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Body and Psychological State Synchrony and Change by the Grant of Prior Knowledge

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***Abstract*—According to recent studies, the existence of previous knowledge has been found to be involved in more advanced knowledge acquisition in the human study. Further, when the body motion synchronized, empathy for others has also been found to be important key of interaction. In this study, we focus on those points, by looking at whether the psychological state and body motion are affected by the prior knowledge, and of evaluating the internal understanding and consent of knowledge understanding from the body synchrony will consider the possibility. Specifically, we conducted the experiment lecturer task on teacher-student interaction. There are two group conditions. One is given prior knowledge, the other is not given prior knowledge. The students of the two groups are given same lecture. psychological state is measured using a questionnaire, physical motion is measured using an acceleration sensors. The results reveal that in prior knowledge group, the psychological synchrony is likely to occur more than no prior knowledge group and the body synchrony is found to occur at an early stage with closer to 0 time lag. These differences are occurred due to the involvement of the lecture. The students with prior knowledge is more likely to be involved in the lecture more than the students with no prior knowledge.**

I. Introduction

In recent years, due to the development of a wearable device, we can be calculating the data of the human interaction field from the body motion and linguistic information in daily lifestyle.

It is generally known that there is overt-potential side in human interaction. In addition, overt communication channel in human interaction is divided into linguistic and no-linguistic channel. Among that, Inoue et al reported that head motion synchrony is occurred when experimental participants have the subjective empathy about the interaction [1].

Previous study [2] reported that in the course of human to understand the story, it is important that they have already acquired some knowledge about new information. In other words, when human perceive the new knowledge, it is easier to create the knowledge linkage with the existing knowledge each individual already have.

In this study, we focus on this point to investigate the relationship between prior knowledge and body motion synchrony, and between prior knowledge and psychological subjective in human learning situation. Specifically, we divide the participants into two condition pairs, one will be given the prior knowledge before the lecture task and another one will be given no information about the lecture before the lecture task. The same lecture content is given by the teacher to both conditions. The measurements on physical motion and internal state are collected by using acceleration sensors and questionnaires respectively.

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II. Methodology

In this study, we carried out the lecture task experiment with two pairs in each trail to investigate the effects of existing knowledge in learning environment, one pair with prior knowledge related to the actual lecture and another pair with no information about the lecture. In each pair, the participants take the role of 1 teacher and 1 student. In actual lecture, the teacher participant memorized the lecture content about 900 characters (one A4 paper), and convey naturally to the student participant. Lastly, the participants took a small test and questionnaires after the actual lecture.

In our analysis method, we used acceleration data measured from accelerometer that attached on the forehead of the participants together with the quantified psychological data measured from the questionnaires to analyze the differences of body motion and psychological change between the pair with prior knowledge and no prior knowledge.

III. Experimental Design

A. Experimental Condition

We selected two articles as the materials in this study. Both articles are published in the National Geographic site. The first article (A) title is “Why we can forget English word immediately, but cannot forget the breakup experience ?” in Japanese version. The second article (B) is “Naps clear brain’s inbox, improve learning” in Japanese version. We selected article A as prior knowledge because it provides general information about brain function and article B as actual lecture content because it is detailed information about brain function. Additionally, the two articles are related to each other, which allows the student to learn the basic information and move on to the

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more advanced information easily.

B. *Experimental participant*

All participants are Tokyo Institute of Technology's students. They are 22 to 26 years old Japanese male participants. The relationship of the participants in each pair is non-friend. We grouped the participants into a set of three, one as teacher participant, and two as the students (with prior knowledge and no prior knowledge). Same teacher teach both prior knowledge group and no prior knowledge group. This grouping process is done randomly.

C. *Experimental Environment*

1) Hardware

We set the experiment room as follows. Table is located at the center of the room. The participants' seats are fixed at the opposite side of each other with the table between them. Two web cameras are placed on the table facing to the participants on each edge. Two personal computers are also placed on the table. There are six motion capture cameras (Nobiteck Co., Ltd.) fixed around the table together with three video recorders (SANYO Co., Ltd.) . Most importantly, seven acceleration sensors (ATR Promotions Co., Ltd.)are used to attach each participant as shown in Fig 2.

