Relation between Mini-Mental State Examination and Motor Control Function Examination on Dementia

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***Abstract*—The authors developed a performance measuring method for motor control function. Using the method, patients suspected of dementia were measured the performance of their motor control function. The method used needs only 25 seconds to complete. It is safe, simple and non-invasive. The relation between the performance of motor control function and mini-mental state examination is discussed. Some parameters of the measurements of motor control function and the score of MMSE shows high correlation. MMSE sub-problem that represents the function of unevenly distributed in cerebellum, link to the parameter of the hand dominated by the brain dominant hemisphere.**

***Index Terms*—motor control function, dementia, MMSE**

I. Introduction

Japan has exceeded the level of aging society already, and aged society that is composed with 27.7% elderly people in the population [1]. The prevalence rate of dementia is estimated to be around 10% in the elderly people [2]. Dementia is currently an irreversible process and treatments only retards the progression of the condition. Therefore, early detection is important as prevention and treatment of dementia.

Mini-Mental State Examination (MMSE) is a convenient examination of dementia [3], [4]. The test requires about 10 minutes to 15 minutes and the sensitivity to the disease condition is not high. The motor control function evaluation method proposed by the authors requires much of brain functions and is effective as an index of the development of brain function in the age group of elementary school students and under [5], [6] [7]. It has also been shown that older people are effective as indicators of brain function decline.

This paper proposes the results of investigating the relationship between MMSE examination result that is a simple dementia examination and various measurement values obtained by the evaluation method for motor control function.

The next section briefly introduces the motor control function evaluation method and MMSE. Next, the summary of the motor control function measurements and the MMSE implementation are proposed. Then, those with high correlation are discussed individually among various evaluation values of MMSE and motor control function evaluation method. Finally, this work is concluded.

II. Motor Control Function Evaluation Method and MMSE

A. Motor Control Function Evaluation Method

The trial of the motor control function evaluation method is a visual stimulus / hand gesture reaction, and evaluates the adjustment process of the hand motion based on the visual stimulus. Examinees are instructed to move their hands in accordance with the inside and outside of the hands displayed and measure the inward / outward movement of their hand [8]. It is one type of visual synchronization task. It requires vision, motion recognition, short-term movement memory, motion generation, and requires a lot of brain functions as shown in Fig. 1. Fig. 2 shows examples of the stimuli images.

We can synchronize our movements with each other. For instance, in playing a dance, 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

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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 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 make the feedback loop. However, for compensating our brain's processing delay, we need to estimate the delay itself and make feedforward.

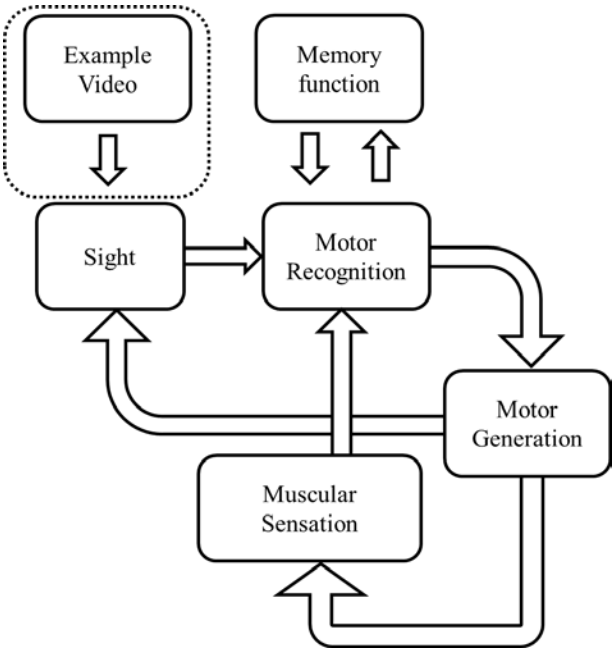

Figure 1. Relation among brain sub-functions in visual synchronization task.

B. Visual Synchronization Task

There are two phases in a new visual synchronization task to measure the short-term memory function about motion as in Fig. 3. In the first phase, a subject sees, remembers the motion displayed on a display, and makes the motion synchronizing the motion displayed on a display. In the next phase, there is no display of the motion. The subject continues to make the motion based on the remembered motion. Through a task, we measure the poses and the positions of the subject's hands and the displayed motion.

In the first phase, a feedback loop connects the subject's motion and the displayed motion. In the next phase, there is no displayed motion. The subject makes the motion only based on the motion remembered in the first phase.

