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Head Motion Synchrony in the Process of Consensus Building: A Comparison between Native English and Japanese Speakers

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Embodied synchrony has been studied in dyadic interaction between adult-neonate, client-counsellor and physician-patient in many past researches. However, the mechanism in which embodied synchrony occurs in human communication is still not well understood due to complex human dynamics. In this study, we investigated the relationship between head motion synchrony and degree of empathy in dyadic interaction using consensus-building task to reveal the degree of dependence on differences between high and low context cultures. A total of 29 pairs of subjects participated in this research. The subjects can be broadly classified into two main groups, namely, native English speakers (Male 4 pairs, Female 4 pairs) and native Japanese speakers (Male 11 pairs, Female 10 pairs). The result showed that a positive correlation exists between head motion synchrony and degree of empathy for both native Japanese and English speakers. In addition, head motion synchrony at low, medium and high frequency of 1.0 Hz, 2.5 Hz and 5.0 Hz respectively are significant for both native Japanese and English speakers. However, at low head motion frequency of 1.0 Hz, the time lag for native Japanese speakers (0 sec to 0.3 sec) is shorter as compared with native English speakers (0.4 sec to 0.5 sec). At high head motion frequency of 5.0Hz, the time lag for native Japanese speakers is longer (0.4 sec to 0.5 sec) but the time lag for native English speakers varies from 0.1 sec to 0.5 sec. These differences may be attributed to different context culture of head motion between native English and Japanese speakers.

Index Terms - Head motion synchrony, Consensus building, Degree of empathy, High and low context cultures

I. INRODUCTION

Consensus building is a decision-making process that seeks the consent of all participants. It is a typical process of dyadic interaction between people. There are many past researches, which investigated the effects of consensus building from a micro perspective (i.e. organizational level, Hyun, 2009) to a macro perspective (i.e. regional level, Matthias and Marcel, 2006). Hyun (2009) studied consensus building through role-playing from the perspective of self-persuasion on simulated civic forum. Matthias and Marcel (2006) studied the effects of consensus building processes on regional collaboration in environmental psychology.

In addition, many past researches reported that body motion and utterance were synchronized during dyadic interaction between people. Condon and Sandar (1974) found that neonate`s motor behaviour was entrained and synchronized with the utterance of adults in the environment. Koss and Rosenthals' study (1997) supported the theoretical proposed link between positivity and interactional synchrony in physician-patient relationship. Kimura and Daibo (2006) studied interactional synchrony between dyadic interactions using pseudosynchrony experimental paradigm and found the degree of perceived synchrony was higher in positive episodes than in negative episodes. Ramseyer and Tschacher (2008) found a high positive relationship between synchrony and the therapeutic bond from a sequence of therapy session taken from one psychotherapy dyad.

However, there are very few research studies on head motion synchrony during consensus building. In addition, Maynard (1987) studied vertical head movement in Japanese dyadic casual conversation and identified eight different categories of head movements based on turning-taking environment and a co-occurrence context. McClave (2000) studied the linguistic functions of head movement's pattern using microanalysis of videotaped conversations between native speakers of American English and found semantic functions associated with different head movements. However, no head motion synchrony between the dyads was investigated in these studies.

In this present study, we investigated the dyadic interaction in adult-adult interaction using consensus-building task based on the earlier work by Yoshida et al. (2008). Specifically, we focused on empathy as an indicator for the degree of consensus building, and researched the relationship between the degree of empathy and head motion synchrony in the process of consensus building with native Japanese and English speakers. We compared the results between native Japanese and English speakers to reveal the degree of dependence between high and low context cultures, which may have significant importance in the process of intercultural consensus decision building.

