Study on Mental Interactions between Difficult Children and Their Nursery Teacher by Biological Information

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Abstract—In this study, DUAL measurements of finger pulse waves were taken from three children (Child A, Child B, and Child C) and their nursery teacher longitudinally (when children were 3 years old and 4 years old). Behaviors of difficult children were evaluated and scored by using "Checklist for Difficult Children" (S. Shimano, 2014) [1]. Four subscales of "troubles (anti-social behaviors)," "dissocial behaviors," "autism behaviors," and "hyperactive behaviors" were evaluated with "Checklist for Difficult Children." Three children who exhibited high scores for all four subscales were selected for the study. According to the nursery teacher, Child A was diagnosed with autism spectrum disorder. Child B's mother had an attitude problem in childrearing, so the child was not disciplined by her. And Child C showed signs of attachment disorder. DUAL measurements were taken from Child A, Child B, and Child C, respectively paired with their nursery teacher, to visualize any mental interactions with the teacher.

Keywords—Finger pulse waves, DUAL measurement, Checklist for "Difficult Children," mental interaction, longitudinal study

I. INTRODUCTION

In recent years, interest in "difficult" children is increasing in childcare centers and kindergartens. In relation to this fact, a number of articles regarding "difficult" children is increasing. This is because they do not know how to optimally treat "difficult" children in group activities of childcare centers and kindergartens and therefore researches and empirical studies are demanded.

S. Shimano (2007) affirmed that in general, many "difficult" children exhibit common behavioral characteristics with children with mild developmental disorder. While no definition has been established for the term "mild developmental disorder," it may be commonly considered as similar to developmental disorder in the society [2].

In childcare centers and kindergartens, children with autism spectrum disorder draw special attention among those with developmental disorders. The three signs peculiar to autism spectrum disorder are: (1) "social impairment," (2) "language and communication disorder," and (3) "restricted interest and obsession to a specific event."

In addition, attachment disorder also requires further researches and actions. Attachment disorder is a generic term for disorders caused by inability to construct a stable attachment relationship with rears due to long-term abuse during babyhood or childhood, parent's death, or another cause. A relationship with loved ones can considerably affect child's independence. Child's confidence in constant protection from the loved ones can foster his/her independence. Attachment disorder can manifest symptoms very similar to those of developmental disorder. Nonetheless, developmental disorder is considered usually not affected by the child's growing environment, while attachment disorder is acquired after birth. But reportedly, developmental disorder can be misrecognized as autistic spectrum because they are indifferent to others.

Based on these understandings, children's behaviors were evaluated using "Checklist for Difficult Children" in advance, and then DUAL measurements of finger pulse waves were taken from children and their nursery teacher.

<Chaos Analysis and the Largest Lyapunov Exponents (LLE) >

In finger pulse waves, finger pulses are measured, as the blood pumped out by the heart circulates in the body and reaches fingertips to cause pulsation. Finger pulse waves change cyclically in synchronization with the heartbeat, but this cycle and the amplitude are fluctuating irregularly all the time [3]. In addition, it has been demonstrated that the irregular changes are affected by physical and mental factors [4]. Finger pulse waves can detect not only the heartbeat but also information about the central nervous system and entire body from the forms of waves. As a result of chaos analysis of these measurements, LLE of a time series obtained has been proved to be associated with mental immunity [5].

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As we need moderate functions and a balance of the sympathetic nerve, which is associated with adaptability to an external environment and the society, mental flexibility, spontaneity, and cooperativeness, in order to live a mentally healthy life, studies have revealed that these measurements are associated with the largest Lyapunov exponents obtained through non-linear analysis. The largest Lyapunov exponent means changes in the orbit of the attractor on the time series plot, and it can be defined as "fluctuation." And it can be inferred to reflect one's mental status [5].

<Differences between chaos and randomness>

A living body is one large and complex system. It is an enormous system taking in information from body organs, blood streams, and external information through five senses that change from moment to moment, and moving in response to orders from the brain; so it is considered literally as the ultimate complex system. Many phenomena in the world occur randomly. Differences between chaos and randomness can be clarified by developing an attractor. If biological information is random, a living body can no longer maintain its system.

