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Relation between Synchronization of Head Movements and Degree of Understanding on Interpersonal Communication

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Abstract— **To investigate relation between synchronization of nonverbal behavior and degree of understanding, we examined a task-oriented communication. The task consisted of an explanation from a lecturer to a student. As a nonverbal behavior, head movement was measured using an accelerometer. Degree of understanding was subjectively evaluated by the student for each section of the explanation. As a result, high degree of understanding tended to be observed in the period of negative correlation between each head movement. The result suggested that synchronization of each head movement related with degree of understanding. The result also indicated that degree of understanding was high when speaker's head and listener's head moved alternately.**

I. INTRODUCTION

A. Motivation

At the scene of project management, some common problems in communication have been reported. For example, the problems are "lack of clarity", "not listening" and "personal attacks" [1]. These problems could lead to disagreement and loss of productivity within human organization. Also, communication process can be divided into following conditions: "transmitted", "received", "understood", "agreed", "converted to useful action" [1]. Especially, the conditions "understood", "agreed", "converted to useful action" are relatively hard to realize [1]. This study focuses on the process of understanding because it is surely important to gain agreement and useful action.

Estimation of listener's understanding from their nonverbal behavior has been reported in e-learning situation [2]. In their study, individual nonverbal information has been used to characterize degree of understanding [2]. However, understanding is a process of bidirectional communication. Only individual nonverbal information of a listener cannot capture the relationship between a speaker and a listener. For further progress, we think it is important to consider relational or social properties.

It is reported that nonverbal behavior tend to spontaneously synchronize thorough communication on particular relationship [3]. It is called interpersonal synchronization. Interpersonal synchronization was suggested to be related to sharing of the context of the communication. Synchronization of speech latency was often observed as agreement between two participants become high in a process of consensus building [4]. Also, people tended to judge the conversation partner as warm personality when the response time between two people synchronized [5]. Posture and body movement also tended to synchronize when the conversation pair was intimate [6]. Thus, interpersonal synchronization was suggested to be related with not only individual state but also relational property of the pair on communication. Therefore, we focus on interpersonal synchronization to investigate degree of understanding.

The purpose of this study was to investigate the relationship between synchronization of nonverbal behavior and degree of understanding. As a kind of nonverbal behavior, head movement is known to play important roles in communication process. The functions of head movements are "agreement", "telling the end of speech", "insisting the order of speech", "filling the silence", "giving responses", "taking rhythm" and "deny" [7]. Also, back-channeling such as short response and nod was found to happen as speakers move their head [7]. Thus, head movement was observed not only in a listener's behavior but also in a speaker's behavior as important signals on conversation.

Previous studies suggested that people move their head for smoothness of communication. Also, speaker's head movement and listener's head movement were found to often occur at the same time. From previous studies of nonverbal behavior [4] [5] [6], synchronization between each head movement is assumed to play an important role in the process of understanding on communication. However, it is not clear whether synchronization of each head movement happens in a process of understanding between a speaker and a listener and whether synchronization is related to degree of understanding. To clarify it, we designed an experiment of task-oriented dialogue. We investigated synchronization of head movements between a speaker and a listener through the experiment. Head movement was measured using an accelrometer. Degree of understanding of a listener was also examined. After the task, listeners evaluated their understanding subjectively about what the speaker told. The evaluation was conducted at each period of 30 seconds in the conversation of the experiment. Then, the relationship between synchronization of head movement and degree of understanding was investigated through correlation analysis.

II. METHODS

A. Task

A task called "Lecture task" was designed in order to achieve the purpose of present study. Lecture task was made

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to observe the process of one-sided information transmission. The task consisted of an explanation from a speaker to a listener. Two people played a role of "Lecturer" and "Student" each. Lecturer chose and read an article of Wikipedia in advance. Once the Lecturer understood the article enough, Lecturer explained Student the article. Student was not allowed to ask question during the measurement. Student was only permitted to say short response such as "yes". Participants followed the rules below.

- "Lecturer" cannot show the article to the "Student"
- "Lecturer" must tell the end of the explanation
- Do not touch anything during experiments
- Keep eye contact
- Speak loudly and clearly
- Focus on the task

The article of "Universe" in Wikipedia was selected for the first experiment. The article of "Baltic states" in Wikipedia was selected for the second experiment.