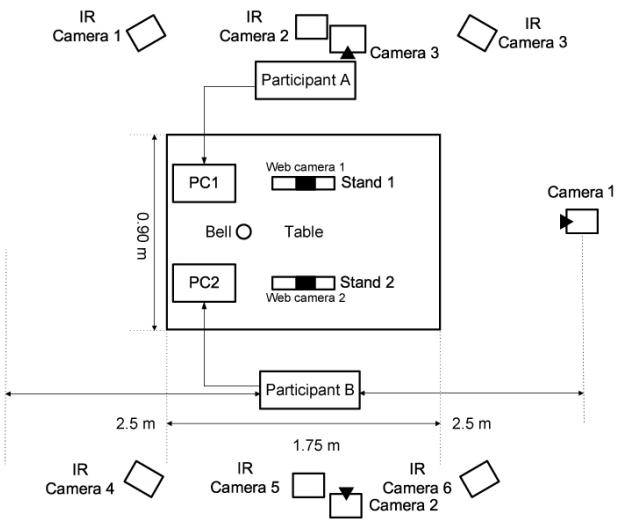

fig. 1. Environment of experimental room. Teacher and Student are sitting in opposite.6 motion capture camera surroundings, 3 video camera, 2 web camera, and 2 microphone.

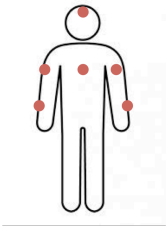

fig. 2. Accelerometer attached on the participant's body. Head, Chest, Right upper-arm, Right lower-arm, Left upper-arm, Left-lower-arm.

2) Software

The acceleration sensor were connected to 2 PC placed on the table via Bluetooth. Further measurement time was synchronized by SyncRecord Software(ATR Promotions Co., Ltd.)

3) Accelerometer attaching

The accelerometer sensors used in our study are small wireless multi-function accelerometers: TSND 121 produced by ATR Promotions Co., Ltd. The sampling frequency is set to 100 [Hz]. On order to observe the head motion as body motion synchrony, we attached the accelerometer to the participants' forehead. The x-axis, y-axis, and z-axis of the accelerometers are set as shown in Fig. 3.

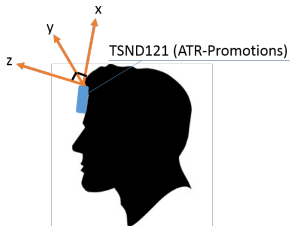

fig. 3. Accelerometer attached to forehead of participant. x represents in vertical direction, in lateral direction z in forward-backward direction.

D. *Procedure*

For prior knowledge group's students, the experimenter gave prior knowledge information to them before the actual experiment. After giving the prior knowledge information, the student participants took the small test about prior knowledge to ensure the understanding in prior knowledge. For no prior knowledge group's students, there was no prior knowledge information provided. And also the teacher was provided no prior knowledge. After finishing the prior knowledge procedure, we moved on to the actual experiment procedure.

1) We explained the rules and content of the experiment to both teacher and students participants. Then, we attached the acceleration sensors on the participants' body. We also asked the teacher to teach the students naturally. In this study, we did not attach a clock and told the participants that there is no time constraint for lecturing so that the teacher participant would not be worried about the time when giving a lecture. The experimenter, therefore, asked the participants to remove their watches and mobile phones as well. In addition, we asked the teacher participant to use natural gestures and convey the lecture in their own way. The student participant also was free to use natural supportive response such as nodding, short utterances. Lastly, we informed the student participant that there will be a test after the lecture in order to increase the concentration in the lecture.

2) Before the beginning of the experiment, all experimenters went out from the experiment room except the experimenter who indicates the signal of lecture starting point. We used the lecture starting point signal as the time synchronization signal among all sensors used. After the

signal, the teacher started teaching the student.

3) After finishing the lecture, the teacher participant rang the bell on the table and then the experimenter will indicate the signal of lecture ending point.

