Gender Difference of Developments of Motor Control Function in Primary School Ages with Visual Synchronization Task of Hands' Movements

Kyota Aoki, Norio Fukuda, and Hisanori Hotta

***Abstract*—There is a difference of development between genders. About motor control function, girls show about two years' progress than boys in primary school ages. However, there is few quantative observation. We need clear views about the gender difference to find pupils that have problems in their developments. The authors proposed the cooperative visual synchronization task, its' measuring method, implementation and experiments to measure and evaluate the performance of motor control function. The new task and the measuring method enable to measure the precise movements safely, easily and in a short period of time. The proposed method is safe, because there is no need to attach the device to a subject nor to make exaggerated motions. With the method, we made the measurements of 400 subjects in primary school ages. From the measurements, this paper shows a clear view of the developments of motor control function. Boys show about 21 months' delay in average of motor control function than girls. Girls ' development about motor control function slowdown at about 130 months from birth.**

***Index Terms*—Development, developmental process, motor control function, measurement, evaluation.**

I. Introduction

A female advantage in primary school is a common finding in education research. Some researches show about two years advance of girls in skillfulness about fingers and hands. However, there is no precise and objective understanding about the gender difference.

There are many motor tasks that measure the abilities of motor functions of a human. They are the Purdue pegboard task, a seal affixation task, a tray carrying task, and etc. [1]-[3]. These tasks estimate the ability of a motor control function of a human with the results of the tasks. There is no observation of the process of the tasks.

There are also some synchronization tasks used to measure human abilities. For example, they are synchronization of finger taps with periodically flashing visual stimuli and synchronization with an auditory metronome. In these tasks, the timing between the stimuli and the action is measured. There is no observation of the movements of fingers [4]-[10].

Recently, many cheap and easy measurement methods for the movements of a human body have been developed. For instance, some of these sensors are a Kinect sensor and a Leap motion sensor [11], [12]. There are many applications that use those sensors for controlling computers. For instance, many video games use those sensors for controlling an avatar in the games [13].

The human hands are the parts of a body that can make the most complex movements. This paper proposes the method that measures the precise movements of hands synchronizing the movements of hands on a display. The synchronization needs visual perception of the displayed hands' images and precise control of the arm muscles. The process includes the perception of motion about a hands' image presented on a display, the perception of motion about subject's hands, motor recognition with muscular sensation, and recognition of processing delay in a subject's brain.

We proposed the new synchronization task and the evaluation method. The resulting measure is very sensitive. With this measure, we can observe the developments of the motor function of pupils in primary school ages [15]. Also, we observed the deteriorations of motor control function of elderly peoples [16].

First, we discuss the new visual synchronization task with visual presentation and its' performance evaluation method. Then, this paper shows the implementation of the proposed new visual synchronization task and its' evaluation method. And we also discuss the experiment's program that enables to measure the whole pupil in a primary school. Then, we discuss the experimental results. And last, we conclude this work.

II. Visual Synchronization Task

A. Target Movement

There are many motor tasks that intend to measure the motor function of a human. However, most of these tasks measure the results from the tasks. There are some tasks that measure the synchronization between a finger tap and stimuli. With human observations, it is difficult to measure the process of synchronizing movements. Now, we can use a Kinect sensor and a Leap Motion sensor. These sensors measure the three-dimensional movements of a human body. With these sensors, we can measure the precise movements of a human body.

We can synchronize our movements with each other. For instance, when dancing, dancers can synchronize their movements with each other. A synchronization of movement is more difficult work than a simple imitation of movement. To generate synchronized movements, we need to observe the motion to be synchronized. We need to generate the motion to be similar to the motion synchronized. We need to observe the generated motion synchronizing the original

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motion. We need to estimate the divergence between the original motion synchronized and the motion synchronizing the original motion. We need to control the speed of the motion synchronizing. These functions form a feedback loop. However, there is a delay in our processing. To compensate our brain's processing delay, we need to estimate the delay itself and make proper amount of feedforward.

