Analysis of Children's Motion in Eurhythmics

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***Abstract*—Our group has been working on longitudinal measurement of children's motion during eurhythmics using small handheld devices. We are also trying to develop some techniques, which can perform the analysis of such measurements. In this paper the overview of the project will be explained followed by some technical aspects of the analysis. And then, some findings on the children's development of social skills are discussed.**

I. Introduction

The involvement using the body is the expression method which becomes the main axis for the child of early childhood whose word is underdeveloped. In this research, we attempt to analyze development of relationships with others, such as sociality, by a quantitative method of measuring bodily expressions of infants.

Traditionally, knowledge on the development of children based on the qualitative evaluation of the observer has been obtained in nursery scenes [1][2]. For example, Suzuki analyzes the developmental features on an episodic basis in order to explore the factors of bodily interaction among children [1]. The conventional method of observing the state of the child, and describing and analyzing the episode has the advantage of being able to analyze detailed behaviors of the object while the quality of the description depends on the skill of the observer. Also, there are disadvantages such as difficulty in mass case analysis. There have been few attempts to quantitatively capture nursery scenes. Kawada and colleagues are trying to measure and predict behavior data of young children in the room, but they are aimed at avoiding danger and do not analyze the quality and development of childcare [3]. If effective data measurement on nursery scenes is realized, there is a possibility that such problems can be solved. The main contribution of this research is to incorporate engineering techniques in the analysis of the developmental stage of infants. The measurement and analysis of a large number of children make it possible to quantitatively understand the developmental change.

In this research, we focus on imitation of movement as a relationship with others through the body and analyze the social development of children. Regarding imitation in early childhood, Suzuki claims that children acquire the feeling of accepting the existence of others through their bodies, identifying themselves, enhancing themselves, and living together by imitation [4]. Imitation using the body is also observed in the free nursery scene. However, in this research, to make it possible to obtain stable data continuously for a certain period of time, we consider the eurhythmics which is one of the setting nursing scenes that can give restriction to some extent in space and time. The eurhythmics is music education aimed at enhancing many automatic motions, guaranteeing the whole muscle function, on the other hand, establishing a quick and reliable communication between the body and mind, and developing a natural rhythmic sense [5]. Through the involvement with music and things, one can observe how children imitate the movement of the leader or imitate themselves with each other. In this paper, as a first step toward a quantitative evaluation of the body expression scene of nursing, we construct a data measurement environment in the actual nursery school and explore some analysis methods of data expressing imitation.

II. Measurement

In constructing the data measurement environment in the eurhythmics scene, we first asked what the teacher wants to expect and what to expect from the data measurement. As a result, the following needs emerged.

Analysis of large amount of child data: In behavioral analysis, it is necessary to observe a child's s case individually, so even if analyzing several children's data, considerable effort is required. If we can measure data automatically, we can measure and analyze dozens of children efficiently and continuously.

Observation of all children in the field: Leaders and caregivers try to take care of all the children as much as possible, but can not always see everyone. It is useful to record and analyze the situation of all the children and provide the characteristics of the children who could not be picked up by the instructor or childcare person.

Training of quality teachers: Child carers are required to accurately grasp the expression of children and the way they grow. However, it is difficult to have an accurate perspective without having experience and an inexperienced teacher may make inappropriate observations. For example, when a child was sitting without participating in an eurhythmics activity, an inexperienced childcare worker tried to let the child join in the activity, considering that the child was not cooperative. On the other hand, another experienced teacher found that the child was carving small rhythm while sitting, and saw that he was enjoying it, she watched over the course without looking at much problems. If the system captures this small but important change with data and present it to a childcare professional who has little experience, it will lead to the delivery of a good quality perspective and the provision of quality childcare. Also, in order to capture the developmental change of children during the eurhythmics, we thought that we should measure such as imitation of teacher's movement, imitation of other children's movement, rhythmic sense, etc.