4) A small test about the lecture content was done by the student participant after the lecture task.

5) After finishing the test, the participants were asked to complete the questionnaire about the interaction during the lecture task and the questionnaire about the subjective internal state on understanding, interest and empathy. Once all questionnaires are done, the experiment is completed.

E. Analysis Method

1) Subjective Analysis Method

In this study, 3 types of questionnaires were used to evaluate the interaction and subjective internal state. Firstly, before the actual experiment, the prior knowledge group's students were provided the questionnaire to measure their interests toward the lecture topic. The purpose of this questionnaire is to evaluate whether having prior knowledge can increase the level of interest in the lecture topic or not. The questionnaire content is shown in Table 1.

TABLE I

QUESTIONNAIRE CONTENT OF BEFORE EXPERIMENT

No.	Student's Questionnaire	No.	Teacher's Questionnaire
1	Are you interested in this topic?	1	Do you know well this topic?
2	Do you have already know about this topic?	2	Do you think you are good teacher?
3	Do you think this topic is related to your daily life?	3	Are you interested in this topic?
4	Do you want to know more about this topic?	4	Do you want to teach this topic for your students?

Table.1. Questionnaire before experiment. For evaluating participants interest, motivation.

Secondly, after the student participant finished the small test after the lecture, questionnaire about the interaction was provided to both teacher and student. The purpose of this questionnaire is to evaluate their interaction during the lecture and to compare the effect of the prior knowledge on interest, understanding and motivation in both prior knowledge and no prior knowledge group. In each topic, there are three to four items asked. The participants intuitively evaluated the interaction. The content of the questionnaire on the empathy part is based on Zoll et al.'s experiment [4].

Thirdly, we have subjective internal state questionnaire. The purpose of this questionnaire is evaluate the internal state by observing their own replayed interaction behaviors on the screen. The participants evaluated their interaction behaviors in term of understanding, interest and empathy for every 30 seconds by watching their interaction recording. The student focused on own subjective body language while the teacher also focused on the student's body language as well.

TABLE Ⅱ

QUESTIONNAIRE CONTENT OF AFTER EXPERIMENT

No.	生徒用アンケート	No.	先生用アンケート
1	Do you want to use the knowledge in your daily life?	1	Do you think your student could understand new knowledge well?
2	Do you think you want to know about the topic after the hearing lecture	2	Did you think your student couldn't keep up with your lecture?
3	Do you grow your motivation to study after the hearing lecture?	3	Are you satisfied with your student's reaction to the lecture?
4	Did you concentrate the lecture?	4	Did you interest your student among your lecture?
5	Do you feel the significance of the topic?	5	Are you satisfied with the communication with your student?
6	Do you think your teacher pay attention to you?	6	Do you think you could communicate with your student well?
7	Were you satisfied with the lecture	7	Do you think your student concentrated your lecture?
8	Did you think the communication was smooth between teacher and student?	8	Do you think your student was going to know this topic after your lecture?
9	Did you think your teacher interest you among the lecture?	9	Could you grow your student's motivation to know this topic?

Table. 2 . Questionnaire after experiment. For evaluating participants interest, attention, and motivation relied on lecture.

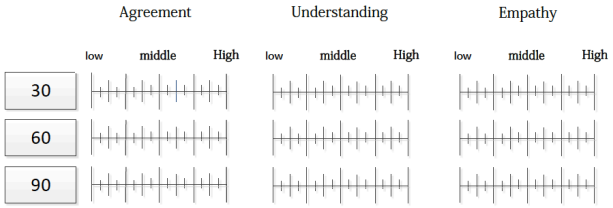

fig. 4. Questionnaire to measure degree of empathy: Evaluation was done every 30 sec from row, middle, and high.

2) Physical Indicator Analysis Method

In this study, we measured body synchrony between the teacher and the student by using the acceleration of each individual, retrieved from the acceleration sensors. The processing sequences are as follows.