Fig. 1 shows the relations among displayed images, and subject's functions. In the first phase, an example video is presented. In the first phase, the presented motion on a display is the strongest standard for generating motion. In the phase, a subject remembers the motion simultaneously. In the second phase, the example video is not presented. There is only remembered motion for the standard.

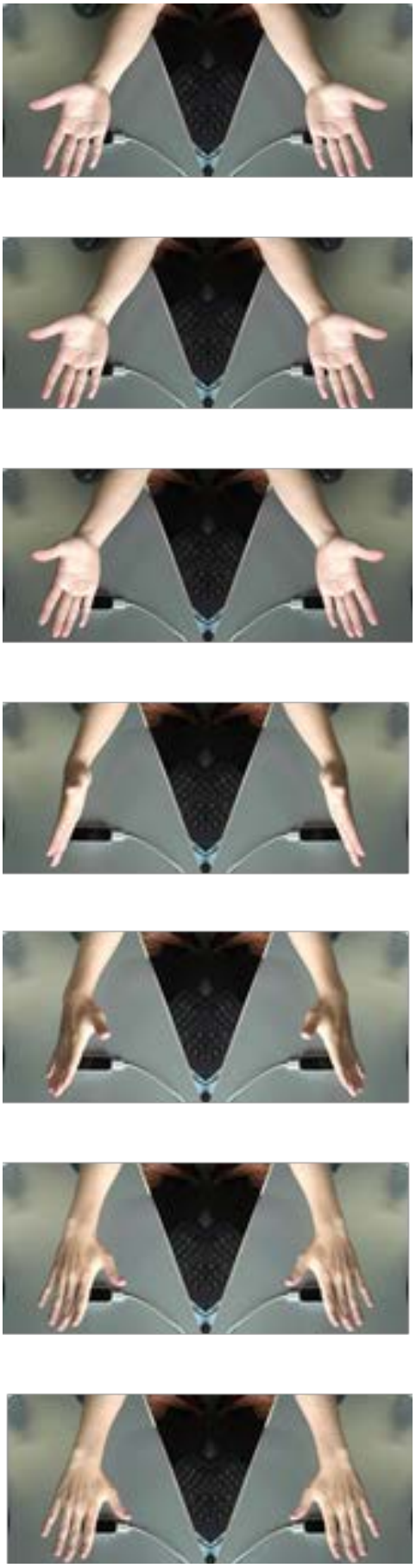

Figure 2. Stimuli images.

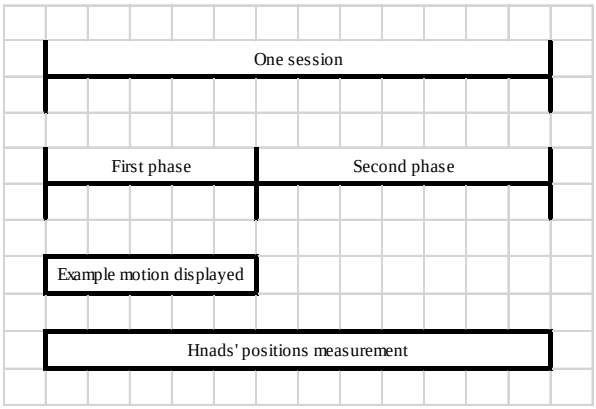

Figure 3. The outline of a proposed task.

C. MMSE

MMSE is a small set of simple tasks to measure the performance of a brain. MMSE is 30-point questionnaire that is constructed 11 simple tasks. This work uses the Japanese version of MMSE (MMSE-J) [1]. Table I shows MMSE-J. Some questions are arranged for Japanese.

TABLE I. JAPANESE MINI-MENTAL STATE EXAMINATION

#	Questions	Maximum Score
1	"What is the year? Season? Date? Day of the week? Month?"	5
2	"Where are we now: State? County? Town/city? Hospital? Floor?"	5
3	The examiner names three unrelated objects (cherry, cat, and tramcar) clearly and slowly, then asks the patient to name all three of them. The patient's response is used for scoring. The examiner repeats them until patient learns all of them, if possible. Number of trials: _____	3
4	"I would like you to count backward from 100 by sevens." (93, 86, 79, 72, 65, …) Stop after five answers.	5
5	"Earlier I told you the names of three things. Can you tell me what those were?"	3
6	Show the patient two simple objects, such as a wristwatch and a pencil, and ask the patient to name them.	2
7	" Repeat the phrase: 'Everyone draws rope together with strength.'"	1
8	"Take the paper in your right hand, fold it in half, and give it me." (The examiner gives the patient a piece of blank paper.)	3
9	"Please read this and do what it says." (Written instruction is "Close your eyes.")	1
10	" Make up and write a sentence about anything."	1
11	" Please copy this picture." (The examiner gives the patient a blank piece of paper and asks him/her to draw the symbol below. All 10 angles must be present and two must intersect.)	1
TOTAL		30

III. MMSE AND MEASUREMENT OF MOTOR CONTROL FUNCTION

A. Subject Overview

We conducted MMSE on patients suspected of dementia. Measurement of motor control function was also conducted for many patients who can obtain a cooperation.