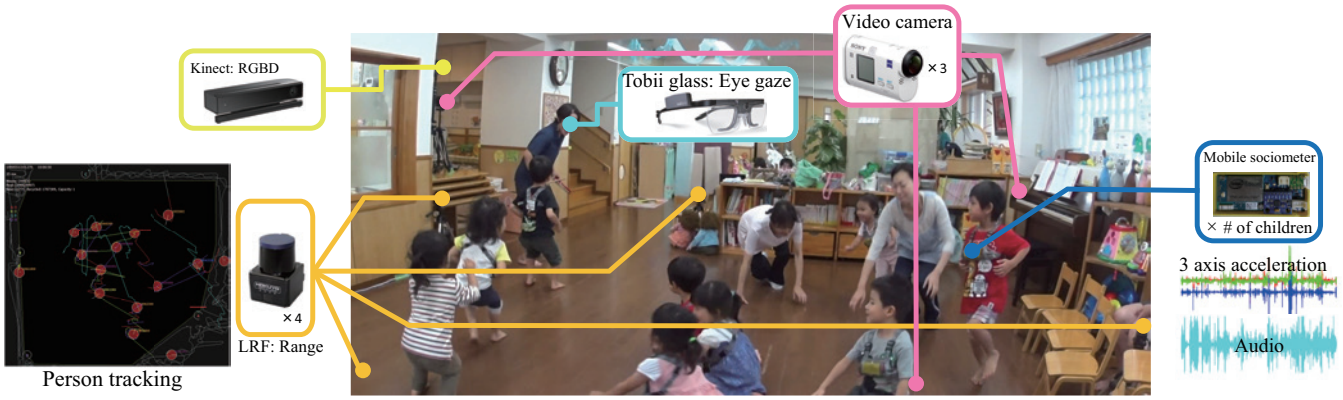

Fig. 1. Sensors and their locations

In consideration of the above requirements, we decided items that can be measured in the actual field, which are the acceleration, voice, position, expression, and viewpoint of the instructor. Figure 1 shows a scenery at the time of survey, the placement of various devices, and examples of acquired data. The equipments used for the measurement are as follows.

Mobile sociometer (small device): The devices are secured to the chest of children, nursery teachers, and instructors by belts, and 3-axis acceleration, 3-axis angular velocity, and voice are recorded. Imitation of movement and increase/sharing of feelings are measured with velocity data, and music/words are measured with voice data.

LRF (laser range finder): Four LRFs are installed in the classroom, and the distance is obtained from reflected light of the laser. We intend to measure the children's position and to understand how do children use the space.

Tobii Grass: The instructor wears the grass and records view images and gaze points. Measure the facial expression of the child and the attention area of the instructor.

Kinect: Two kinects are set up in the classroom and we record the RGBD data. We track the person position by using face recognition etc.

Video camera: Three video cameras are installed in the classroom, and images are recorded. After the experiment, we analyze finely from various perspectives.

III. Analysis

We quantitatively analyze what is happening in the eurhythmics activity from the data. Children and teachers relate to each other by physical expression, and imitation of movement is extracted. We explore the clues for social development of children from the change of flow of information transmission of imitation relations. In addition, the relationship with the sound which is one of the important elements of the eurhythmics, the body matching the rhythm is caught as movement. We also asked experienced nursery teachers to annotate the data for grand truth.

A. Correlation between movement and sound

The movement of the body regarding imitation is extracted by the phase difference and the correlation value of the waveform of the time series data. The square root of the sum of squares of 3 axes acceleration acquired by the mobile sociometer is taken as the magnitude of movement. Speech signals are processed to capture sound energy. The cross correlation between the magnitude of motion of each subject and the speech energy waveform is computed as,

$$Cov_{XY}(\tau) = \sum_{t=1}^{T}\{X(t)Y(t+\tau) - \mu_X(t)\mu_Y(t+\tau)\}$$

$$\hat{\tau} = \arg\max_{\tau} Cov_{XY}(\tau) \quad (1)$$

$$A_{ij} = \begin{cases} Cov_{X_iY_j}(\hat{\tau}) & (i < j) \\ \hat{\tau} & (i > j) \end{cases} \quad (2)$$