II. MATERIALS AND METHODS

A. Experiment Task

The present study involves dialogue between two participants on a consensus building task using Japanese apartment information taken from the Japanese housing property website “SUUMO”. In this task, each participant was given two different apartment information which are closely related to each other, namely Material A and Material B. Materials A and B are two different apartments which contains the following information such as subway line, bus station, monthly rental and room type etc. Material A contains all the essential details of a Japanese apartment except the monthly rental price in Japanese yen. Material B contains another apartment details, which are incomplete. Both participants need to exchange information with each other to complete the missing information on their copy of material B and use it as a reference to make a guess on the unknown monthly rental price on material A. When the price has been agreed upon, a consensus was reached between both participants.

B. Participants

A total of 29 pairs of subjects participated in this present study. The subjects are either native English or Japanese speakers. For native English speakers, there are 4 pairs of male (age between 23 to 42) and 4 pairs of female (age 19 to 39). The native English speakers come from the following countries: 6 from US, 4 from UK, 3 from Canada, 2 from New Zealand and 1 from Australia. For native Japanese subjects, there are 11 pairs of male (age between 17 to 26) and 10 pairs of female (age between 18 to 26). All the subjects of each pair belong to the same gender. All the Japanese subjects knew each other and were able to talk to each other naturally. However, 5 out of 8 pairs of English subjects do not know each other beforehand. In this case, a 45 minutes icebreaker activity was conducted beforehand for these subjects to get to know each other better before the start of the experiment.

C. Experiment Environment

Figs. 1 and 2 show the schematic diagram and snapshot of the experiment environment. The experiment was conducted in a conference room. The humidity, temperature and brightness level of the room were adjusted to a comfortable level for the participants. During the experiment, there were only two participants in the room. The two participants were seated at opposite end of the table (1.75 m by 0.90 m). Two video cameras (CMOS Xacti Full HD, SANYO, Japan) were located vertically at a distance of 2.5 m away from the left and right hand side of both participants. Two book stands used to support the dialogue materials were positioned on the table facing each participant. Two laptops with Sennheiser headsets attached were positioned on the table to record the real-time vocal data of each participant. In addition, a voice recorder (ICD-UX533F, SONY, Japan) was also positioned on the table to record the real-time dialogue of the participants for playback. A bell was also positioned on the table for the participant to ring and alert the experimenter at the end of the dialogue. An accelerometer (WAA-006, OMRON, Japan) was attached to the forehead and body of each participant to record the head and body motion data in real-time.

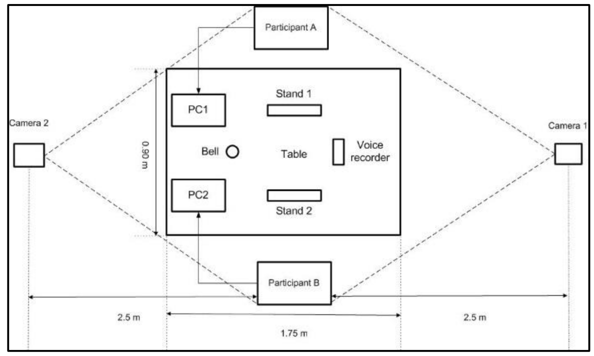

Fig. 1. Schematic diagram of experiment environment.

Fig. 2. Snapshot of experiment environment. Two digital video cameras capture the participants, two laptop with headsets record real-time vocal data, and accelerometers attached to forehead and body of participant record real-time head and body motion data.

D. Experiment Procedures

Before the experiment, the experiment procedures and rules were explained to the participants. The participants were informed that there was no time limit for the dialogue. When the participants had confirmed their understanding of the task, they were first given a practice session before the actual session. During the practice session, the participants were given a set of practice material. The participants exchanged information and reached a consensus on the target price based on their given set of practice materials. No questionnaire was administered during this session to assess the degree of empathy of both participants during the practice session. After the practice session, the participants were given a short break of 5 minutes, which was followed by the actual session. During the actual session, the participants were given a different set of materials. Accelerometers were secured to the forehead and body of each participant using elastic bands and each participant put on their respective headsets. The experimenter will leave the room during the experiment. When a consensus had been reached, one participant rang the bell on the table to alert the experimenter. After the dialogue, the target monthly rental price was revealed to both participants. Finally, the participants were given a questionnaire to rate their degree of empathy with each other by listening to the playback from the voice recorder once. However, the participants were allowed to listen to the playback twice at their own discretion. As a form of incentive and motivation for the participants, the participants were informed that their monetary allowance would increase if there was a close agreement (±5000 yen) between the agreed price and target price just before the practice session of the experiment. This information was disseminated to all native Japanese speakers. However, 5 out of 8 native English speakers were not informed of the incentives before the experiment as the experiment were conducted on two different occasions.