Step 1: Calculating the acceleration norm

We use the acceleration sensors attached on the forehead of both participant to measure the head motion acceleration. The sampling frequency of the sensors are set to be 100 (Hz). We calculated the norm |a(t)| from axial directions (x, y, z). The equation is shown as follow.

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

Time resolution of the time t was set to 0.01 (sec). We illustrate this calculation example in fig.5. Fig. 5 shows that nodding is represented as a relatively large peak.

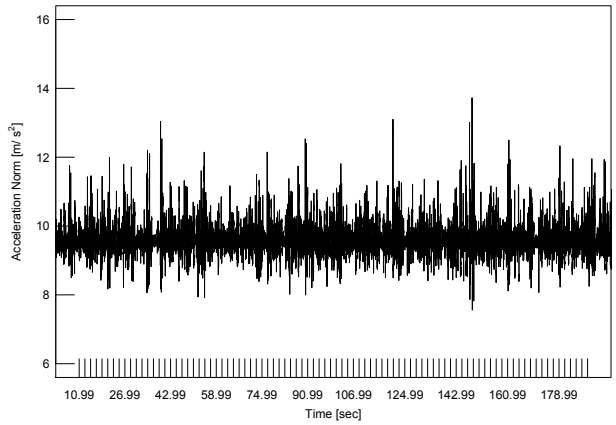

fig. 5. Head acceleration norm. x-axis represents time in sec and y-axis represents acceleration norm in m/s^2

Step 2 : Time-Frequency Analysis of Head Acceleration Norm

Once the acceleration norm is calculated, we applied short-time Fourier transform (STFT) using a Hamming window $\omega(t)$ as a window function. The window width is set to 1.28 [sec]. STFT of the head acceleration norm was calculated as follow:

$$F(\nu,t) = \int_{t-0.64}^{t+0.64} a(t')\omega(t')\exp(-2\pi i t'\nu)dt' \qquad (2)$$

where ν = Frequency in Hz, $\omega(t)$ = Hamming window function, t = Central time of window function. We decided to move the window for each 0.1 (sec) as the time to calculate the Fourier transform. Furthermore, by applying the linear interpolation with respect to the frequency direction ν, we created a continuous three-dimensional data to the frequency direction. We illustrate this calculation example in Fig.6. Fig. 6 shows that the more black color is the greater of the amplitude spectrum (high intensity).

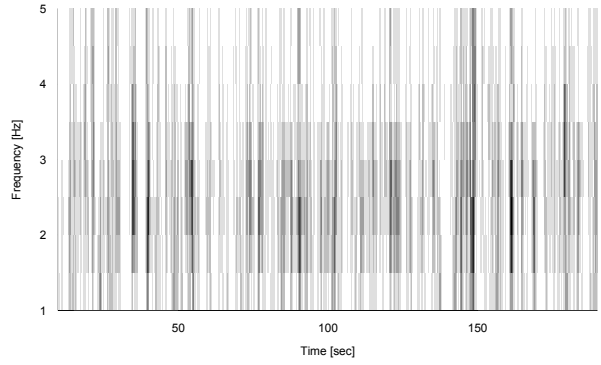

fig. 6. Typical STFT plot. X-axis represents time ins sec and y-axis represents frequency in Hz. Dark and light region represents high and low intensity regions respectively.

Step 3 : Calculation of Head Motion Indicator

Against the calculated short-time Fourier transformation in Step 2, with respect to the frequency band ranging from 1.0 (Hz) from 5.0 (Hz), and extracts an amplitude spectrum by 0.5 (Hz) the vertical axis, a horizontal axis as a time. It shows the calculation example in fig.7. We extracted the phenomena of body synchrony from the result.