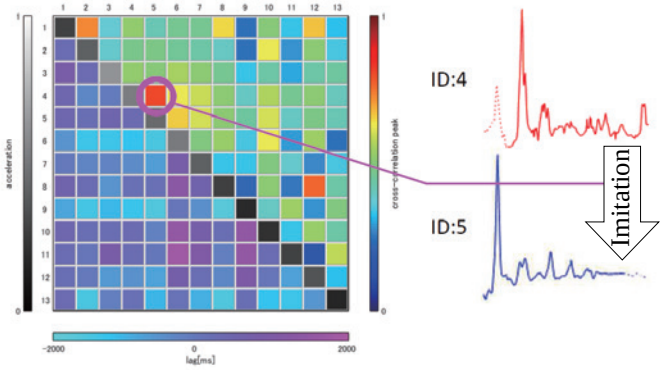

Fig. 2. Cross correlation of motions

The imitation relationship of all subjects for a certain 2 seconds is represented by the color matrix A_{ij} in Fig.2. The upper triangular matrix of the color matrix represents the peak value of the cross-correlation function of Eq.(2), and the lower triangular matrix represents the phase difference of the waveform of Eq.(1). As an example, A_{54} and A_{45} show the situation where the subject ID:4 starts moving right after ID:5 and its motion is similar to ID:5's one.

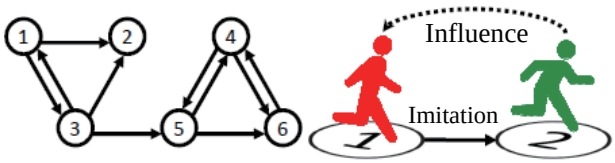

Fig. 3. Example of web structure

We perform the analysis with a window width of 2s and a shift width of 0.1 s, with an eurhythmics activity of less than 30 minutes per class as one session.

B. Influence in eurhythmics activity

From the viewpoint of who is imitated from many others in the activity, the degree of influence is computed by using the PageRank algorithm [6] which is a method of judging the degree of importance of a web page used in the Google search engine.

1) PageRank: The idea of PageRank is that web pages are important if they are pointed from other important pages [7]. In the algorithm, hyperlinks are considered to be recommended, pages with high recommendation are important, recommendation weights from the recommended page are high, and the popularity score is voted by lowering the weight of the random recommendation . Here, for example, a small web structure is shown in Fig. 3. This directed graph can be represented with the hyperlink matrix $\mathbf{H}$.

$$\mathbf{H} = \begin{bmatrix} 0 & 1/2 & 1/2 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 \\ 1/3 & 1/3 & 0 & 0 & 1/3 & 0 \\ 0 & 0 & 0 & 0 & 1/2 & 1/2 \\ 0 & 0 & 0 & 1/2 & 0 & 1/2 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \tag{3}$$

The steady state vector of this transition probability matrix is obtained by the power method. Here, we add $\mathbf{G}$ to the Google matrix with probabilistic adjustment to the dangling nodes that accumulate PageRank in the iterative process of power multiplication, and primitive adjustment for power multiplication convergence to Eq.(4).

$$\begin{aligned} \mathbf{G} &= \alpha(\mathbf{H} + 1/n\mathbf{a}\mathbf{e}^T) + (1-\alpha)1/n\mathbf{e}\mathbf{e}^T \\ &= 0.85 \begin{bmatrix} 0 & 1/2 & 1/2 & 0 & 0 & 0 \\ 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \\ 1/3 & 1/3 & 0 & 0 & 1/3 & 0 \\ 0 & 0 & 0 & 0 & 1/2 & 1/2 \\ 0 & 0 & 0 & 1/2 & 0 & 1/2 \\ 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix} \\ &+ 0.15 \begin{bmatrix} 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \\ 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \\ 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \\ 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \\ 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \\ 1/6 & 1/6 & 1/6 & 1/6 & 1/6 & 1/6 \end{bmatrix} \end{aligned} \tag{4}$$

The PageRank vector $\boldsymbol{\pi}$ is expressed by Eq.(5) and the PageRank vector in the link structure of Fig.3 is expressed as Eq.(6).

$$\begin{cases} \boldsymbol{\pi}^T = \boldsymbol{\pi}^T \mathbf{G} \\ \boldsymbol{\pi}^T \mathbf{e} = 1 \end{cases} \tag{5}$$

$$\boldsymbol{\pi}^T = \begin{bmatrix} 0.0517 & 0.0737 & 0.0574 & 0.3487 & 0.1999 & 0.2686 \end{bmatrix} \tag{6}$$

The interpretation of $\pi_1 = 0.0517$ is that the random surfer visits page 1, using 5.17 % of the time.