E. Empathy Evaluation

Evaluation of the degree of empathy was done using questionnaire. A sample of the questionnaire was shown in Fig. 3. The questionnaire uses a 5-level rating system, starting from 0 (very low empathy) to 4 (very high empathy). The participants were informed that if the content of the dialogue was based on facts, knowledge and logical thinking, the empathy level was low. However, if the content of the dialogue was based on mutual understanding and emotional feelings, the empathy level was high. Each participant listened to the playback from the voice recorder once and put a rating on the questionnaire every 30 seconds. For confidential reasons, a partition was placed in between each participant, so that each participant was not able to see each other's questionnaire during this process.

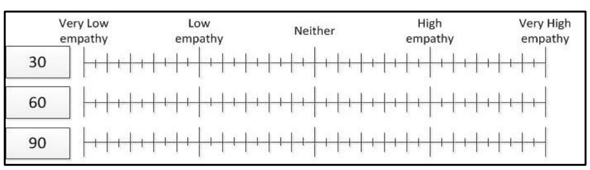

Fig. 3 Questionnaire to measure degree of empathy: Evaluation was done every 30 sec from 0 (very low empathy) to 4 (very high empathy).

F. Head Motion Synchrony Analysis

The method of analysis used to determine the synchrony of head motion between both participants is a four-step process: namely (1) calculation of head acceleration norm; (2) time-frequency analysis of head acceleration norm; (3) calculation of head motion indicator; and (4) calculation of time lag between head motion indicator of both participants using correlation analysis. The detailed mathematical modellings were explained in the following sections.

1) Calculation of Head Acceleration Norm

Fig. 4 shows the schematic diagram of the accelerometer attached to the forehead of the participant. Fig. 5 shows a typical head acceleration norm of one participant. The sampling period is 10 ms and the sampling frequency is 100 Hz. The head acceleration norm *a(t)* of a participant in the vertical direction, $a_x(t)$, lateral direction, $a_y(t)$ and forward-backward direction, $a_z(t)$ was calculated as follows:

$$a(t) = \sqrt{a_x^2(t) + a_y^2(t) + a_z^2(t)} \quad (1)$$

where $a_x(t)$ = Acceleration in vertical direction, $a_y(t)$ = Acceleration in lateral direction, $a_z(t)$ = Acceleration in forward-backward direction.

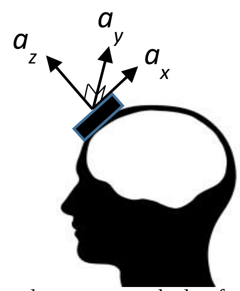

Fig. 4. Accelerometer attached to forehead of participant. a_x represents acceleration in vertical direction, a_y in lateral direction, a_z in forward-backward direction.

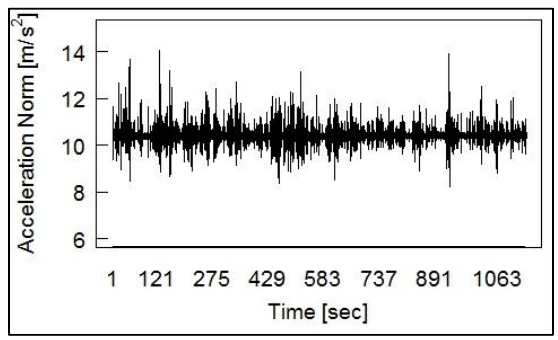

Fig. 5. Head acceleration norm. *x*-axis represents time in sec and *y*-axis represents acceleration norm in m/s^2.