B. Participants

Two people were sampled for this case study. Participants were two students of graduate school (a: twenty-five-year old male, b: twenty-eight-year old male). The participants agreed the contents of the experiment which was explained before the experiment. Experiments were conducted for two times with the combination (left: Lecturer, right: Student) of (a, b) and (b, a). In order to promote the conversation, we set the pair based on previous study [8] as follows. The pair was same grade, same sex, same nationality and within five-year-old difference.

C. Experimental setup

Based on previous study [4], we set the experimental environment as follows.

- Only two participants left in the separated space
- Light, noise, temperature were suitable for conversation
- Participants sat the seat at a distance of 2 m

Speech was measured using mono directional microphone developed by Buffalo inc. Head movement was measured using small accelerometer developed by Wireless Technologies, inc. The sampling rate of the accelerometer was 100 Hz. Each participant wore the sensor on their forehead with band as shown in Fig. 1. Voice recorder was set on the table to evaluate subjective degree of understanding later.

D. Procedure of subjective evaluation

In order to investigate the relationship between the synchronization of head movement and degree of understanding, Student evaluated degree of understanding at each period after the task. Student judged degree of understanding by listening recorded speech. The experimenter stopped the play of the recorder and asked "Did you understand what Lecturer explained in the past 30 seconds?". Student remembered the degree of understanding and rated it using five point scale at each 30 seconds. Items of five point scale were *strongly agree, agree, neither, disagree and strongly disagree*. Each answer was labeled as five, four, three, two, one point. The answers were mapped on time series of head movement as abbreviated label "U". Recorded voice was only used for evaluation because Student should not judge their mental state using visual information of head movement.

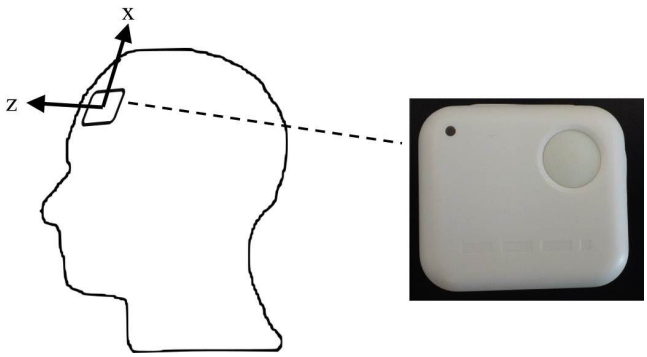

Fig. 1. Orientation of the attached accelerometer. Vertical direction (x) and front-back direction (z) were only used to detect approximate nodding. The accelerometer was developed by Wireless Technologies, inc. The sampling rate was 100 Hz. The sampled data from accelerometers was automatically synchronized.

E. Analysis method of head movement

In this research, nod was approximately defined as vertical and front-back oriented head movement. The vertical and front-back directions of acceleration were the objects of analysis. Raw data of head movement were gained at each x, y, z axis. Orientation of y was not in consideration based on the definition of nod. Total magnitude of two-axis was calculated using (1) in order to quantify the power of head movement.

$$XZnorm(t) = \sqrt{x(t)^2 + z(t)^2} \tag{1}$$

Here, time resolution of $XZnorm(t)$ was 0.01 second. Maximum values from each ten points were extracted. From the extracted maximum values, a new time series was composed. Time resolution of the new time series was 0.1 second. This conversion was calculated because relatively macroscopic observation was suitable for the analysis of head movement.

The purpose of this study was to investigate the synchronization of the conversation pair, and to examine how it relates with the degree of understanding. Synchronization was approximately quantified by calculating correlation between two time line of head movements at each 30 seconds. After that, we investigated how it relates with the subjective degree of understanding using correlation analysis. Spearman's rank correlation coefficient r_s was used because statistical normality of the data could not be supposed. The correlation coefficient was regarded as a characteristic of synchronization between each head movement.

III. RESULTS

Duration of explanation was about four minutes and twenty seconds for the first experiment. Therefore, the subjective evaluations for each 30 seconds were conducted at nine points. Duration of explanation was about two minutes

