiment conducted in Kyoto City in Section 3. In Section 4, the results of the experiment are discussed. Finally, this paper concludes with perspectives for future research.

2. METHOD

This method estimates a group’s mood on a tour by analyzing the synchronization of group members’ HR peaks in the following four steps:
1. Collect individual members’ HR in a group through a wearable device and find their HR peaks
2. Extract the number of synchronized HR peak for all members in each period
3. Judge the synchronicity of HR peaks, that is, Much sync or Less sync, in each period
4. Estimate the group mood using the sync situation in all periods

This study developed a prototype system using Apple Watch Series 3 as a wearable device, iPhone 5SE as a smartphone, and their healthcare and self-development iPhone applications, as shown in Figure 1.

2.1 Measure heart rates and find heart rate peaks

This method continuously measures the wearer’s HR through the Apple Watch [15]. The Apple Watch sends the measured data to the healthcare application on the iPhone connected to the watch via Bluetooth. The method uses one Apple watch and one iPhone to collect each person’s HR. The iPhone stores the average HR every 5 s through the healthcare application in units of counts/s. The self-development application acquires the individual’s HR, HR acquisition time, and current position (latitude and longitude) as recorded in the healthcare application and sent to the server every 10 min via http communication through the iPhone.

This method detects HR peaks from individual HRs in two steps. Figure 2 shows the algorithm for detecting the HR peaks. This method collects HR every 5 s from a person. First, this method compares the current and previous-time HR and the current and next-time HR. If the HR of the current time is higher than the previous and next HR or if the HR of the current time is equal to the next HR, it defines the HR of the current time as the HR peak. Second, the method stores the Boolean value with the timestamp. True means a peak has happened and False that it has not. It shifts the time by 5 s from the next time after the start time to the end time and detects all HR peaks for all members to obtain information on whether there is an HR peak at the same time in group members.

2.2 Extract the synchronized heart rate peaks

This method extracts the synchronized HR peak of a group based on the algorithm shown in Figure 2. It sets the term (10 s) to obtain the synchronized HR peak from individual HR peaks. It checks the HR peak synchronization for the group’s members in that term. This procedure is performed on all HR peak data by shifting the term at 15-second intervals.

Table 1 shows an example extraction of a synchronized HR peak based on the algorithm, as shown in Figure 2. The group in this example comprised three members, and HR peaks of members A, B, and C were detected at 12:00:10, 12:00:15, and 12:00:05, respectively, within the term (boxed time by the red line in Table 1).

Therefore, this method determined that this group had a synchronized HR peak between 12:00:05 and 12:00:15. It stores the latest timestamp of the HR peak (i.e., 12:00:15) and the number of members (i.e., three).
Members: The number of members in a group
HeartRateData: Stores heart rates with timestamps of all members as an associative array. The rates are measured every five seconds.
PeakData: Stores the information with the timestamp that a peak of heart rate has happened (True) or not happened (False) of all members.
Sync: The peak data with the timestamp of all members that occurred within 15 seconds, stored as an associative array. The key and value of an associative array is a member and a timestamp.
SyncSeries: Holds the number of members that a heart rate peak has synchronized and the timestamp when the synchronized heart rate peak happened as an associative array. The key and value of an associative array is time and member.

//Find peaks in an individual's heart rates
FOR member in Members DO
    FOR heart in HeartRateData[member] DO // heart: The value of heart rate with the timestamp
        IF previous == NULL THEN  Put heart into previous
        ELSE IF current == NULL THEN Put heart into current
        ELSE Put heart into next
        ENDIF
        IF previous != NULL && current != NULL THEN
            IF previous.value < current.value THEN
                IF current.value > next.value THEN   Put “True” into PeakData[member] with the timestamp of key
                ELSE IF current.value == next.value THEN Put “True” into PeakData[member] with the timestamp of key
                ELSE Put “False” into PeakData[member] with the timestamp of key
                ENDIF
            ELSE Put “False” into PeakData[member] with the timestamp of key
            ENDIF
            Put current into previous, Put next into current
        ENDIF
    ENDFOR
ENDFOR