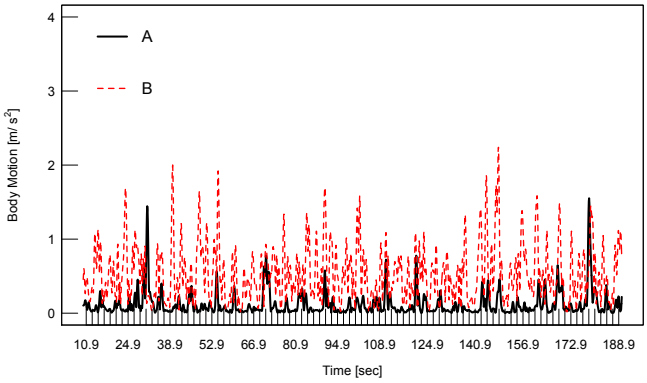

fig. 7. Head motion indicator of both participants. X-axis represents time in sec and y-axis represents head motion indicator in m/s^2

Step 4 : Calculation of Time Lag between Head Motion Indicator of Both Participants

We calculated spearman's rank correlation form the distribution of the frequency spectrum that is divided for each 0.5 (Hz) extracted in Step 3 to detect the body synchrony. After that, we determined the synchrony determination condition described as follows. Window width of correlation was set to 1.8 (sec), the maximum shift time of the window is 0.5 (sec), the window width of the calculation it was decided to shift to each 0.1 (sec). The reason for defining the window width and 1.8 (sec), the time interval at which a human can synchronize a 1.8 [sec], P.Fraisse reported the it when it becomes difficult to recognize together as a single rhythm pattern if it exceeds the upper limit 1.8 (sec) [5]. We set also the maximum deviation time 0.5 [sec]. The reason is that Komori Nagaoka et al reported that it is due to the body motion of the counselor who had received high evaluation is running behind 0.5 [sec] from the body motion of the client in the counseling dialogue [3].

In This study, we set two conditions as follows to determine the criteria for body synchrony.(1) rank correlation of Spearman is a significant positive correlation. (2) Average value of the amplitude spectrum of the body motion of the subject A and B is at least 90% of the total amplitude spectrum. The reason for (2) is that we can avoid the problem that the accidentally detection of the body synchrony because of short time and high resolution calculation of correlation to detect the synchrony in this study. It shows a calculation example of body synchrony extraction in fig.8. In this figure, we can see happening the body synchrony where the part has been filled with black color

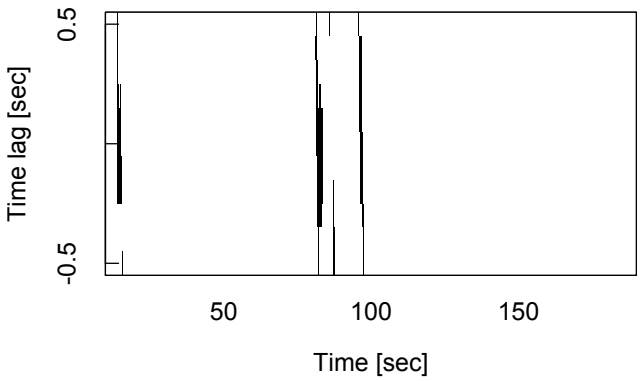

fig. 8. Typical head motion synchrony plot between both participants. x-axis represents time in sec and y-axis represents time lag in sec.

IV. Results

A. Psychological data Results

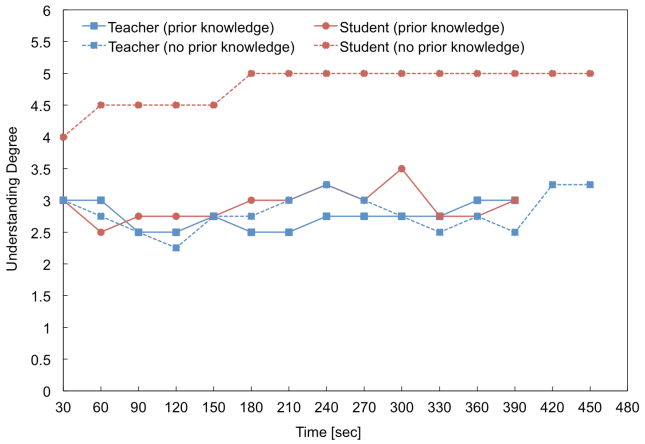

fig. 9. Degree of Understanding versus time for lecture tasks. The students' result between prior knowledge and no prior knowledge group was significantly different. However, there is slightly different in teacher's result.