A chaos system has a deterministic rule, rather than being driven by probabilistic factors. Deterministic chaos means a phenomenon in which complex behaviors are caused by non-linearity of the system itself, despite absence of probabilistic factors. Characteristics of chaos can be described as sensitive dependence on initial condition, orbital instability, long-term unpredictability, and short-term predictability. In chaos, however, geometric structure of the attractor, which shows steady behaviors in state space, does not basically change and is stabilized, even when orbital instability is caused by minimal disturbance. Moreover, sensitivity to initial condition can be predicted probabilistically, over a short term until impacts of these appear.

<How to find "regularity" of chaos>

There are several ways to distinguish chaos from randomness. A common way is to develop an attractor. An attractor can be generally classified into four categories: (1) The point attractor converges to one point, in a spiral form. (2) The cycle attractor draws a circle, and (3) the semi-cycle attractor forms a donut shape. (4) The chaos attractor forms a geometric figure, and this is our focus. Chaos attractors do not follow the same orbit as the previous one, but the orbits are facing a similar direction, forming a characteristic pattern.

<What are characteristics of randomness?>

Numerical figures arranged in a random array are called random numbers. We can generate 1,000 random numbers equal to or greater than 0 but smaller than 1 using the Excel RAND function, and draw a line graph with these values. But no regularity can be found in these variations. To check presence or absence of regularity, an attractor should be developed.

We can apply "Takens embedding theorem." In this method, we can take points n from the wave profile measured in different time slots, and plot them in the X-dimensional space to develop an attractor. When an attractor is developed from the graph of random numbers using this method, the orbit of these variations is unorderly, and no regularity can be found. In other words, this is in the random state.

However, if chaos is present behind the chronological wave profile data, an attractor developed from it forms a geometric figure under certain regularity. Even if the wave pattern may appear irregular from a chronological perspective, in other words, regularity can be observed when an attractor is developed by applying Takens embedding theorem.

<Finding chaos in fingertips>

Changes in hemoglobin levels in fingertip capillaries were measured, as one of biological signals. Changes in hemoglobin levels in fingertip capillaries were measured by an infrared ray sensor and chronologically plotted to a graph. This chronological wave profile shows irregularly repeated changes in hemoglobin levels. When this is converted to the four-dimensional attractor applying Takens embedding theorem, nonetheless, an orbit shows a certain pattern.

Finger pulse waves represents deterministic chronological chaos data issued by these biological systems.

Several proofs can be raised, and it satisfies the following four conditions:

1: There are no characteristic frequency components, and it exhibits a broad power spectrum.
2: Adjacent orbits passing through attractors' subspace are oriented to similar directions.
3: The maximal Lyapunov exponents calculated from the attractor are positive numbers.
4: When correlation dimension (fractal dimension) is investigated, it is validated to be different from white noise.

These four conditions can be validated by using the G-P method (correlation dimension calculation method) on chronological pulse wave data. As illustrated in this figure, finger pulse waves satisfies the above four conditions. Therefore, this is the chronological chaos data.

<Measurement and analysis of chronological chaos data Measurement of pulse waves>

Fingertips and ear lobes are sites where arteries and veins meet at capillaries. To measure pulse waves, as illustrated in the figure, changes in blood hemoglobin levels were measured by an infrared ray sensor at 200 Hz to obtain analog data. This data was converted from analog to digital to obtain pulse wave data equal to or greater than 10 bits.

Although it can be measured in short time, measurement over one minute or more is required to increase accuracy of the autonomic balance values based on heart rate. In addition, it is dangerous to assess mental sanity based on one time measurement only, considering the chaotic nature of a living body. So it is recommended to take several measurements over time, depending on a purpose of use.

<What does LLE calculated from finger pulse waves mean?>

(A) A method to calculate from a mathematical model

(B) Changes during general anesthesia

Finger pulse wavesy is considered as a variety of signals issued by multiple sites, such as blood pressure, heart rate and respiration. An artificial wave profile was synthesized by considering many conditions of biological models. As a result, it has been demonstrated that a simulation with the cerebral central nervous system formula produces a wave profile of a mathematical model that is close to one obtained from measurements in the study. Although the formula is omitted here, it was inferred that a mathematical model of finger pulse waves contained information of the cerebral central nervous system. To obtain further data for verification, we needed to run an experiment by blocking the central nervous system. Therefore, with cooperation of surgeons, pulse waves of cancer patients undergoing a surgery were measured starting before administration of general anesthesia until completion of a surgery. The figure shows LLE, calculated based on data output of an automatic pulse wave counter and anesthetic time tables provided by surgeons, in addition to changes in sympathetic and parasympathetic nerve activities. LLE values rapidly fell after administration of anesthesia, and this state lasted until anesthesia wore off. But they did not become zero. This is considered to be caused by cardiac movements. From a simulation using a model and data obtained during anesthesia, it has been demonstrated that LLE values were relevant to the central nervous system.