//Extract the synchronized heart rate peaks in a group
Initialize Sync, count and sync_members to zero // sync_members: the number of synchronized members in 15 seconds
FOR peak in PeakData DO // peak: The Boolean data (True or False) with the timestamp
    Increase count by one // 1 count means 5 seconds
    FOR member in Members DO
        IF peak[member] == True THEN
            Put member and peak[member].time as key-value data into Sync
        ENDIF
    ENDFOR
ENDFOR
IF count == 3 THEN // Shift the interval by 3 counts (15 seconds) as default
    Count the key-value data in Sync and Put it into sync_members.
    Put the latest timestamp in Sync as the key data and sync_members as the value data into SyncSeries.
    Initialize count and sync_members to zero, and Initialize Sync // Set a new start time
ENDIF

// Judge the situation of synchronicity of HR peaks in a period (10 minutes)
Initialize count and sync_times to zero // sync_times: the number of synchronized HR peaks of three members
FOR syncdata in SyncSeries DO // syncdata: Hold timestamp as key-data and the number of synchronized members as value-data
    Increase count by one
    IF syncdata.members == 3 THEN
        Increase sync_times by one
        IF count == period THEN // the period is 40 counts as default (40 counts = 120 counts (10 minutes) / 3 counts (15 seconds))
            Judge that the group’s situation is “Much Sync” in the period.
        ELSE Judge that the group’s situation is “Less Sync” in the period.
        ENDIF
        Initialize sync_times and count to zero
    ENDIF
ENDIF

Figure 2: Algorithm for finding peaks in an individual’s heart rates, extracting the synchronized heart rate peaks for all members in a group, and judging the group’s HR peak sync situation based on the number of synchronicities of heart rate peaks in the period
2.3 Judge the group’s synchronicity situation of HR peaks

This method determined the group’s sync situation of HR peaks during a period based on the number of synchronized HR peaks of all members. However, this study defined the period as 10 min because the prototype system could send individual pulse rate data to the server every 10 min.

If the number of members whose HR peaks were synchronized is below the threshold within a period, this study determines the group to be in the “Less sync” situation in the period; If the number of members whose HR peaks were synchronized is above the threshold within a period, this study determines the group to be in the “Much sync” situation in the period.

The threshold is defined by

\[ \text{Threshold} = (P_t / I_t) \times \text{Prob} \]

where \( P_t \) is the period time and is 10 min (120 counts); \( I_t \) is the interval time, 15 s (three counts); and \( \text{Prob} \) is the probability that the three members’ HR peaks will be synchronized, 0.125.

Table 2 shows an example of the decision of a group’s situation in each period. The group strolled around a POI for about 30 minutes (three periods).

3. EXPERIMENT

This study hypothesized that a group’s mood on a POI could be estimated using the number of synchronized HR peaks of all members within a specified period. This study conducted a field experiment at nine POIs, that is, six temples and three shrines in Kyoto City, to verify the hypothesis. The experiment was conducted using 12 groups (G01–G12). One group was composed of three friends, and each group had visited one of the POIs. The participants were 12 male and 2 female college students in their 20s. However, there were some groups with the same participants in the 12 groups, and the pair of G03 and G04, G09 and G10, and G11 and G12 visited the same POI. The groups experimented on different days, and their weathers were fair.

This study also evaluated the relationship between the number of synchronized HR peaks of all members in a group and the Japanese version of the Positive and Negative Affect Schedule (PANAS) scale [16]. The Japanese version of the PANAS is two 8-item mood scales, and each item is rated on a 6-point scale. However, it does not include “interested” and “attentive,” which are positive affect, or “guilty” and “hostile,” which are negative affect.

The participants completed the PANAS, a mood scale for measuring positive and negative affect, before, during, and after strolling around a POI. The definition of the “before” time is the situation just before strolling around a POI. They also completed the PANAS after gathering in front of the POI and enough communicating with each other to make a group. This study assumes that a group’s mood before they start walking affects its mood in the earlier periods of the experiment. They also completed the
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Table 3: The averages and standard deviations of the PANAS scores of group members at certain times and all times at each POI

![Table 3](image)

PANAS once during the experiment based on the group’s discretion. This study defined this situation of which they had responded to the PANAS as the “during” time. However, the interval for completing the PANAS was set at 10 min or more. Finally, they completed the PANAS at the POI just after finishing their strolling around the POI. This study defined this situation where they had completed the PANAS as the “after” time.