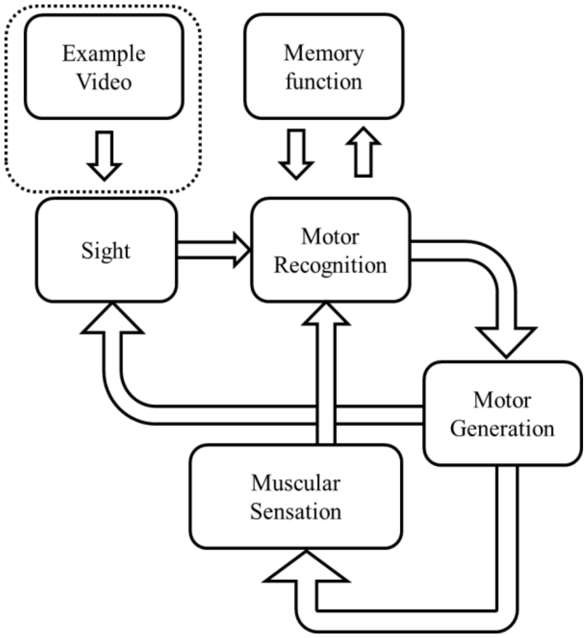

Fig. 1. Relations among functions.

This processing loop is shown in Fig. 1. For estimating the total brain function, we need to include all the functions of the brain. The visual synchronization task includes vision and motor functions. The vision includes not only the static sight, but also the dynamic sight.

The visual synchronization is more difficult than audio synchronization. So, we observe the wider brain functions with the visual synchronization tasks than the audio synchronization tasks.

Our proposed visual synchronization task is the synchronization between the position of stimuli on a display and the position of the hands. Our synchronization task is not the synchronization between the timing of the stimuli and the timing of action. The measurement of timing is only one scalar value in a cycle of stimuli. In our proposed synchronization task, the measuring result is a sequence of triples of the positions of the stimuli and the ones of subject's hands in a cycle of stimuli. For instance, we have 100 measurements in a cycle of stimuli.

The human hands are the parts of a body that can make the most complex movements. There is no apparent danger about hands' movements. With gross motions, there is a danger about accidental injury. The authors select hands' rotations for a target movement. The hands' rotation is shown in Fig. 2. This hands' rotation is more difficult than a waving of hands. It needs complex coordination of muscles.

We observe the total process of object's hands rotation. However, we need the method to estimate the performance of motor control function of a subject from the measured hands' poses. If we used the unplanned hands' movement for a target motion, it is difficult to estimate the performance of motor control function.

The authors select the hands' rotation that follows pure sine curve as the target motion. If a target motion follows a pure sine curve, it is very simple to evaluate the performance of motor control function of a subject. If the motor control function is perfect, the resulting hands' movements follows sine curve also. If the motor control function differs from the perfect performance, the resulting hands' movement differs from the pure sine curve also.

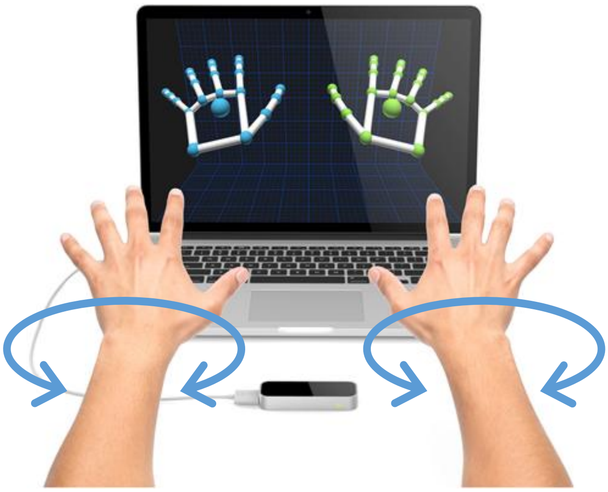

Fig. 3. Movements of hands.

B. *Motion Synchronization Measure*

As the authors define a target motion as a pure sine curve, we can easily define a performance measure invoking the signal-noise ratio in communication theory. The authors utilize the noise-signal ratio as the performance measure of motor control function of a subject.

The authors define the synchronization measure using Fast Fourier Transform (FFT) results of the estimated poses of both hands in each cycle as (1). This measure increases with the distance from ideal sine curve.

$$NSM = \left(\sum_{x=2}^{t/4} m_x\right) \Big/ m_1 \qquad (1)$$

In (1), t is the number of terms. m_x is the absolute value of the x-th term of the result of FFT. m_1 is the power of the lowest frequency. This represents one cycle of a hand's rotation. If the rotation of a hand follows the stimuli images precisely, m_1 carries all powers of the hand's rotation. Other terms carry no power. In that case, the measure in (1) is 0.

m_0 is a value that represents the average of poses. This is not included in (1). As a result, this measure does not depend on the absolute poses of hands.