<What does LLE mean?>

LLE was calculated in the first 17 seconds, and displayed every second thereafter. In measurement for three minutes, 163 points of LLE are displayed. LLE is normalized between 0 and 10 for display. As stated previously, LLE means fluctuation of attractor orbit, which is constantly changing and fluctuating, rather than being stable. This fluctuation is essential as an indicator to assess mental sanity. A healthy mental state exhibits constant increases and decreases of LLE values. In other words, values should be fluctuating. If LLE values do not change and remain stagnant, it means the person is indifferent to changes in the external environment or unable to respond to them. If low levels (LLE = 0-2) continue, it shows the lack of adaptability to the external environment, and it is often observed in patients with a mental disease such as dementia or depression. If high values continue (LLE = 8-10), a person may become aggressive to others or him/herself. In many cases, the person is unaware of his/her state, and it is dangerous.

So constant fluctuation in LLE values is associated with mental sanity. We can consciously increase or decrease our LLE if we are mentally sound. As their social withdrawal is recently viewed as a significant problem, depressed patients may always exhibit low LLE no matter when it is measured. Additionally, extreme elevation of LLE (LLE = 1-10) represents a loss of self-control, and it also requires an attention of those who surround the person.

In recent years, it is said that a number of children with difficult behaviors is increasing in childcare centers and kindergartens. Difficult behavioral characteristics include an aversion to communications with friends, resistance to join others for playing, withdrawal into their own worlds, and lack of ability to hear what teachers and friends say.

Although we can be aware of situational circumstances from children's difficult behaviors, it is hard to know whether the children are unable to communicate in fact, and people's mental state is hard to be sensed unless it is expressed. In particular, it is even more difficult to understand children because of their immature language output. This study reports results of examination of mental interactions between difficult children and their nursery teacher based on finger pulse waves.

The purpose of this study is to perform chaos analysis of finger pulse wave data and visualize mental interactions between children and their nursery teacher. Behavioral characteristics of children were evaluated by using a checklist. Four areas of troubling behaviors, dissocial behaviors, autistic behaviors, and hyperactive behaviors were evaluated with the checklist.

Specific objectives were determined as follows:

1. To study mental interactions between children who exhibit difficult behavioral characteristics and their nursery teacher, based on their biological information. To perform chaos analysis of finger pulse wave data obtained from DUAL measurements of children and their nursery teacher and visualize their mental interactions.

2. To longitudinally compare changes in difficult children's behavioral characteristics. To examine changes in mental interactions between children and their nursery teacher, caused by changes in children's behavioral characteristics, based on DUAL measurements.

This research/study was conducted with guardians' informed consent.

Ⅱ. METHODS

1. Period of Measurement
   The first time (when three years old): Three days including November 30, December 1, and December 7, 2017
   The second time (when four years old): June 19, 2018
2. Place of Measurement
   A certified child center in Hyogo Prefecture, Japan
3. Tools Used in the Research/Study
   1) "Checklist for Difficult Children"
      "Checklist for Difficult Children" was developed by Shimano (2014). "Troubles (anti-social behaviors)," "dissocial behaviors," "autism behaviors," and "hyperactive behaviors" can be evaluated and scored. Percentages to the maximal score were calculated as evident rates for four subscales. Shimano stated, "If the evident rate is 50% higher, the behavior can be characteristic to that of a difficult child."
   2) Measurement Device for Finger pulse waves
      Lyspect 3.5 [Chaos Technology Research Laboratory] was used.

4. Administration of the Checklist

“Checklist for Difficult Children” was filled by their (female) nursery teacher on the day before measurement of finger pulse waves. It was filled for 42 children (21 boys and 21 girls) when they were 3 years old (the first time) and 4 years old (the second time).