All group members wore one Apple watch (Series 3) as a smartwatch for measuring heart rates and carried one iPhone (5se) as a smartphone to collect heart rate data. The iPhone was used to send the data to the system’s server. One of the members recorded their conversations during the tour using the iPhone. These experiments were performed with the approval of the Ethics Committee of Kyoto Sangyo University.

3.1 Investigation of differences in PANAS scores

This study investigated the PANAS scores of the 12 groups before, during, and after strolling around a POI. Table 3 shows the average and standard deviation (SD) of the PANAS scale score of each group at a certain time and at all times in every POI. However, this study calculated the average of positive affect (PA), negative affect (NA), and positivity rate (PR), including the PANAS scores measured before a group started walking around a POI. This study assumes that the group’s mood in the earlier periods may affect the PANAS score before they start strolling around.

Statistical significance (p < 0.05) between the PANAS before, during, and after visiting a POI was examined with nonparametric multiple tests adjusted for many-to-many comparisons by the Steel-Dwass-Critchlow-Fligner method [17]. There was no statistically significant evidence
between three times ("Before," "During," and "After") concerning PR, PA score, and NA score.

3.2 The relationship between the PANAS scores and number of synchronized HR peaks of all members

Table 4 showed the relationship between the PANAS scale score and the synchronized HR peaks of all members. This table was sorted in descending order based on the average PR value for each group.

This study classified the ten groups, excluding two groups (G09 and 11), into two clusters for investigating the relationship between the average PR value and the synchronized HR peaks. However, a PR value is a PA score divided by a NA score. This study excluded two groups (G09 and 11) for analysis. The reason is that the average PR values for these two groups were 1.91 and 1.83, respectively. The PR value is 1.0 if the PA score is equal to the NA score. These values were in the range of 0.5 to 2.0 and close to 1.0. Therefore, this study concluded that these groups were neither positive nor negative. One cluster (Cluster A) consisted of the top five groups (G03, 04, 07, 08, and 10) of average PR value. The median of average PR values in Cluster A was 2.75. All groups in Cluster A had the “Much sync” situation at least once during all periods. Another cluster (Cluster B) consisted of the bottom five groups (G01, 02, 05, 06, and 12) of average PR value. The median of average PR values in Cluster B was 2.58. All groups in Cluster B had the “Less sync” situation in all periods.

Statistical significance ($p<0.05$) between the number of synchronized HR peaks of two clusters was tested using the two-sided Wilcoxon-Mann-Whitney test, a nonparametric test. Two clusters had different effects [Z = 3.38, $p$-value = 0.0004 $<$ 0.05]. The results in Table 4 and in the statistical analysis show that the proposed method might predict a group’s positive mood using the two situations: “Much sync” and “Less sync.”

Table 5 showed the PANAS scores of every item for each time ("Before," "During," and "After"). As for the groups in Cluster A, the four groups (G03, 04, 08, and 10) showed values above 4.0 on many PA scales at all periods. G07 showed values greater than 4.0 of all periods on the “Active” scale and of one period on the “Excited” scale. However, as for all items of G07, the median of average PA values is 3.3, and the median of average NA values is 1.2.

As for the groups in Cluster B, G02 and 06 showed only one value greater than 4.0 on the “Excited” scale.

### Table 4: The relationship between the average and SD of the PANAS scale and the number of synchronized HR peaks of all members in each period