If a subject makes complete synchronization to the stimuli, the resulting pose of both hands follows a complete sine curve. As a result, at every cycle of the rotation of hands, the result of FFT has a zero value at the second term or higher terms.

We call this measure as Non-Smoothness-Measure (NSM). This measure may span from 0 to infinity.

Our proposed system observes two hands. So at every cycle, we have two NSMs.

TABLE I: DISTRIBUTION OF SUBJECTS

School year	Girls	Boys	Total
1	25	32	57
2	32	29	61
3	36	35	71
4	34	34	68
5	27	33	60
6	36	29	65
Total	190	192	382

TABLE II: AVERAGE NSMTS IN SCHOOL YEAR

School year	Girls	Boys	Total
1	0.382	0.414	0.400
2	0.337	0.412	0.372
3	0.314	0.363	0.338
4	0.285	0.317	0.301
5	0.281	0.309	0.297
6	0.257	0.284	0.269
Total	0.305	0.348	0.327

III. EXPERIMENTS AND DISCUSSIONS

A. Experiments Setup

From the pre-experiments, the speed of the hands' rotation is best at one cycle per second. Subjects need about three cycles to synchronize their movements of hands to the proposed motion images and remember the motion. As a result, one trial of an experiment needs at least 4 S. For getting reliable results, we decide that the length of a trial is 15 cycles of rotations. This means that one trial needs 15 S. A cycle is one flip of hands. Fig. 3 shows the structure of trial and measurement.

B. Experiment

1) Subjects

We measured whole pupils of a primary school in JAPAN. The school have about 400 pupils.

We measured the whole pupil at morning of July 5 2016. We used six sets of measuring systems in two rooms. The shortness of the proposed visual synchronization task enables to measure whole pupils in a school.

2) Performance measure for a trial

In a single cycle, measured movements of hands may match the proposed example movements accidentally. We estimate the performance of the motion control function with the average motions in three continuous cycles. And, we estimate the performance of a subject in a trial with the best movements in the averages of three continuous cycles.

Equation (2) defines the performance of a hand in a trial.

$$\mathrm{NSMH} = \min_{i=1,12} average(NSM_i, NSM_{i+1}, NSM_{i+2}) \qquad (2)$$

NSMH is the performance of a hand in a trial. NSM_i is the *NSM* at i-th cycle defined as (1). We define the performance of a hand with the minimum of every average of continuous three NSMs. If we use the minimum of every NSMs, a defined NSMH may accidentally be very small. The average of continuous three NSMs represents the performance of a subject well.

We have two NSMHs in a trial. They represent the performances of both hands. Fig. 3 shows the relation between measurements and NSMH.

We hope to have a single scalar measure of performance at a trial. We define the performance measure in a trial as (3).

$$\mathrm{NSMT} = \min\,(NSMH_L, NSMH_R) \qquad (3)$$

In (3), NSMT is the performance measure in a trial. $NSMH_L$ is the NSMH of the left hand. $NSMH_R$ is the NSMH of the right hand. This NSMT represents the performance of a subject in a trial. This simply selects a good one in a both hands. In previous experiments, there is a little difference between both hands in health people. So, we can simply select a good one for the performance measure of a trial.

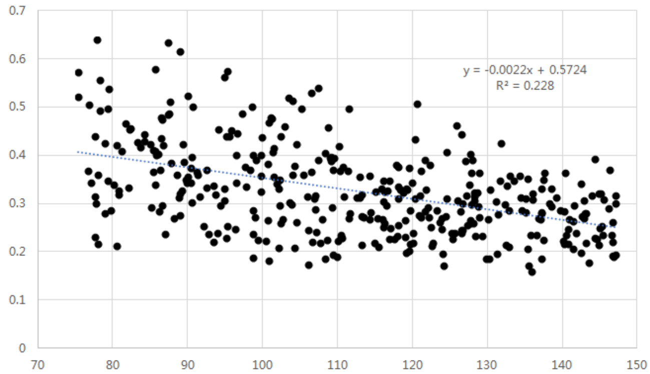

Fig. 4. Distribution of age and NSMT.