5. Measurement of Finger pulse waves

1) Children measured with finger pulse waves

-The first time: 42 children who were in the class of three years old, paired with their nursery teacher.

-The second time: Three children who exhibited high scores for all the subscales in the first behavior evaluations with “Checklist for Difficult Children,” who were selected as study subjects and underwent DUAL measurements paired with their nursery teacher (who also took the first time).(See: Percentage of the number of people in four areas on behavioral characteristics of children)

According to their teacher, Child A was diagnosed with autism spectrum disorder. Child B’s mother had an attitude problem in childrearing, so the child was not disciplined by her as suitable for the child’s age. Not adequately treated by parents, Child C reportedly exhibited signs of attachment disorder.

2) How finger pulse waves was measured

The room temperature was moderate. DUAL measurements were taken for one minute from a child and his/her nursery teacher, who sat on a chair with open eyes, wearing a cuff on the tip of the second finger of the left hand. A child and his/her nursery teacher faced each other holding their right hands, while the teacher talked to the child calmly.

Ⅲ. ANALYSIS AND RESULT

Statistical analysis software JMP (SAS Institute Inc.) was used for data analysis. Data was analyzed as follows:

<Factors Examined>

1) 42 boys and girls were sorted by sex and examined for significant differences, to identify any changes in their behavioral characteristics (“troubles (anti-social behaviors),” “dissocial behaviors,” “autism behaviors,” “and “hyperactive behaviors”) between the time when they were 3 years old and the time when they were 4 years old.

2) As for the three children studied, their changes in scores for the four subscales in the “Checklist for Difficult Children” between the first and the second measurements were summarized in the figure.

3) Chaos analysis was performed on the data obtain by DUAL measurement, and the largest Lyapunov exponents was derived. As for the three children studied, results of their DUAL measurements with those of their nursery teacher were combined and plotted, to visualize mental interactions between children and their teacher.

<Results of Examination and Discussion>

Tables 1 and 2 show results of a significance test for scores of the first and second measurements, sorted by sex, on the four subscales of children’s behavioral characteristics. Significant difference were observed for all behavioral characteristics among both boys and girls.

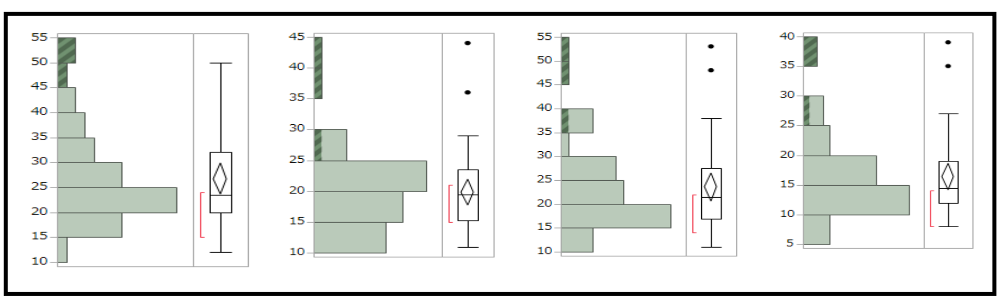
The second measurements were taken about 7 months after the first. Children were about 3 years and 8 months old on average during the first measurements, and about 4 years and 3 months old during the second measurements.

J. Piaget called the period between the ages 2 and 7 as the “preoperational stage.” And the period between the ages 2 and 4 was the “pre-conceptual stage” of thinking. During this period, children start to use mental images and languages, besides activities. Not always being controlled by situations, they learn to adjust situations for their own convenience. Generally, they start to manage pre-conceptual reasoning [7].

Children’s behavioral characteristics, or degrees of their “troubles (anti-social behaviors),” “dissocial behaviors,” “autism behaviors,” and “hyperactive behaviors,” can be observed in their relationships with others, and such behaviors call attention mainly in group activities.

Significant differences observed among both boys and girls may have been derived from different levels of development of body and mind in growing children aged 3 or 4, and they may be associated with social and environmental factors, including family situations and group activities in a childcare center.