2) Time-Frequency Analysis of Head Acceleration Norm

Time-frequency analysis of head acceleration norm was done using short-time Fourier transform (STFT). STFT of the head acceleration norm was calculated as follows:

$$F(\xi, t) = \int_{-\infty}^{\infty} f(t)\omega(t-\tau)\exp(-2\pi j\xi\tau)\, d\tau \quad (2)$$

where ξ = Frequency in Hz, $\omega(t)$ = Hamming window function, t = Central time of window function. The window length is 1.28 sec and frame shift is 0.1 sec. Fig. 6 shows a typical STFT plot of the head acceleration norm.

3) Calculation of Head Motion Indicator

From the STFT results of head acceleration norm of participant A and B, we extracted the data at 0.5 Hz interval between the frequency bandwidth of 1.0 Hz to 5.0 Hz and calculated the amplitude spectrum at each frequency band every 0.1 sec. Fig. 7 shows a typical plot of the head motion indicator between both participants.

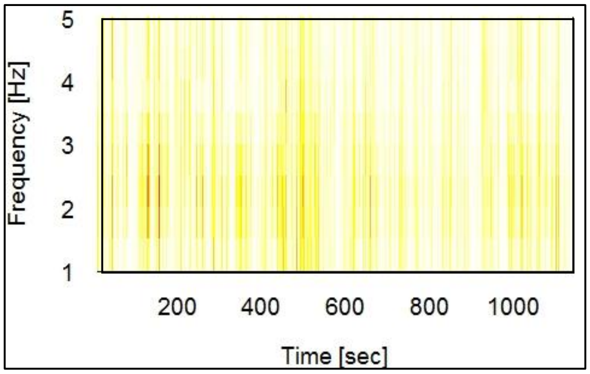

Fig. 6 Typical STFT plot. *x*-axis represents time in sec and *y*-axis represents frequency in Hz. Dark and light region represents high and low intensity regions respectively.

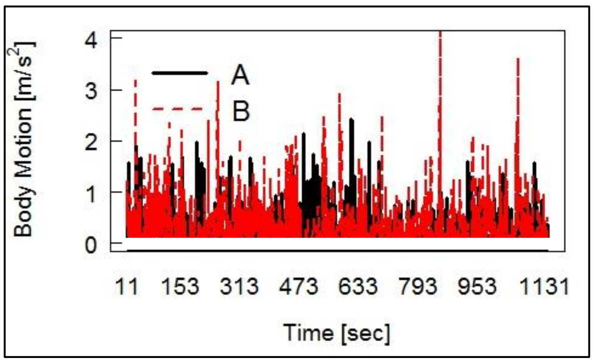

Fig. 7. Head motion indicator of both participants. *x*-axis represents time in sec and *y*-axis represents head motion indicator in m/s^2.

4) Calculation of Time Lag between Head Motion Indicator of Both Participants.

Finally, head motion synchrony between both participants was analyzed using Spearman rank-order correlation coefficient. We conducted a correlation analysis of the head motion indicator at 0.5 Hz intervals between the bandwidth of 1.0 Hz to 5.0 Hz, using a window length of 1.8 sec and a frame shift of 0.1 sec to determine the head motion synchrony between both participants in the time lag interval between -0.5 sec and 0.5 sec. We used a threshold of 90 percentile of the population data as the criterion for head motion synchrony. When the peak of two consecutive head motion indicators was above the 90 percentile line with a time lag between -0.5 sec to 0.5 sec, this was counted as head motion synchrony. The reason for a time-lag value between -0.5 sec and 0.5 sec is because Komori and Nagaoka (2010) reported that for a positive psychotherapeutic counselling session between clients and counsellors, the counsellors' body movements occur with a 0.5 sec delay. A positive time lag value indicates that participant A has a faster head acceleration motion as compared with participant B and a negative time lag value indicates otherwise. Fig. 8 shows a typical plot of the head motion synchrony between both participants for native English speakers.