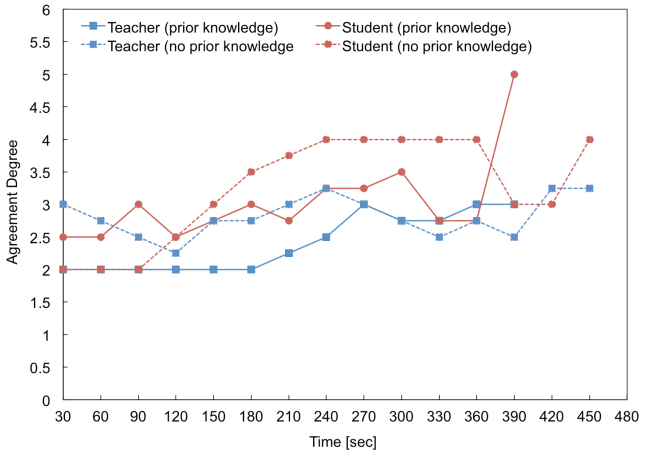

fig. 10. Degree of Interest versus time for lecture tasks. The degree of interest in both groups increases according to the time.

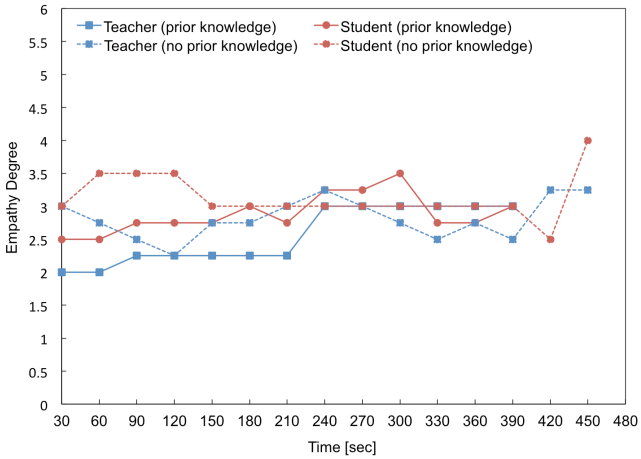

fig. 11. Degree of Empathy versus time for lecture tasks.

Fig.9,10,11 shows the results of questionnaire that was given to the teacher and student participants. We can see the representation of changing in the degree of understanding, interest, and empathy against the time line.

First, in fig.9. it shows that between prior knowledge and no prior knowledge group, the evaluation on understanding from the student side is very different. However, it can be seen that no significant change with respect to the teacher side. This means that the difference in psychological synchrony of teachers and students is occurred. Fig.10 demonstrates that student with prior knowledge gave higher score compared to the student with no prior knowledge from start until 120 seconds, after that , the degree of interest of the student with no prior knowledge is found to be increased. And fig.10,11 show that the results of the student with prior knowledge has more tendency of intense variation to the time line than the student with no prior knowledge.

TABLE Ⅲ
ABSOLUTE DIFFERENCE OF EACH DEGREE AVERAGE

Degree	Prior Knowledge	No Prior Knowledge
Understanding	0.23	1.86
Interest	0.55	0.72
Empathy	0.33	0.42

Table.Ⅲ. Absolute difference of average understanding degree, interest degree, and empathy degree in table. Calculated by following formula |Teacher's Degree – Student Degree| / total points number.

In Table.3, we calculated the difference between the data of the teacher and student participants obtained in fig.9,10,11. using arithmetic mean. We calculated each data of understanding, interest and empathy respectively. The results from the table Ⅲ present that the score of the pair with prior knowledge is generally lower than the pair with no prior knowledge.