Percentage of the number of people in four areas on behavioral characteristics of children



Troubling behaviors Dissocial behaviors Autism behaviors Hyperactive behaviors

Table 1 As a result of the t test of child's behavior (Boys) *** p<.001

		Mean (SD)/1st	Mean (SD)/2nd	t-value	df	p-value
child's behaviors	troubles (anti-social behaviors)	31.7(9.8)	21.1(9.3)	10.24	39	***
	dissocial behaviors	21.1(7.6)	14.2(5.6)	10.42	39	***
	autism behaviors	27.4(10.0)	17.9(10.5)	9.91	39	***
	hyperactive behaviors	19.3(7.6)	14.3(7.2)	4.57	39	***

Table 2 As a result of the t test of child's behavior (Girls) *** p<.001

		Mean (SD)/1st	Mean (SD)/2nd	t-value	df	p-value
child's behaviors	troubles (anti-social behaviors)	21.9(6.7)	15.2(6.0)	6.611	39	***
	dissocial behaviors	18.6(5.0)	12.1(2.6)	6.474	39	***
	autism behaviors	19.9(7.0)	13.7(6.1)	5.845	39	***
	hyperactive behaviors	13.5(4.8)	9.6(4.5)	5.351	39	***

Table 3 Changes in Child's Behavior

	troubles (anti-social behaviors)		dissocial behaviors		autism behaviors		hyperactive behaviors	
	1st	2nd	1st	2nd	1st	2nd	1st	2nd
Child A	45(75%)	**43(72%)**	44(80%)	**31(56%)**	53(96%)	**47(85%)**	35(88%)	**31(78%)**
Child B	56(93%)	**36(60%)**	36(65%)	**26(47%)**	48(87%)	**38(69%)**	39(98%)	**21(53%)**
Child C	50(83%)	**39(65%)**	29(53%)	**21(38%)**	35(64%)	**23(42%)**	26(65%)	**25(63%)**

On the other hand, Child A’s score for “dissocial behaviors” notably decreased, while he/she had exhibited high scores for all the four subscales. We believe this was caused by his/her growth, supported by the nursery teacher and friends during group activities (See Table 3, Fig 1, 4, and 7).

With mother’s attitude problem in childrearing, Child B’s evident rate for “troubles (anti-social behaviors)” decreased by 33% to 60%, and the evident rate for “hyperactive behaviors” decreased from 98% to 53%. It was inferred that considerable decreases in evident rates of “troubles (anti-social behaviors)” and “hyperactive behaviors” were achieved by Child B’s development of body and mind as well as learning of behaviors suitable for situations from group activities.

With signs of attachment disorder, Child C decreased scores for three subscales “troubles (anti-social behaviors),” “dissocial behaviors,” and “autism behaviors,” but no notable change was observed for “hyperactive behaviors.” It is known that those with attachment disorder are always frustrated, restless, and unable to sustain attention, and therefore sometimes present symptoms very resembled to those with attention deficit or hyperactivity disorder [8]. Based on these facts, Child C with signs of attachment disorder is considered to be hyperactive in an ordinary situation (See Table 3, Fig 1, 4, and 7).

Next, we would like to discuss results of DUAL measurements of finger pulse waves with Child A, Child B, and Child C, as well as their teacher.

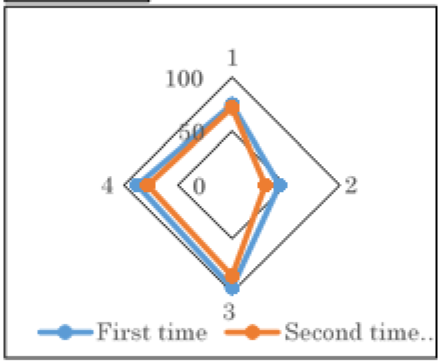
When results of DUAL measurements of finger pulse waves of Child A and the teacher are combined and plotted, the first measurements do not suggest their adequate interactions, but the second measurements imply that both Child A and the nursery teacher sensed the atmosphere and interacted with each other (See Fig 2 and 3).

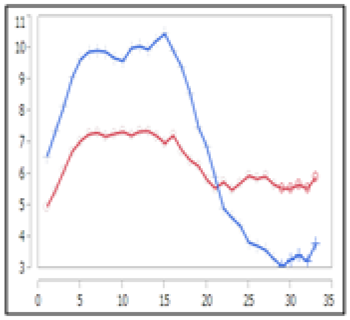
As for Child B, a salient feature was observed in the latter half of the second measurements. It is considered that the nursery teacher got closer to the heart of Child B and stimulated it (See Fig 5 and 6).