| Group | PANAS score of all times | The frequency of HR peak’s sync in all group members and predicted mood in each period |
|-------|--------------------------|----------------------------------------------------------------------------------------|
| PR    | PA | NA | Period | 1 | 2 | 3 | 4 | 5 | 6 | Sum | Ave. |
| G03   | Ave. 3.14 | 33.33 | 13.00 | Frequency HR peak’s sync Predicted Mood | 3 | 6 | 2 | 1 | 5 | 17 | 3 |
|       | S.D. 0.27 | 1.20 | 1.15  | L | M | L | L | M |
| G07   | Ave. 2.90 | 26.33 | 9.89  | Frequency HR peak’s sync Predicted Mood | 4 | 3 | 2 | 3 | 7 | 26 | 4 |
|       | S.D. 0.24 | 0.33 | 0.38  | L | L | L | L | M |
| G04   | Ave. 2.75 | 27.89 | 11.10 | Frequency HR peak’s sync Predicted Mood | 13 | 12 | 10 | 11 | 46 | 12 |
|       | S.D. 0.52 | 1.35 | 2.60  | M | M | M | M | M |
| G10   | Ave. 2.71 | 27.67 | 11.89 | Frequency HR peak’s sync Predicted Mood | 9 | 4 | 0 | 6 | 4 | 23 | 4 |
|       | S.D. 0.25 | 1.53 | 2.27  | M | L | L | L | M |
| G08   | Ave. 2.69 | 30.56 | 15.89 | Frequency HR peak’s sync Predicted Mood | 4 | 8 | 3 | 4 | 15 | 5 |
|       | S.D. 0.06 | 0.38 | 0.77  | L | M | L |
| G12   | Ave. 2.63 | 27.00 | 11.67 | Frequency HR peak’s sync Predicted Mood | 4 | 2 | 2 | 8 | 3 |
|       | S.D. 0.19 | 2.91 | 0.58  | L | L | L |
| G01   | Ave. 2.59 | 24.33 | 9.56  | Frequency HR peak’s sync Predicted Mood | 1 | 4 | 1 | 1 | 7 | 2 |
|       | S.D. 0.23 | 2.33 | 0.19  | L | L | L | L |
| G02   | Ave. 2.58 | 21.67 | 8.44  | Frequency HR peak’s sync Predicted Mood | 1 | 3 | 1 | 3 | 4 | 14 | 2 |
|       | S.D. 0.46 | 2.40 | 0.51  | L | L | L | L | L |
| G05   | Ave. 2.26 | 24.78 | 11.56 | Frequency HR peak’s sync Predicted Mood | 0 | 3 | 3 | 1 | 0 | 8 | 1 |
|       | S.D. 0.19 | 1.64 | 0.38  | L | L | L | L | L |
| G06   | Ave. 2.02 | 21.44 | 11.22 | Frequency HR peak’s sync Predicted Mood | 4 | 2 | 2 | 8 | 3 |
|       | S.D. 0.29 | 2.55 | 0.96  | L | L | L |
| G11   | Ave. 1.91 | 24.44 | 18.44 | Frequency HR peak’s sync Predicted Mood | 4 | 4 | 5 | 4 | 20 | 4 |
|       | S.D. 0.05 | 0.84 | 0.69  | L | L | M | L |
| G09   | Ave. 1.83 | 25.33 | 18.33 | Frequency HR peak’s sync Predicted Mood | 5 | 2 | 1 | 4 | 12 | 3 |
|       | S.D. 0.17 | 0.33 | 2.19  | M | L | L | L |

[Note]
- PA: Positive Affect, NA: Negative Affect, PR: Positivity Rate is calculated by PA/NA, HR: Heart rate, M: much sync, L: less sync
- Threshold was 5.0. If the frequency of HR peak’s sync is more than 5.0, then the method estimated the situation as “Much sync.”
- Bolded red groups are in Cluster A. Bold groups are classified as Cluster B.
- This table is sorted in descending order based on the average PR value for each group.
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Table 5: The PANAS score at each time (before, during and after the POI visit) of all groups