B. Physical Data Results

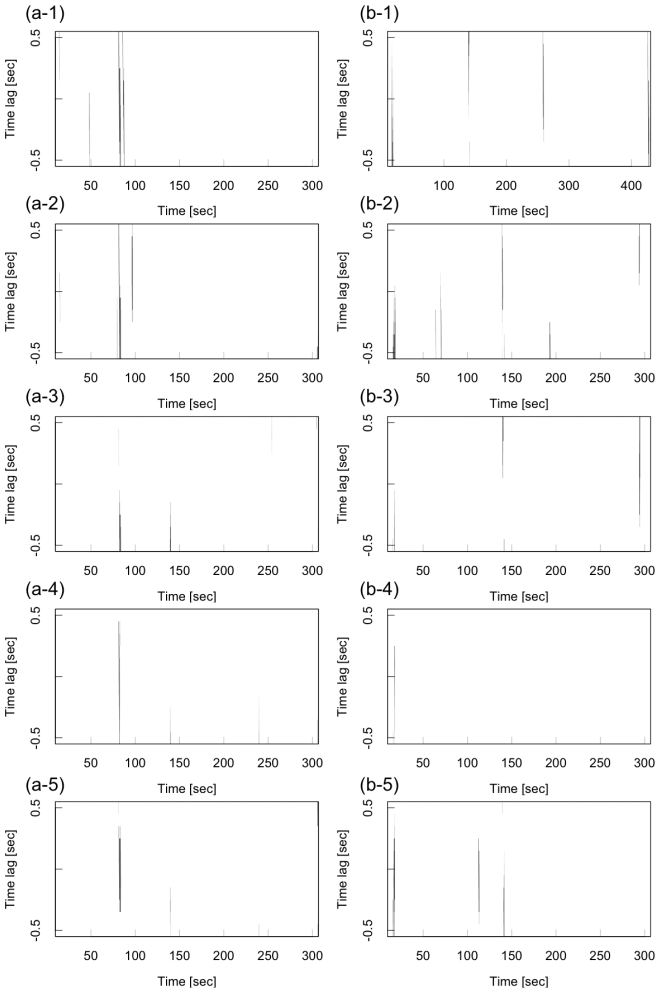

fig. 12. Head motion synchrony plot of teacher and student. (a) is the prior knowledge pair series, (b) is the no prior knowledge pair series.

The results of body tuning detection is shown in fig.12. Sequence of (a) shows the pair with prior knowledge, and sequence (b) shows the results of a pair with no prior knowledge. The increase in the index of (a-n) represents the frequency from 1.0 (Hz) to 5.0 (Hz) shifted by 1.0 (Hz). We can see from the results in fig.12 that regardless of frequency changes, sequence of (a) is found to occur in early state and the synchrony timeline is also occurred according to the time lag axis.

V. Discussion

A. Psychological data

We can say that psychological synchrony and the psychological state stabilization are appeared by applying prior knowledge, because the all of the psychological average degree of understanding, interest and empathy become smaller when the student participant has prior knowledge on the lecture topic while the degree of interest and empathy are fluctuated when the student participant has no prior knowledge on the lecturer topic. The reason why this phenomena was occured is that prior knowledge might facilitate and stabilize the student participant's understanding subjective feeling

B. Physical data

The body synchrony phenomena occurred earlier in the pair who has prior knowledge due to the fact that they obtained related knowledge to the new information. Changes in time lag are reported to vary by participation structure interaction according to the previous study [1]. They state that the relationship of leader and follower in free conversation's time lag occurs really close to 0. We can also observed that the pair with prior knowledge has higher chance to have close to 0 time lag and more likely to emerges the leader and follower relationship than the pair with no prior knowledge. It is because the student with prior knowledge has already known the lecture theme and can follow the lecture content more easily.

C. Conclusion

In this study, we learn that psychological state is more easily synchronized and body synchrony appears at an earlier stage. It was shown that the time lag is likely to spread to a large area when we provide prior knowledge to student. The difference between these results can be explained by the presence or absence of prior knowledge. The lecture content is interpreted and perceived differently between prior knowledge and no prior knowledge group even though all students were given the same lecture. Difference in the semantic content of the individual that occurs when creating the knowledge linkage with the new information results in the difference in body motion.

Acknowledgment

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