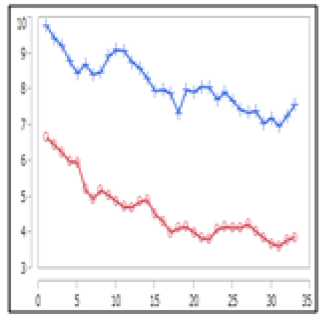
Child C’s Lyapunov exponents largely fluctuated, and Child C tried to respond to the nursery teacher’s approach (See Fig 8 and 9).

Finally, presented here are the DUAL measurement results of Child D, who exhibited low scores for all four subscales of behavioral characteristics. Interactions between Child D and the nursery teacher were observed in both the first and second measurements (See Fig 10 and 11).

Child A





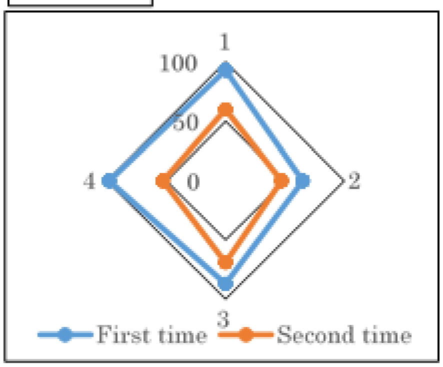


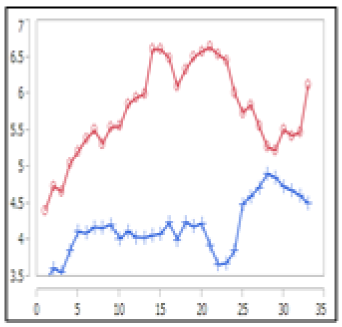
Child　Nursery teacher

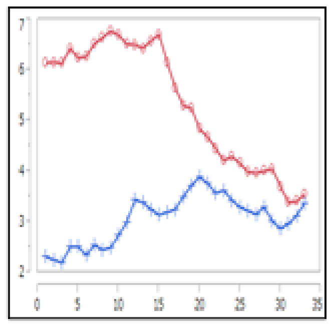
Fig.1 changes in child's behaviors　Fig.2 DUAL Measurement (1st)　Fig.3 DUAL Measurement (2nd)

1=troubles (anti-social behaviors) 2=dissocial behaviors 3=autism behaviors 4=hyperactive behaviors

Child B





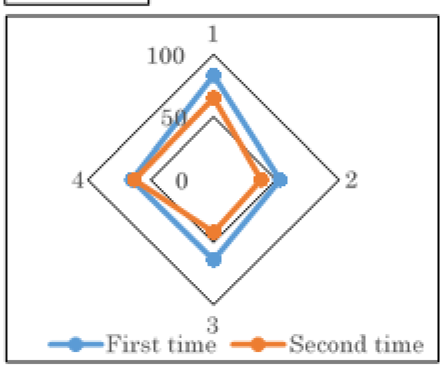


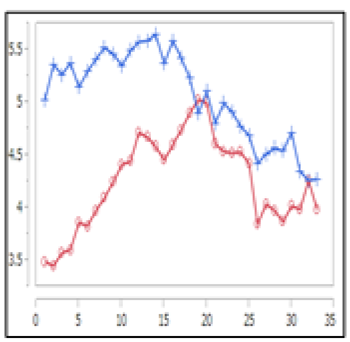
Child　Nursery teacher

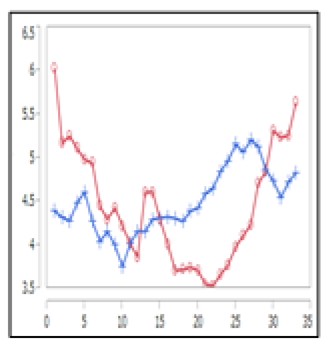
Fig.4 changes in child's behaviors　Fig.5 DUAL Measurement (1st)　Fig.6 DUAL Measurement (2nd)

1=troubles (anti-social behaviors) 2=dissocial behaviors 3=autism behaviors 4=hyperactive behaviors

Child C







Child　Nursery teacher

Fig.7 changes in child's behaviors　Fig.8 DUAL Measurement (1st)　Fig.9 DUAL Measurement (2nd)