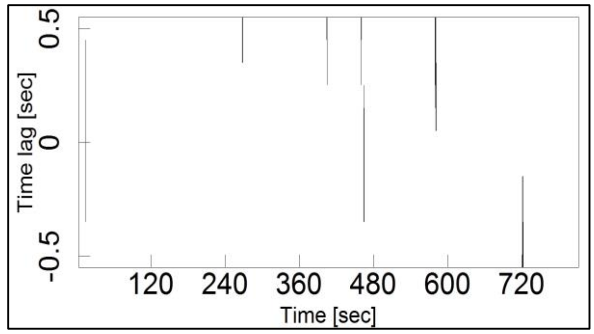

Fig. 8. Typical head motion synchrony plot between both participants. *x*-axis represents time in sec and *y*-axis represents time lag in sec.

III. RESULTS

A. Empathy Analysis

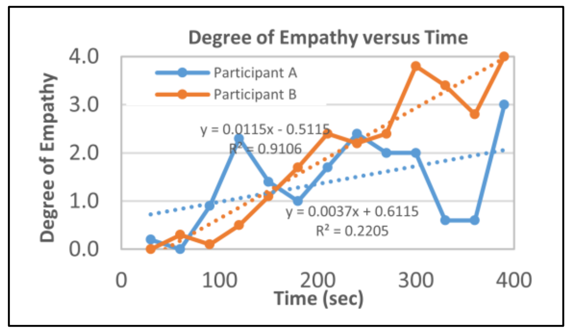

Fig. 9. Degree of empathy versus time for consensus building with native English speakers. Degree of empathy increases with time for both participants.

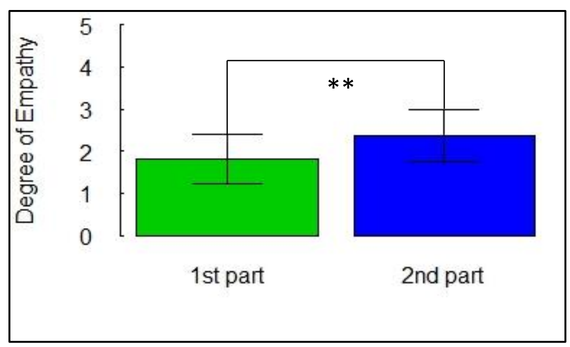

Fig. 10. Significant difference test for native Japanese speakers. Degree of empathy for second half of dialogue is higher as compared with first half (**: $P < 0.01$).

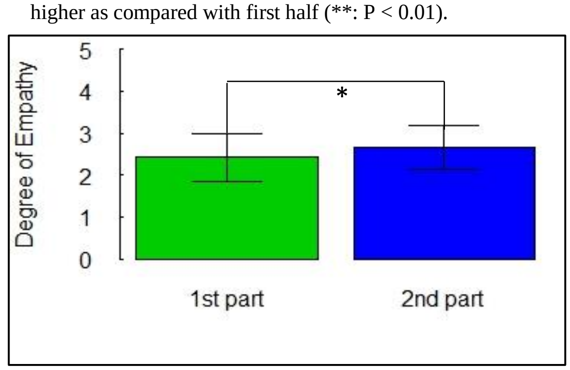

Fig. 11. Significant difference test for native English speakers. Degree of empathy for second half of dialogue is higher as compared with first half (*: $P < 0.10$).