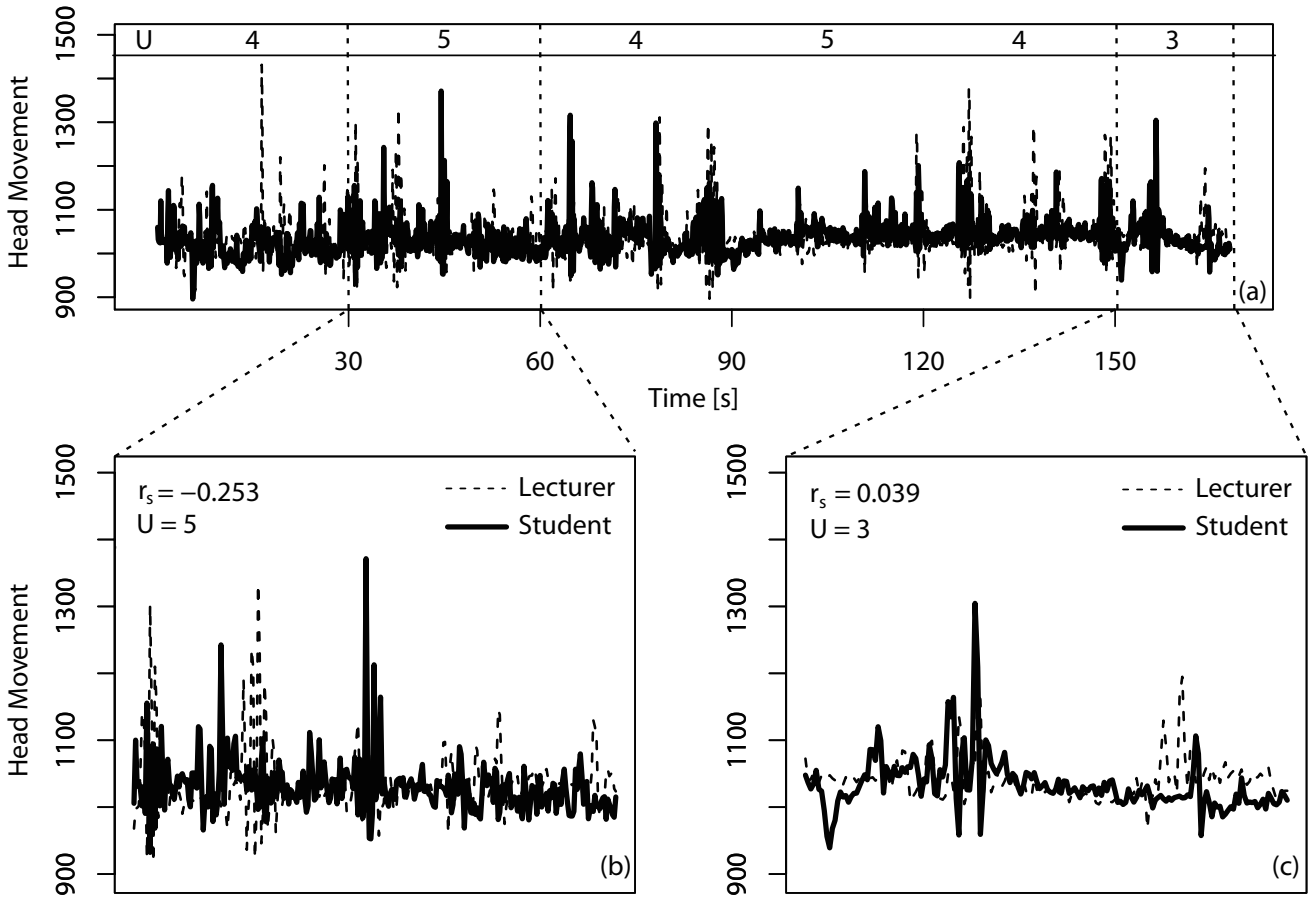

Fig. 2. Time series of the head movements. Horizontal axis represents time [s]. Vertical axis represents the two-axis norm of the acceleration. Dashed line represents head movement of Lecturer. Thick line represents head movement of Student. Time resolution of the time line was 0.1 second. Labeled "U" represents the evaluated degree of understanding by Student as shown above in Fig. 2(a). The typical example of labeled 5 (high degree of understanding) is shown in Fig. 2(b). In this example, the correlation between the pair was negative and statistically significant. The typical example of labeled 3 (middle degree of understanding) is shown in Fig. 2(c). In this example, the correlation between the pair was slightly positive.

and forty eight seconds. Therefore, the subjective evaluations for each 30 seconds were conducted at six points.