| Group | Before | During | After | Ave. | Before | During | After | Ave. | Median | Before | During | After | Ave. | Median |
|-------|--------|--------|-------|------|--------|--------|-------|------|--------|--------|--------|-------|------|--------|
| G01   | 8.0    | 5.0    | 3.0   | 4.6  | 8.0    | 5.0    | 3.0   | 4.6  | 2.8    | 8.0    | 5.0    | 3.0   | 4.6  | 2.8    |
| G02   | 3.0    | 4.0    | 5.0   | 4.6  | 3.0    | 4.0    | 5.0   | 4.6  | 1.2    | 3.0    | 4.0    | 5.0   | 4.6  | 1.2    |
| G03   | 4.0    | 5.0    | 6.0   | 6.0  | 4.0    | 5.0    | 6.0   | 6.0  | 3.5    | 4.0    | 5.0    | 6.0   | 6.0  | 3.5    |
| G04   | 5.0    | 6.0    | 7.0   | 6.0  | 5.0    | 6.0    | 7.0   | 6.0  | 1.6    | 5.0    | 6.0    | 7.0   | 6.0  | 1.6    |
| G05   | 6.0    | 7.0    | 8.0   | 7.0  | 6.0    | 7.0    | 8.0   | 7.0  | 1.4    | 6.0    | 7.0    | 8.0   | 7.0  | 1.4    |
| G06   | 7.0    | 8.0    | 9.0   | 8.0  | 7.0    | 8.0    | 9.0   | 8.0  | 1.3    | 7.0    | 8.0    | 9.0   | 8.0  | 1.3    |
| G07   | 8.0    | 9.0    | 10.0  | 9.0  | 8.0    | 9.0    | 10.0  | 9.0  | 1.3    | 8.0    | 9.0    | 10.0  | 9.0  | 1.3    |
| G08   | 9.0    | 10.0   | 11.0  | 10.0 | 9.0    | 10.0   | 11.0  | 10.0 | 1.9    | 9.0    | 10.0   | 11.0  | 10.0 | 1.9    |
| G09   | 10.0   | 11.0   | 12.0  | 11.0 | 10.0   | 11.0   | 12.0  | 11.0 | 2.3    | 10.0   | 11.0   | 12.0  | 11.0 | 2.3    |
| G10   | 11.0   | 12.0   | 13.0  | 12.0 | 11.0   | 12.0   | 13.0  | 12.0 | 2.3    | 11.0   | 12.0   | 13.0  | 12.0 | 2.3    |
| G11   | 12.0   | 13.0   | 14.0  | 13.0 | 12.0   | 13.0   | 14.0  | 13.0 | 2.4    | 12.0   | 13.0   | 14.0  | 13.0 | 2.4    |
| G12   | 13.0   | 14.0   | 15.0  | 14.0 | 13.0   | 14.0   | 15.0  | 14.0 | 2.4    | 13.0   | 14.0   | 15.0  | 14.0 | 2.4    |

| Group | G01 | G02 | G03 | G04 | G05 | G06 | G07 | G08 | G09 | G10 | G11 | G12 |
|-------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Ave.  | 4.6 | 2.8 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 | 3.0 |

**Table Note:**
- Each item is rated on a 6-point scale: it applies very much, it applies a lot, it applies a little, it does not apply a little, it does not apply a lot, and it does not apply at all. These responses are converted to numerical values for computational purposes, from it applies very much (6) to it does not apply at all (1).
- Bolded red groups are in Cluster A. Bold groups are classified as Cluster B.
- Bold red values indicate > 4.0 = It applies a little, and Bold blue values indicate > 2.0 = It does not apply a lot.

G01 observed values greater than 4.0 on the “Active” and “Excited” scales in all periods. G05 observed values greater than 4.0 on the “Excited” scale in all periods. However, for all items of the four groups (G01, 02, 05, and 06), the median of average PA scores is less than 3.0, and the median of average NA scores is less than 2.0. G12 showed values above 4.0 on many positive scales. However, G12 did not observe the values above 4.0 for all items in the “After” period. In addition, as shown in Table 3, G12 was the only group whose PA score decreased by more than 3.0 after the POI visit.

The results from Table 5 indicate that the proposed method might estimate the group’s positive mood using two-sync situation information.
3.3 Effectiveness of synchronized HR peaks in predicting mood

This study investigated whether the sum of each member’s HR peaks can estimate the mood of a group. Table 6 shows the number of HR peaks for each member in each period for all groups. The ten groups, excluding two groups (G09 and 11), were divided into two clusters: Cluster A is the group (G03, 04, 07, 08, and 10), and Cluster B is the group (G01, 02, 05, 06, and 12). This grouping is the same as in Section 3.2.

Statistical significance (p<0.05) between the sum of the number of HR peaks of each member of the two clusters was tested using the two-sided Wilcoxon-Mann-Whitney test, a nonparametric test. There was not a statistically significant difference between the two clusters [Z = 1.5667, p-value = 0.1508], showing that the sum of each member’s HR peaks cannot serve to estimate the mood of the group. On the other hand, in Section 3.2, the number of synchronized HR peaks of all group members could estimate the mood of the group. Comparison of both results shows that the number of synchronized HR peaks is effective in estimating the mood.

4. DISCUSSION

The purpose of this study was to estimate a group’s mood using the number of synchronicities of the heart rates of the group during a period on a tour.