IV. RESULT AND DISCUSSIONS

A. Measurements Outline

The authors have the profile of development about motor control function in a small scale experiment. From the experiments, we have the linear approximation of the relation between the age and the NSM. (4) shows the relation between age and NSM [15].

$$M = 193.8 - 263.2NSMT \qquad (4)$$

TABLE III: T-TEST BETWEEN SCHOOL YEARS

School year	2	3	4	5	6
1	0.148	0.0008	1.54E-08		
2		0.0503	8.47E-06	3.88E-06	
3			0.0106	0.00534	1.89E-06
4				0.702	0.00251
5					0.0123

In (4), *M* is the estimated months from the birth from NSMT. The estimated months from the birth calculated using (4) represents a developmental age of motor control function. The authors decide that there are some problems at the measurements shows over 60 months' difference between the developmental age and the real age. We only use the measurements without any problem. Table I shows the distribution of gender and age of subjects that made correct measurements. Fig. 4 shows the distributions of age and NSMT of valid measurements. We can confirm the trend of decrease of NSMT with the increase of age. The linear approximation shows (5).

$$NSMT = -0.0022M + 0.5724 \tag{5}$$

In (5), *M* is the months from birth.

B. Differences among School Years

Table II shows the average of NSMT in school years. In Table II, with growing up, NSMT decreases. However, we need to confirm the deference between the distributions of NSMTs at each school year. Table III shows the both-side possibility of the t-test between two school ages. In adjacent school years, there are apparent difference in 2-3, 3-4, and 5-6 pairs of school years. In the 1-2 and 4-5 pairs of school years, there is not an apparent difference of the distribution s of NSMT. However, in the pairs of two years' difference in school years, all pairs show apparent difference. We can conclude that NSMT has an enough descriptive power to measure the developments of motor control function in primary school years.

C. Difference between Genders

In Table II, there are differences between the average performances of boys and girls. In all school years, girls show better performance than boys. The average difference is 0.043 in NSMT.

Fig. 5 and Fig. 6 show the distributions of age and NSMT of boys and girls, respectively. The linear approximation of boys' distribution is (7).

$$NSMT = -0.0024M + 0.6215 \tag{7}$$

The linear approximation of girls' distribution is (8).

$$NSMT = -0.0019M + 0.5197 \tag{8}$$

Comparing (7) and (8), the girls develop slower than boys do. However, it is difficult to discuss precisely.

TABLE IV: T-TEST BETWEEN BOYS AND GIRLS IN EACH SCHOOL YEAR

School year	Probability of sameness
1	0.260
2	0.00332
3	0.0375
4	0.0419
5	0.0976
6	0.0498

In Fig. 6, we can show the slowdown of development in over 130 months. Therefore, we compare the developments of boys and girls under 130 months from the birth. The linear approximation of girls' pairs of age and NSMT is (9).

$$NSMT = -0.0024M + 0.5708 \tag{9}$$

Comparing (7) and (9), the slants are similar. The slant is -0.0024. The difference is 0.0507. The difference of 0.0507 in NSMT is the difference of 21.1 months in developmental age as (10).

$$\frac{0.0507}{0.0024} \approx 21.1 \tag{10}$$

A report shows that there is progress from half year to one year of girls in developments. Other report says that there is two years' progress of girls in fine movements of hands and fingers. This paper's result is more precise understanding of gender difference in primary school ages.

V. CONCLUSION

This paper proposes and implements a novel measuring method of motor control function, and shows the result of large scale measurements in a primary school.

Our method and its implementation needs only 15 seconds to measure. And it is safe enough for small pupils.

The experimental results show the girls' 21 months' progress of motor control function from boys in primary school. This is much more precise understanding than classical works.

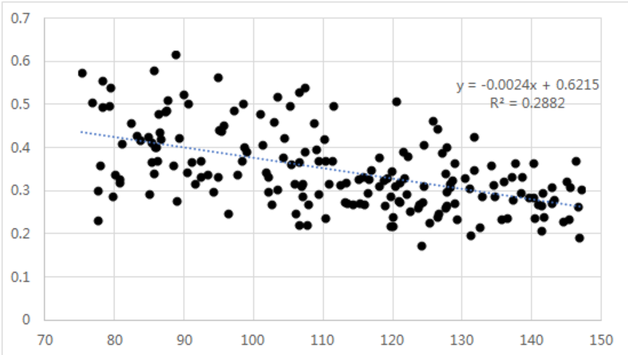

Fig. 5. Distribution of age and NSMT of boys.