This paper analyzes subjects who have undergone both MMSE and motor control function tests. The number of effective subjects who received both examinations is 32. Table II shows the age distribution of subjects. Subjects are 63 years old to 95 years old. Since our motor control function test can be carried out extremely easily, it is carried out multiple times to the same subject, and 120 measurements are carried out. The minimum number of measurements is one, and the maximum number of measurements is 11.

TABLE II. DISTRIBUTION OF SUBJECTS IN AGES

Age	Number of subjects
63	1
69	1
74	1
75	2
77	1
78	1
79	4
80	5
82	3
84	3
85	1
86	1
88	1
89	1
90	1
92	1
93	1
94	1
95	2
Total	32

B. Results Overview

1) MMSE

The MMSE has a full score of 30 points and the larger the score, the better the cognitive function. Mild cognitive impairment is suspected below 27 points.

The total distribution of subjects are shown in Fig. 4. In Fig. 4, the horizontal axis is age, and the vertical axis is MMSE score. The mean value of the score of the 32 subjects is 18, and the standard deviation is 5.8. The minimum value is three, and the maximum value is 27.

2) Motor control function test

To evaluate a whole trial, Trial Non-Smoothness Measure (TNSM) is introduced. TNSM is the minimum of three moving average of NSM which is the evaluation

value of the non-smoothness of motion control function at each rotation [5]. TNSMs of all trials are distributed as shown in Fig. 5. The horizontal axis represents age and the vertical axis represents TNSM.

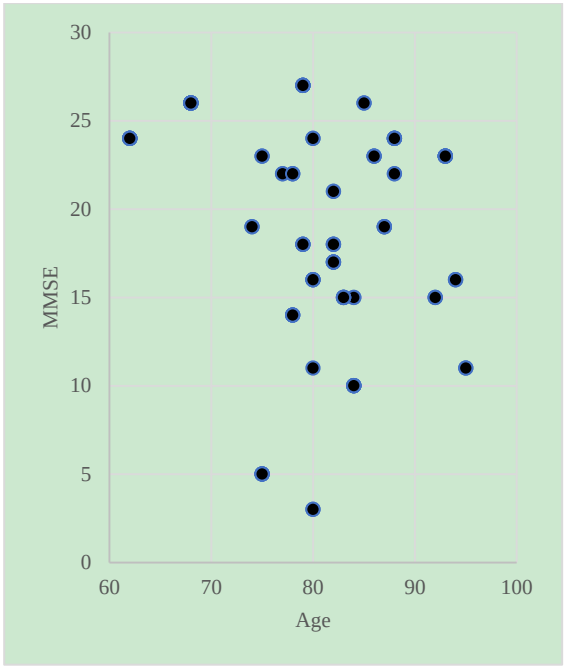

Figure 4. Distribution of MMSE and ages.

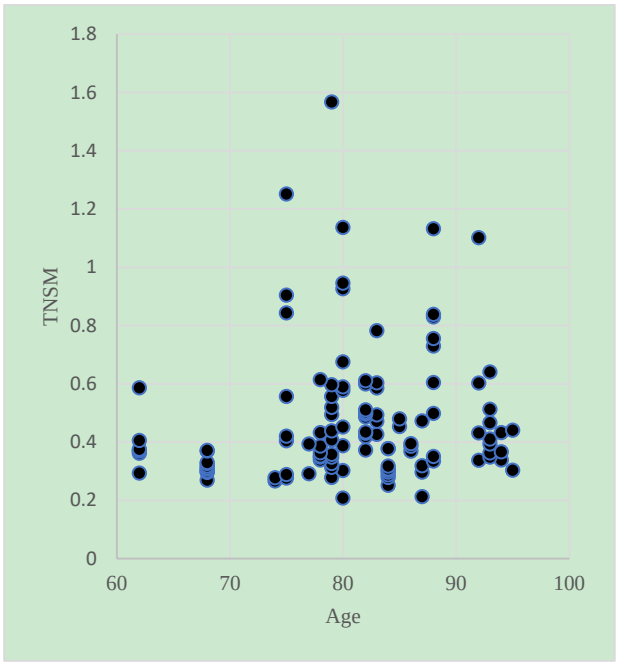

Figure 5. Distribution of minimum TNSM.