2) PageRank in eurhythmics: A person is a node in the eurhythmics, a movement imitating someone is a link to that person, and it is replaced with a hyperlink relation on a web page (Fig.3). Using the PageRank algorithm, we calculate the proportion of a person being imitated in the eurhythmics activity (level of influence). The transition probability matrix $\mathbf{H}$ which is input is shown in Eq.(7). As the motion waveforms are similar, as the imitation probability is high, each element of the matrix is found by the cross correlation function of the waveform described in section III-A.

$$\mathbf{H}_{ij} = \begin{cases} Cov_{X_i Y_j}(\hat{\tau}) & (\hat{\tau} < T/2) \\ 0 & (\hat{\tau} > T/2) \end{cases} \tag{7}$$

C. Annotation

Labeling of each scene of the eurhythmics is done using the annotation software ELAN [8] (Fig.4). We evaluate who is imitating, type of imitations, change in feelings, and so on, with expert teachers. The types of imitations distinguished at this stage are as follows.

* synchronization: the child makes the same movement unconsciously and reflectively.
* imitation: the child moves and observes trying to make the same move as the other.
* getting a cue: the child has an image of his/her own body expression, but there is no opportunity to start moving, he/she starts to move like someone is attached to it, but the way of expression is different.

In the future, we will examine whether it is possible to distinguish from the relationship between the kind of imitation and the developmental stage of the child, from the motion data.

IV. Results

A. Correlation between movement and sound

The correlation values between subjects are two-dimensionally plotted so that those with high correlation values are arranged close by MDS (multidimensional scaling method). At this time, the correlation between movement and sound described in section III-A is summed throughout the session, and the correlation valued between subjects is taken as the distance. The result of MDS for each session is shown in Fig.5.

B. Result on PageRank

We summed the transition probability matrix described in section III-B2 throughout the session and calculated the PageRank for each subject. The link structure is drawn from the transition probability matrix of a certain session, and Fig.6 shows the calculation result of PageRank with the transition probability matrix as input. Each node corresponds to the subject/voice, and the outgoing link from the node represents the transition probability (mimicking relation). In the figure, in