1=troubles (anti-social behaviors) 2=dissocial behaviors 3=autism behaviors 4=hyperactive behaviors

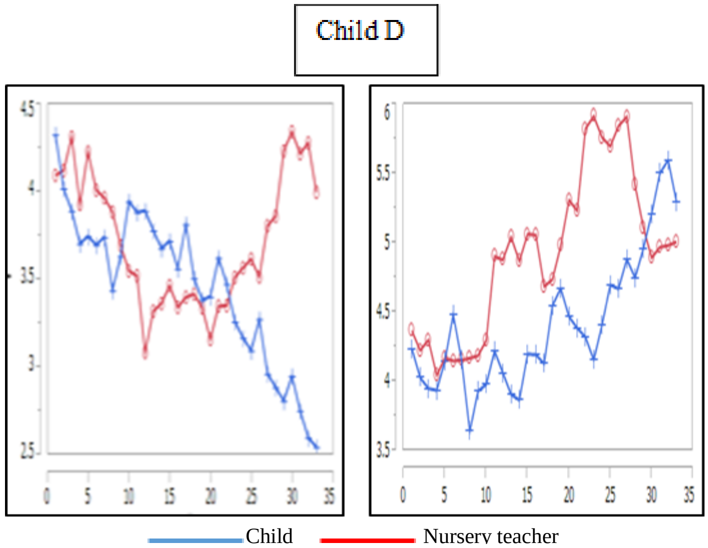


Fig.10 DUAL Measurement (1st) Fig.11 DUAL Measurement (2nd)

IV. CONCLUSION AND REMARK

Children who follow group activities at childcare centers and kindergartens grow with education and care from nursery teachers, as well as influences from their friends.

It is inferred that difficult children monitored in this study grew primarily through group activities. Through visualization of mental interactions between children and others, it becomes possible to know children's mental state.

In particular, knowing mental state of children with developmental disorder or difficult children can give us a clue to develop a human relationship with them [9] [10].

In an effort to scientifically understand the relationship between behavior in children and their biological signals, we measured the finger pulse waves of children and carried out chaos analysis of the measured data. We think that our analysis will contribute to the prevention of behavioral problems in children and encourage the adoption of early countermeasures.

We would like to conduct further research to track mental states of children with developmental disorder and difficult children, by using finger pulse waves data as relevant biological information.

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REFERENCE

[1] S. Shimano, Study (7) on "difficult children" :check lists are made based on surveys of "difficult children" in kindergartens. Bulletin of Morioka Junior College 24, 33-44, 2014.

[2] S. Shimano, A study of difficult children: research on the difficult child as observed in preschools by students of a junior college. Bulletin of Morioka Junior College 17, 21-35, 2007.

[3] T. Shimizu and T. Miao, Evaluations of Driver's status by chaotic analysis of finger pulse waves. human interface 6(1), 97-99, 2004.

[4] M. Oyama-Higa and T. Miao, Discovery and application of new Index for cognitive psychology. 2006 IEEE Conference on Systems, Man, and Cebernetics, 2040-2044, 2006.

[5] M .Sano and Y. Sawada, Measurement of the Lyapunov spectrum from a chaotic time series. Physical Review Letters, 55, 1082, 1985.

[6] M. Oyama-Higa, Development of a self-check system for mental health, which uses Nonlinear Chaos Analysis of Pulse Waves. The 12th Open Symposium "Humanities Science and Database" Executive Committee, 31-41, 2006.

[7] J. Piaget, The Psychology of intelligence. 1960 (translator) Malcolm piercy and D. E. Berlyne, 2001, Routledge.

[8] A. Tomotoda, ADHD and attachment Disorder. Japanese journal of child and adolescent psychiatry 58(5), 623-627, 2017.

[9] J. Tsujino, M. Tanabiki, S. Tanabiki, M. Maekaw and H. Denma, A study on the divergence value of autistic spectrum children and the validity of the divergence value. Bulletin of Himeji Hinomoto College 39, 23-35, 2016.

[10] J. Tsujino, M. Tanabiki, T. Fukui, T. Hayashi and H. Kihara, Characteristic of children with special needs in nonlinear chaos analysis of pulse wave of fingertip. Bulletin of Himeji Hinomoto College 40, 97-106, 2017.