First, we examined whether synchronization of head movement was observed. The typical example of time line of head movement is shown in Fig. 2(a). This time line was the result of second experiment. Time lines of objective head movement and subjective degree of understanding were recorded firmly. The typical example of labeled 5 (high degree of understanding) is shown in Fig. 2(b). In this example, the correlation between the pair was negative. The correlation coefficient r_s was -0.253 $(p < .01)$. Also in other periods, significant correlation coefficients between each head movement were found. The typical example of labeled 3 (middle degree of understanding) is shown in Fig. 2(c). In this example, the correlation between the pair was slight positive. The correlation coefficient r_s was 0.039.

We found that negative correlation of head movements tended to be observed in the period of high degree of understanding. Also, we found that no or slight positive correlation of head movements tended to be observed in the period of middle degree of understanding. In order to confirm this tendency was statistically significant, correlation coefficient between correlation coefficient between each head movement and degree of understanding was calculated. The correlation coefficient r_s was -0.527. Exact p value could not be calculated because there were tie rank in the data. The correlation coefficient was statistically significant ($p < 0.05$) if the tie ranks were modified to the averaged rank.

The distribution of correlation coefficient classified by the degree of understanding is shown in Fig. 3. Horizontal axis represents the degree of understanding. Vertical axis represents Spearman's rank correlation coefficient between head movements of the pair for each 30 seconds. The thick line at middle of the box represents median value. Bottom and top of the box represents 25 percentile and 75 percentile each. Negative correlation of head movements was observed in the period of high degree of understanding as shown in Fig. 3.

IV. DISCUSSION

First, head movements between the pair were found to correlate significantly. The results suggested that synchronization of head movement occurred between a speaker and a listener. Synchronization of head movement were observed

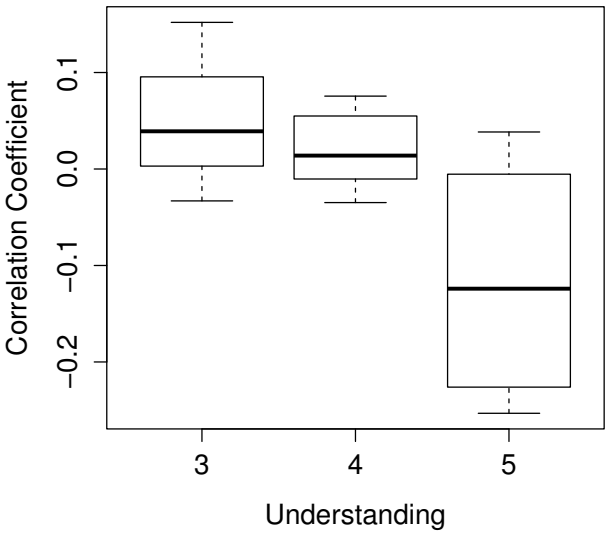

Fig. 3. The box plot of correlation coefficients classified by the degree of understanding. Horizontal axis represents the degree of understanding. Vertical axis represents Spearman's rank correlation coefficient between head movements of the pair for each 30 seconds. The group of 5 (high degree of understanding) tended to score negative correlation coefficients.

both positively and negatively.

Statistically significant relationship between synchronization of head movement and degree of understanding was suggested. Middle degree of understanding tended to be observed in the period of no or slight positive correlation. On the other hand, high degree of understanding tended to be observed in the period of negative correlation. Significant correlation between the correlation of head movements and degree of understanding was observed. These results suggested that degree of understanding was high when head movement happened alternately between speaker and listener. Not only listeners, speakers appeared to move their head at the end of their speech.

Synchronization of nonverbal behavior has been suggested to be related with sign of intimacy [6] or the process of consensus building [4]. Also, nod behavior was suggested to relate with nice impression [10]. From these previous studies, synchronization of nonverbal behavior and nodding were suggested to be one indicator of smooth communication. If the result of previous study and the present study are discussed together, alternate exchange of nodding might promote smooth transmission of intention. However, we cannot identify the reason from this experiment because we examined whole tendency of head movement. We are going to examine if the conclusion is decisive with large sample size because the sample size in this study is too small. Japanese tended to nod more often than people from other country did [7]. Study of cultural difference is also needed in the future work.

V. CONCLUSION

To investigate a relation between nonverbal behavior and transition of mental state in communication, we examined a task-oriented dialogue. The task consisted a process of explanation from a speaker to a listener. As results, middle degree of understanding of the listener tended to be observed in the period of no or slight positive correlation of head movements. On the other hand, high degree of understanding of the listener tended to be observed in the period of negative correlation of head movements. These results suggested that degree of understanding was high when each head moved alternately between speaker and listener. In the future work, we are going to examine the tendency with large sample size.

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