Fig. 9 shows a typical degree of empathy versus time plot for consensus building with native English speakers. The data for first 60 seconds of dialogue were removed as the criteria for consensus-building task has not yet been defined. For native English speakers, the degree of empathy of both participants increases with time. Simple linear regression was performed for the data set of each participant and a positive correlation between degree of empathy and time was confirmed. Figs. 10 and 11 show the comparison of the mean degree of empathy for the first half and second half of dialogue for native Japanese and English speakers respectively. For both native Japanese and English speakers, the mean degree of empathy for the second half of dialogue was higher as compared with the first half. The mean degree of empathy for the first and second half of dialogue for native Japanese and English speakers were (1.8, 2.4) and (2.4, 2.7) respectively. There was a significant difference between the first and second half of dialogue for native Japanese speakers ($P < 0.01$) and native English speakers ($P < 0.1$) using Wilcoxon signed rank test.

B. Head Motion Synchrony Analysis

We calculated the mean value of head motion synchrony for the first and second half of dialogue when the frequency of head motion synchrony is significant for both native Japanese and English speakers. The mean value of head motion synchrony for the second half of dialogue is higher as compared with the first half for both native English and Japanese speakers when the frequency of head motion synchrony is significant. These results showed that head motion synchrony increases with time in the process of consensus building. In comparison with the results for degree of empathy for native Japanese and English speakers from Figs 10 and 11, the results showed that there is a positive correlation between head motion synchrony and degree of empathy in the process of consensus building for both native English and Japanese speakers. Tables 1 and 2 show the mean value of head motion synchrony between the first and second half of dialogue when the frequency of head motion synchrony is significant for native Japanese and English speakers respectively.

TABLE 1
MEAN VALUE OF HEAD MOTION SYNCHRONY FOR NATIVE JAPANESE SPEAKERS.
(**: $P < 0.05$, *: $P < 0.10$)

Frequency (Hz)	Time Lag (sec)	Mean Head Motion Synchrony		P
		First Half	Second Half	
1.0	0	0.12	0.22	*
	0.1	0.13	0.24	*
	0.2	0.13	0.22	**
	0.3	0.11	0.19	**
2.5	0.5	0.34	0.50	*
4.5	0.3	0.33	0.51	*
	0.4	0.33	0.51	*
	0.5	0.30	0.46	*
5.0	0.4	0.32	0.50	*
	0.5	0.30	0.47	*

TABLE 2
MEAN VALUE OF HEAD MOTION SYNCHRONY FOR NATIVE ENGLISH SPEAKERS.
(**: $P < 0.05$, *: $P < 0.10$)

Frequency (Hz)	Time Lag (sec)	Mean Head Motion Synchrony		P
		First Half	Second Half	
1.0	0.3	0.05	0.17	**
	0.4	0.10	0.28	**
2.0	0.3	0.24	0.52	*
2.5	0.3	0.16	0.51	*
	0.4	0.16	0.48	*
	0.5	0.17	0.49	*
4.0	0.3	0.20	0.37	**
4.5	0.3	0.18	0.43	*
	0.4	0.23	0.52	*
	0.5	0.28	0.50	*
5.0	0.1	0.13	0.35	*
	0.2	0.13	0.40	**
	0.3	0.15	0.43	**
	0.4	0.22	0.41	*
	0.5	0.25	0.45	*

C. Comparison of results

Finally, we performed a significance test using Wilcoxon signed rank test between the time lag interval (0 sec to 0.5 sec) and head motion frequency (1.0 Hz to 5.0 Hz) to determine the degree of significance of head motion synchrony at high and low frequency for both native English and Japanese speakers. Table 3 and 4 show the significance test results of head motion synchrony for native English and Japanese speakers respectively. The results showed that head motion synchrony at low, medium and high frequency of 1.0 Hz, 2.5 Hz and 5.0 Hz respectively were significant for both native English and Japanese speakers (Wilcoxon signed rank test, $P < 0.05$, $P < 0.10$). However, at low head motion frequency of 1.0 Hz, the time lag for native Japanese speakers are shorter (0 sec to 0.3 sec) (Wilcoxon signed rank test, $P < 0.05$, $P < 0.10$) as compared with native English speakers (0.4 sec to 0.5 sec) (Wilcoxon signed rank test, $P < 0.05$). Furthermore, at high head motion frequency of 5.0 Hz, the time lag for native Japanese speakers is longer (0.4 sec to 0.5 sec) (Wilcoxon signed rank test, $P < 0.10$), whereas the time lag for native English speakers varies from 0.1 sec to 0.5 sec (Wilcoxon signed rank test, $P < 0.05$, $P < 0.10$). These results may be attributed to different context cultures of head motion between native English and Japanese speakers.