This study designed an algorithm that estimates the group’s situation in a period on a tour using the number of synchronicities of their heart rates. The algorithm determined the group as a “Less sync” situation if the number of members whose HR peaks were synchronized is below the threshold within a period. The algorithm determined the group as a “Much sync” situation if the number of members whose HR peaks were synchronized is above the threshold within a period. The threshold for a group with three members was five counts, and the period was 10 minutes. The proposed method estimated the group’s mood based on the synchrony situation of the group.

This study conducted a field experiment with 12 groups at nine POIs using the prototype system. This study divided the ten groups, excluding two groups, into two clusters based on average PR value. One cluster A comprised the top five groups of average PR value and had the “Much sync” situation at least once during all periods. Another cluster B comprised the bottom five groups of average PR value and had the “Less sync” situation in all periods. This study statistically examined the differences in the number of synchronized HR peaks between the two clusters. The two clusters showed different effects, such that the group’s positive mood might be predicted by the number of synchronized HR peaks of all group members in each period. In addition, this study found that the group’s mood might be positively related to the situation where many HR peak syncs are observed.

However, this method would benefit from potential improvements. The average PR value for G12 classified in Cluster B was close to the average PR value for G08 classified in Cluster A. However, the difference between the median of average PR values in cluster A

| Member | Period | Sum | Ave. |
|--------|--------|-----|------|
| G01    | 1  22  | 21  22  | 14  | 79  | 19.8 |
|        | 2  10  | 11  5    | 5   | 31  | 7.8  |
|        | 3  16  | 19  20  | 20  | 75  | 18.8 |
| Ave.   | 16  17 | 15.7  | 13  | 61.7 | 15.7 |
|        | 1  18  | 21  20  | 24  | 23  | 18  | 124  | 20.6 |
| G02    | 2  11  | 23  9    | 15  | 10  | 12  | 80  | 13.3 |
|        | 3  16  | 14  23  | 17  | 14  | 15  | 99  | 16.5 |
| Ave.   | 15  19.3 | 17.3 | 18.7 | 15.7 | 101 | 17.0 |
|        | 2  16  | 19  11  | 18  | 22  | 86  | 17.2 |
|        | 4  24  | 22  17  | 13  | 18  | 94  | 18.8 |
|        | 5  18  | 23  16  | 11  | 18  | 86  | 17.2 |
| Ave.   | 19.3  | 21.3  | 14.7 | 14  | 19.3 | 88.7 | 17.7 |
| G04    | 6  22  | 25  19  | 22  | 88  | 22.0 |
|        | 7  22  | 17  20  | 17  | 76  | 19.0 |
|        | 8  22  | 25  19  | 22  | 88  | 22.0 |
| Ave.   | 22  22.3 | 19.3 | 20.3 | 84  | 21.0 |
| G05    | 3  14  | 24  8    | 8   | 46  | 15.3 |
|        | 6  22  | 20  19  | 9   | 61  | 20.3 |
|        | 8  24  | 11  13  | 8   | 48  | 16.0 |
| Ave.   | 20  18.3 | 13.3 | 11.7 | 12.7 | 11  | 77  | 13.0 |
| G06    | 3  18  | 17  16  | 17  | 8   | 9  | 14.8 |
|        | 6  4  | 17  10  | 12  | 11  | 10  | 64  | 10.7 |
|        | 8  11  | 18  14  | 6   | 14  | 15  | 78  | 13.0 |
| Ave.   | 11  17.3 | 13.3 | 11.7 | 12.7 | 11  | 77  | 13.0 |
| G07    | 3  14  | 24  8    | 8   | 46  | 15.3 |
|        | 6  22  | 20  19  | 9   | 61  | 20.3 |
|        | 8  24  | 11  13  | 8   | 48  | 16.0 |
| Ave.   | 20  18.3 | 13.3 | 11.7 | 12.7 | 11  | 77  | 13.0 |
| G08    | 3  18  | 22  22  | 62  | 20.7 |
|        | 6  18  | 21  21  | 60  | 20.0 |
|        | 9  22  | 20  20  | 62  | 20.7 |
| Ave.   | 19.3  | 21  21  | 61.3 | 20.5 |
| G09    | 10  21  | 19  18  | 19  | 77  | 19.3 |
|        | 11  21  | 16  25  | 25  | 87  | 21.8 |
|        | 12  15  | 10  11  | 16  | 52  | 13.0 |
| Ave.   | 19  15  | 18  20  | 72  | 18.0 |
| G10    | 9  31  | 17  19  | 1   | 20  | 16  | 104  | 17.3 |
|        | 13  25  | 23  24  | 22  | 17  | 17  | 128  | 21.3 |
|        | 14  18  | 9  7  | 6   | 20  | 18  | 78  | 13.0 |
| Ave.   | 24.7  | 16.3  | 16.7 | 9.7 | 19  | 17  | 103.3 | 17.2 |
| G11    | 10  20  | 22  17  | 24  | 23  | 106  | 21.2 |
|        | 11  18  | 20  18  | 16  | 20  | 92  | 18.4 |
|        | 12  19  | 12  15  | 10  | 71  | 14.2 |
| Ave.   | 19  18  | 16.7 | 18.3 | 17.7 | 89.7 | 17.9 |
| G12    | 9  24  | 24  18  | 66  | 22.0 |
|        | 13  8  | 8  15  | 31  | 10.3 |
|        | 14  29  | 20  17  | 66  | 22.0 |
| Ave.   | 20.3  | 17.3  | 16.7 | 54.3 | 18.1 |