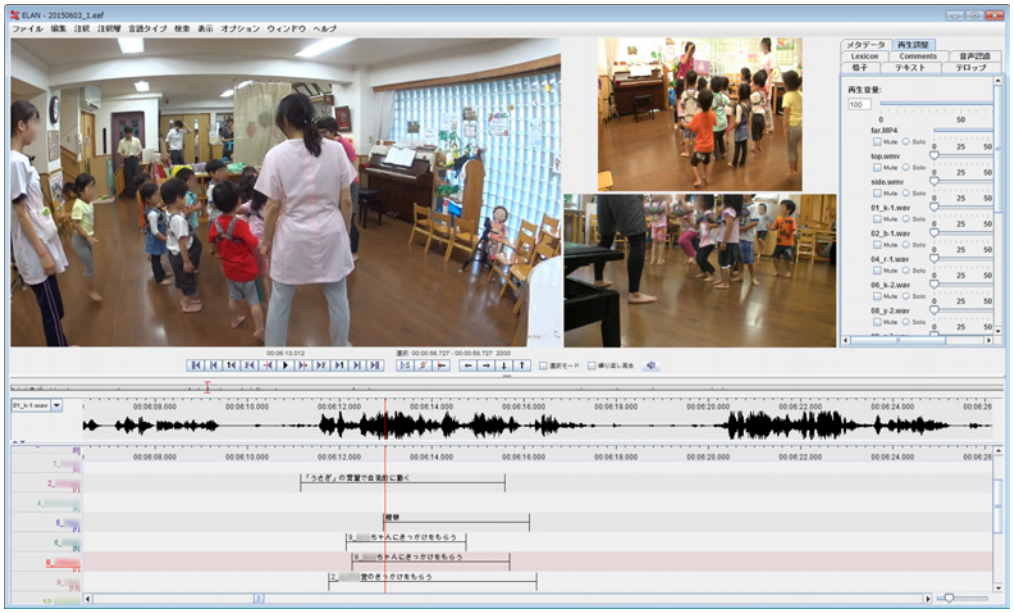

Fig. 4. Annotation using ELAN

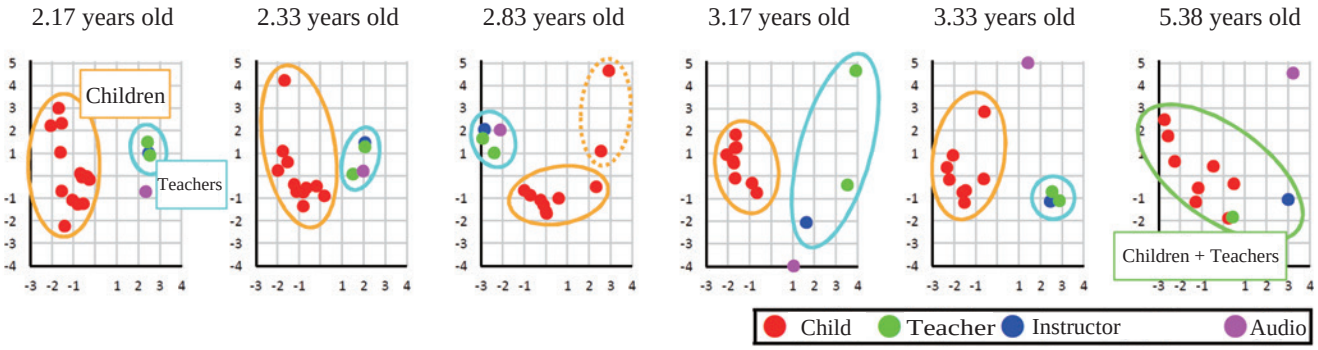

Fig. 5. MDS plots of motion cross correlation

order to clarify the visualization, only the top three outgoing links from each node were taken.

C. How do children use space?

From the tracking data using LRFs we visualized the position of the children in the classroom during eurhythmics by heat map. Also, the average distance between children for each age is shown in Fig.7.

D. TS juvenile personality test

In order to investigate the correlation between behaviors and personality in the eurhythmics, nursery teachers are asked to answer the TS juvenile personality test for each child.

V. Discussions

A. Correlation

In the session of 5.83 years old (Fig.5), the correlation between the child and the teacher is high, and it seems that the field is united. This time, we attempted to capture the imitation in the eurhythmics scene using the cross correlation of the magnitude of the movement. However, there are many scenes where the imitation relationship defined using the cross correlation does not match the labeling described in section III-C. The possible causes are as follows.

The first point is that the waveforms were compared by normalizing the magnitude of the movement taking into consideration differences in the size of the body between the child and the instructor, individual differences in the body expression, and so on. Since filtering of small motion is not performed, there is a possibility that a small waveform like noise and a waveform to be captured are extracted as an imitation relation.

As the second point, we compare independently for each window (2s width, 0.1s shift) to compare the waveforms, and do not use the information on the time series connections before and after the window.

In addition, it may be necessary to extract imitations of movement with Granger causality rather than simple cross