For healthy subjects, the mean of TNSM follows (1) [6].

$$\text{TNSM} = 0.0022\text{age} + 0.12070 \quad (1)$$

In (1), 'age' is the age of a subject. 'TNSM' is the TNSM of a trial. The standard deviation is 0.00646. From (1) and the standard derivation, mean + 4σ value at the age of 95 is 0.3555. Looking at the TNSM distribution of the subject shown in Fig. 5, TNSM is less than 0.35 in only 38 measurements, and in other 81 measurements, it is possible to detect abnormalities only with TNSM.

IV. Precise Discussion about Relation between MMSE and Motor Control Function Test

For 114 measurements except for cases where TNSM is 1.0 or more, the correlation between the MMSE and various evaluation values obtained from the motion control function evaluation method was investigated.

A. MMSE

MMSE consists of 11 partial tasks. Each task includes multifaceted elements to measure various cognitive abilities. On the other hand, the motor control function evaluation method used in this study does not require short-term and long-term memory although it requires extremely short-term memory. In addition, it does not measure language ability.

1) MMSE score

The motor control function evaluation value showing a high correlation with the MMSE score is the absolute value of the difference between the minimum value of 3 times moving average NSM of left and right hands, and the correlation value is -0.49.

The mean and the median of the motion power of the left hand in seven times rotations with stimuli image also shows relatively high correlation as 0.43 and 0.48.

2) MMSE question 3

The third partial task of MMSE shows a high correlation with the absolute value of the difference between the minimum value of the three times moving average NSM on the left and right hands like the MMSE score. The correlation value is -0.66. It also shows the correlation to the minimum value of the three-time moving average NSM on the right hand, and the correlation coefficient is -.057.

It also shows a correlation to the motion power of the phase1. The mean and median of the left hand motion power in the phase1 shows some correlation. The correlation coefficients are 0.456 and 0.448 respectively.

The third sub-task is a task of instantly reproducing by voice with the names of the three objects presented by voice, and is a task of voice stimulus input and voice response output. The memory time is similar to the motor control function evaluation method.

3) MMSE question 6

The sixth problem of MMSE is an item nomenclature task, which is a visual stimulus input / voice response output. As with the MMSE score, it shows relatively high correlation to the absolute value of the difference between the minimum value of the three times moving average NSM of the left and right hands, and the correlation value is -0.66.

It shows relatively high correlation to the minimum value of the three-time moving average NSM on the right hand, and the correlation value is -0.54.

The sixth problem of MMSE shows relatively high correlation to the median and 1/3 value of NSM of a right hand at phase1. Phase1 is the period where the stimuli

images are displayed. The correlation value is -0.401 and -0.463 respectively.

It also shows some correlations with absolute difference between minimum NSM of the right and the left hands in the phase1. The correlation coefficient is -0.488.

The sixth problem of MMSE shows some correlation to the absolute difference between the minimum NSM of the right and the left hand of first five times of rotations in the phase2. The correlation coefficient is -0.529. It also shows some correlation to the absolute difference between the minimum NSMs of both hands at the last part of the phase2. The correlation coefficient is -0.409.

This problem is an immediate response, and the problem reaction time is similar to the motion control function evaluation method.

4) MMSE question 9

The ninth partial task of MMSE shows high correlation value 0.63, 0.53, 0.43 with the mean, median, 1/3 value of the right hand power in the phase1 that is the seven times with the stimuli images. The score of the partial task 9 is binary zero or one, and the correlation coefficient does not exceed 0.87 even when it shows perfect correlation with the motion power of the motor control function evaluation method having three significant digits. For the left hand, it shows only a correlation of 0.34 at the maximum. MMSE partial task 9 is a writing task. It is visual input, and motor response. The motor control function evaluation method is a hand motion expression in the exemplification video presentation, and the sensory instrument responsible for the stimulation / reaction is the same as the reactor.

5) MMSE question 7

The seventh partial task of MMSE shows correlation with mean, median, and 1/3 value in seven times rotations with example images as well as the ninth sub task. The correlation coefficients are 0.56, 0.49, and 0.43 respectively. In addition, it shows correlation to the mean of the left hand power.