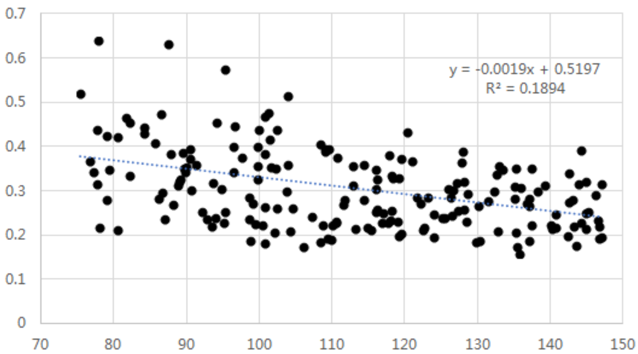

Fig. 6. Distribution of age and NSMT of girls.

We need much large-scale measurements to understand the development of motor control function in many areas and hierarchy.

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REFERENCES

[1] Lafayette Instrument. Purdue pegboard test. [Online]. Available: http://www.lafayetteevaluation.com/product_detail.asp?ItemID=159, retrieved 2016/08/29

[2] S. Hirata, Y. Kitajima, T. Hosobuchi, and M. Kokubun, "The speed and accuracy of fine motor actions in children with intellectual disabilities," Bulletin of Tokyo Gakugei University, vol. 59, pp. 263-267, 2008.

[3] M. Kokubun, "Are children with down syndrome less careful in performing a tray-carrying task than children with other types of mental retardation?" *Perceptual and Motor Skills*, pp. 1173-1176, 1999.

[4] M. J. Hove, J. R. Iversen, A. Zhang, and B. H. Repp, "Synchronization with competing visual and auditory rhythms: Bouncing ball meets metronome," *Psychological Research*, vol. 77, pp. 388–398, 2013.

[5] Y. Sugano, M. Keetels, and J. Vroomen, "The build-up and transfer of sensorimotor temporal recalibration measured via a synchronization task," *Front Psychol*, vol. 3, 2012.

[6] V. Krause, B. Pollok, and A. Schnitzler, "Perception in action: The impact of sensory information on sensorimotor synchronization in musicians and non-musicians," *Acta Psychologica*, vol.133, Issue 1, pp. 28–37, January 2010.

[7] J. Lee, J. Chai, and P. S. A. Reitsma, "Interactive control of avatars animated with human motion data," *ACM Transactions on Graphics*, pp. 491-500, 2002.

[8] S. Vercruysse, J. Spildooren, E. Heremans, J. Vandenbossche, O. Levin, N. Wenderoth, S. P. Swinnen, L. Janssens, W. Vandenberghe, and A. Nieuwboer, "Freezing in parkinson's disease: A spatiotemporal motor disorder beyond gait," *Movement Disorders*, vol. 27, no. 2, pp. 254-263, 2012

[9] M. A. Smith, J. Brandt, and R. Shadmehr, "Motor disorder in Huntington's disease begins as a dysfunction in error feedback control," *Nature*, pp. 544-549, 3 February, 2000.

[10] K. Rubia, A. B. Smith, M. J. Brammer, B. Toone, and E. Taylor, "Abnormal brain activation during inhibition and error detection in medication-naïve adolescents with ADHD," *Am Psychiatric Assoc.*, vol.162, no. 6, pp. 1067-1075, June 2005.

[11] Microsoft. Kinect for Windows. [Online]. Available: https://www.microsoft.com/en-us/kinectforwindows/

[12] Leap motion. leap motion SDK. [Online]. Available: https://developer.leapmotion.com/, retrieved at 20150317.

[13] Microsoftstore. Kinect. [Online]. Available: http://www.microsoftstore.com/store/msusa/en_US/list/Kinect/categoryID.64752700

[14] K. Aoki and H. Hotta, "Brain activity estimation with precise motor measurements of visual synchronization task of hands," *Global Health 2015*, pp.39-44, July 2015.

[15] K. Aoki, H. Hotta, N. Otabe, N. Fukuda, and K. Harada, "Motor skill developments in 6 to 12 years old girls with visual synchronization task," in *Proc. 2016 Hawaii International Conference on Education Honolulu*, USA, pp. 953-959, 2016.

[16] K. Aoki and H. Hotta, "Aging measurements with precise observations of synchronization hands' movements — Aging effects about motor control function," *Global Health Challenges 2016*, pp. 49-55, 2016.

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