TABLE 3
SIGNIFICANT DIFFERENCE TEST OF HEAD MOTION SYNCHRONY FOR NATIVE ENGLISH SPEAKERS
(**: $P < 0.05$, *: $P < 0.10$)

Time Lag (sec)	Native English Head Motion Frequency (Hz)								
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0.0	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
0.1	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*
0.2	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	**
0.3	n.s.	n.s.	*	*	n.s.	n.s.	**	*	**
0.4	**	n.s.	n.s.	*	n.s.	n.s.	n.s.	*	*
0.5	**	n.s.	n.s.	*	n.s.	n.s.	n.s.	*	*

TABLE 4
SIGNIFICANT DIFFERENCE TEST OF HEAD MOTION SYNCHRONY FOR NATIVE JAPANESE SPEAKERS
(**: P < 0.05, *: P < 0.10)

Time Lag (sec)	Native Japanese Head Motion Frequency (Hz)								
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
0.0	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
0.1	*	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
0.2	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.
0.3	**	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*	n.s.
0.4	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	*
0.5	n.s.	n.s.	n.s.	*	n.s.	n.s.	n.s.	*	*

IV. DISCUSSION

The present study investigated the correlation between degree of empathy and head motion synchrony in the process of consensus building with native English and Japanese speakers. For both native Japanese and English speakers, we found that the mean head motion synchrony for the second half of dialogue was higher as compared with the first half. In addition, the mean degree of empathy for the second half of dialogue was higher as compared with the first half with a significant difference for both native Japanese and English speakers. These results showed that a positive correlation exists between degree of empathy and head motion synchrony for both native English and Japanese speakers. These results were consistent with the research by Koss and Rosenthal (1997), and Ramseyer and Tschacher (2008).

In addition, we performed a significance test for both native English and Japanese speakers to determine the degree of significance of head motion synchrony at the head motion frequency between 1.0 Hz to 5.0 Hz with a time lag between 0 sec to 0.5 sec. The result showed that head motion synchrony at low, medium and high frequency of 1.0 Hz, 2.5 Hz and 5.0 Hz is common for both native English and Japanese speakers. However, at low head motion frequency of 1.0 Hz, the time lag for native Japanese speakers are shorter (0 sec to 0.3 sec) as compared with native English speakers (0.4 sec to 0.5 sec). In addition, at high head motion frequency of 5.0 Hz, the time lag for native Japanese speakers are longer (0.4 sec to 0.5 sec) whereas the time lag for native English speakers varies from 0.1 sec to 0.5 sec. These suggested the context culture of head motion at low and high frequency are different between native English and Japanese speakers. We need to perform a video analysis of the dyadic interaction with native Japanese and English speakers to reveal the difference in context culture of head motion.

Finally, it should be noted that the significance test of head motion synchrony for native English speakers was based on the combined data from the incentive group (3 pairs) and non-incentive group (5 pairs). As such, we were unable to determine the effects of incentive on head motion synchrony and degree of empathy as it is beyond the scope of this study. In addition, the results for native English speakers were based on the combined data of participants from different native English-speaking countries. It should be noted that even between native English speakers, there exist different context culture of head motion. For future work, we will continue to collect more data from native English speakers under the same condition (i.e. with incentives) to reveal the degree of dependence of head motion synchrony and empathy on high and low context culture between native Japanese and English speakers. As an extension of this present framework, we wish to apply the timing results in engineering applications to realize a fluid human-robot communication in the near future.

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