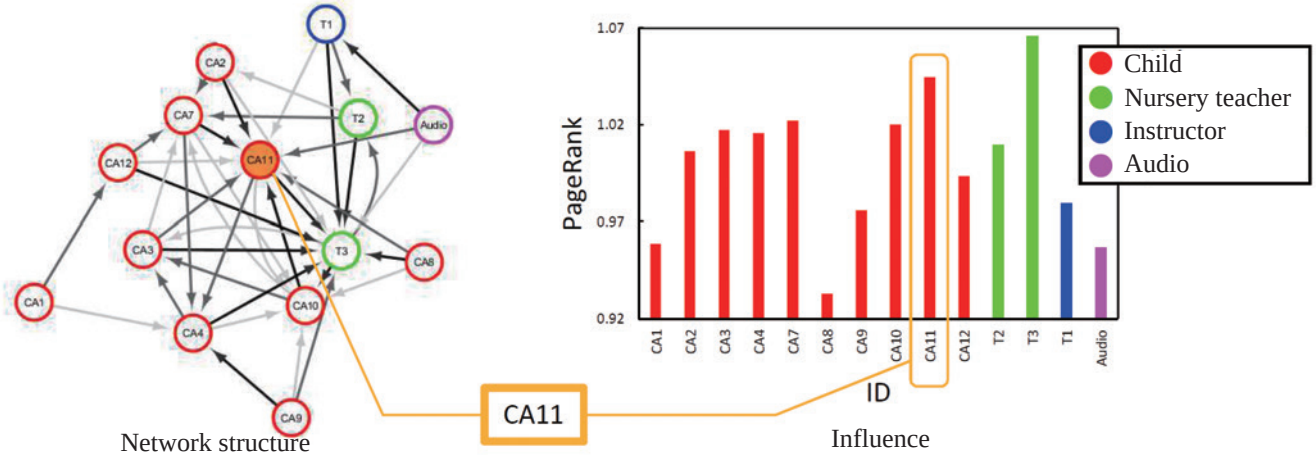

Fig. 6. Example of PageRank

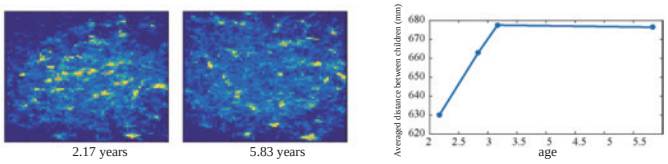

Fig. 7. Result of space usage

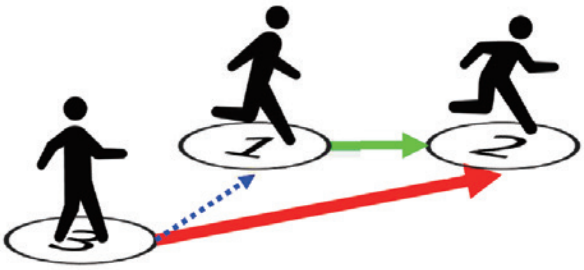

Fig. 8. Example of indirect link

correlation.

B. PageRank

In Fig.6, it can be seen that a child (ID: CA 11) actively engaged throughout the session becomes the subject of imitation of other children and influence is high. However, since the imitation relation which is the input of PageRank is computed by the cross correlation described as above, the reliability of the PageRank may become low. Also, when using the PageRank algorithm used in web pages in the analysis of eurhythmics, it is questionable whether the magnitude of the transition probability can be represented by the correlation value. In addition, indirect links via pages on the web also have meanings as recommendations from the recommended page, but even in the eurhythmics where everyone can be represented by a one-to-one direct link, it is not clear whether it is necessary to consider indirect links as weights. In this way there are still many points to consider. In the example of Fig.8, the time to propagate t can be represented as

$$t_{red} < t_{green} + t_{blue} \tag{8}$$

If the outgoing link from node 1 does not exist other than node 2, the outgoing link (blue) from node 3 to node 1 represents a pseudo imitation and is not an element to be extracted. Considering the above points, it is necessary to rethink the link structure in the eurhythmics activity.

C. Usage of Space

In the heat map of Fig.7, the space being used is concentrated at the center of the classroom at 2.17 years old. On the other hand, at the age of 5.83, one can see how children are active using the whole classroom. Moreover, the distance between children tends to increase with increasing age. Infant's personal space (interpersonal distance) is known to increase as the age rises [9]. This result may support this finding.

In the current analysis, it is impossible to specify (track) the position of the individual because the position estimation is performed using the distance data of the LRF. Furthermore, children can be crouching or lying down, which makes tracking of individual location extremely hard. Now we are trying to track positions of individuals together with face recognition, human position estimation by using multiple kinect sensors.

VI. Conclusion

In this paper, we constructed, measured, and analyzed a group of children in eurhythmics activity. The purpose of this research is to obtain knowledge about the development of children's sociality by quantitative survey by measurement. As a result, we showed the relationship of imitation of movement, the influence in the field of eurhythmics and the possibility to obtain clues to objectively grasp how space is used.

Future works include further examination of analysis methods, analysis of labels of annotations for each label, TS type infant / child character diagnostic test and analysis of measurement data. Ultimately, we aim for objective assessment

of the relationship between children's social development and eurhythmics, modeling of child developmental stages, and application for instructors.

ACKNOWLEDGMENT

This work is supported by Grant-in-Aid for Scientific Research on Innovative Areas (Cognitive Interaction Design: 26118003). I would like to thank the members of A02 group for their fruitful discussions.

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