[Note] • Some subjects had very few HR peaks because they were measured as having the same value continuously over a specific period. • Bolded red groups are in Cluster A. Bold groups are classified as Cluster B.
and the average PR value of G12 in Cluster B was 0.12. On the other hand, the difference between the median of average PR values in cluster B and the average PR value of G12 in Cluster B was 0.05. This might indicate that our algorithm could not detect the synchronized HR peaks of a group because some subjects had very few HR peaks due to the continuous measurement of the same HR value over a specific period. This situation occasionally occurs in field experiments with consumer devices. We need to investigate the occurrence of this situation by conducting experiments in more groups. In addition, we have to improve the algorithm to handle this situation.

The two groups excluded from the analysis were measured “Much sync” in one period. The NA values of the two groups were higher than the other groups. Negative moods in the group may have affected the synchronized HR peaks. To investigate this issue, we need to conduct experiments with more groups and more POIs.

In this experiment, we collected the PANAS only three times, before, during, and after strolling around the POI. Therefore, this study could not compare the number of synchronized HR peaks in each period with the PANAS score in the same period. We need to investigate the relationship between synchronized HR peaks and emotions in a period.

In this study, each group consisted of three friends, all healthy college students in their 20s who visited POIs in Kyoto, Japan. The proposed method was shown to be beneficial in estimating the mood of a group with three members. However, it is necessary to conduct new experiments with more than three members and evaluate this method in other generations.

5. CONCLUSION

This paper proposed a method to detect the synchronicity of heart rate peaks in a group to estimate the group’s mood at a POI. This method determined the group’s situation to be either “Much sync” or “Less sync” based on the number of the group’s members whose HR peaks were synchronized is above or below the threshold within the period.

This study constructed a prototype system and conducted a field experiment for 12 groups at nine points of interest in Kyoto City, Japan. This study excluded two groups that are neither positive nor negative from 12 groups and divided the ten groups into two clusters based on average PR value. This study statistically examined the differences in the number of synchronized HR peaks between the two clusters. One cluster comprised the groups with the top five of average PR value and had the “Much sync” situation at least once during all periods. Another cluster comprised the groups with the bottom five of average PR value and had the “Less sync” situation in all periods. Statistical significance ($p<0.05$) of the difference in the number of synchronized HR peaks between the two clusters was tested using a nonparametric test. The two clusters showed different effects, indicating that the number of synchronized HR peaks of all members might serve to estimate the group’s mood. In addition, this study investigated the relationship between the number of synchronized HR peaks of groups and their PA scores. The results indicated that the group’s mood might be positively related to the situation where many heart-rate peak syncs are observed. From the results, we conclude that the method was effective in estimating the mood of the group.

In future work, we will investigate the number of synchronized HR peaks of groups in a period and mood during the period. In addition, we will design and develop a prototype proactive recommender system based on the method proposed in this paper to shift a mood to a more positive one.

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NOTES

1. This study is an extended version of the previous paper [18], which was ISIS2019&ICBAKE2019.

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