The partial task 7 is short-term memory reproduction with respect to voice. Although the motor control function evaluation method and the stimulus input and reaction output are different, they are similar in terms of storage time.

6) MMSE question 2

The second problem of MMSE shows correlation to the absolute difference of TNSMs of both hands. The correlation coefficient is -0.407. It does to TNSM of the right hand. The correlation coefficient is -0.407.

It also does correlation to the mean, median and 1/3 value of the left hand power of the phase1. The correlation coefficients are 0.457, 0.517 and 0.449 respectively. The right had does not show a correlation over 0.4.

7) MMSE question 8

This shows correlation to the minimum NSM of the right hand in the phase1. The correlation coefficient is -0.530. It also does to the median and 1/3 value of the motion power of the left hand in the phase1. The value is 0.434 and 0.416 respectively. With the right hand power in the phase1, the difference and the standard derivation show correlations. The values are -0.460 and -0.446 respectively. It shows relatively high correlations to the difference of minimum NSMs of both hands in the phase1, and its absolute value. The correlation coefficients are -0.445 and -0.580 respectively.

B. Motor Control Function Parameters

This sub-section discusses items that show relatively high correlation to MMSE.

TABLE III. CORRELATION BETWEEN MMSE AND THE DIFFERENCE OF TNSMS OF BOTH HANDS

MMSE	Right	Left	R-L	Abs(R-L)
Score	-0.3544	-0.2076	-0.2449	-0.4879
1	-0.1121	-0.0543	-0.0879	-0.2162
2	-0.4046	-0.2263	-0.2895	-0.4081
3	-0.5749	-0.2406	-0.4851	-0.6647
4	-0.1502	-0.1039	-0.0893	-0.2998
5	-0.1949	-0.2055	-0.0515	-0.1837
6	-0.5401	-0.1896	-0.4889	-0.6576
7	-0.2002	-0.1253	-0.1311	-0.3251
8	-0.1840	-0.2871	0.0362	-0.2108
9	-0.3848	-0.1960	-0.2928	-0.3890
10	-0.1775	-0.1382	-0.0915	-0.3345
11	-0.0971	0.0668	-0.1799	-0.3143

1) Absolute value of the difference between the minimum value of the 3 times moving average NSM on each side

The absolute value of the difference between the minimum value of the 3 times moving average NSM on each of the left and right shows correlation with the MMSE score, MMSE problems 2, 3 and 6. The correlation values are -0.49, -0.41, -0.66, and -0.66, respectively. Table III shows the correlation between the right hand, left hand TNSM, R - L, and its absolute value, and each item of MMSE. In Table III, the absolute values over 0.4 are marked.

2) Right hand 3 times Minimum value of moving average NSM

The minimum value of the right hand three times moving average NSM correlates with the MMSE partial tasks two, 3, and 6. Correlation values are -0.40, -0.57, and -0.54, respectively.

3) Hand rotation power with stimuli motion image

Table IV shows the correlation between the measurement values concerning the rotation power in the phase 1 and the item of the MMSE on the right hand and the left hand. In the table, '1/3' is the smaller one third. 'SD' is the standard derivation. In Table IV, the absolute values over 0.4 are marked. Right hand rotation power shows a relatively large correlation with the MMSE problems 7, 8, 9, 10 in terms of mean, median, 1/3 value and max-min. In the MMSE problem 9, the right hand side shows a remarkably large correlation. It evaluates the ability to read a sentence, and it seems to reflect the state of the left-brain largely.

TABLE IV. CORRELATION BETWEEN MMSE AND THE POWER IN THE FIRST PHASE

MMSE	Right hand						Left hand					
	Mean	Median	1/3	min	Max-min	SD	Mean	Median	1/3	min	Max-min	SD
Score	0.360	0.344	0.367	0.341	-0.137	-0.133	0.442	0.483	0.406	0.224	-0.016	0.004
1	0.155	0.113	0.149	0.164	-0.047	-0.047	0.187	0.224	0.135	-0.025	0.125	0.141
2	0.304	0.327	0.343	0.297	-0.165	-0.165	0.457	0.517	0.449	0.225	-0.006	0.000
3	0.407	0.378	0.352	0.278	0.003	0.004	0.456	0.448	0.394	0.250	-0.012	-0.006
4	0.167	0.160	0.181	0.176	-0.108	-0.096	0.196	0.228	0.175	0.154	-0.079	-0.055
5	0.270	0.253	0.306	0.377	-0.194	-0.206	0.215	0.265	0.284	0.200	-0.164	-0.145
6	0.186	0.203	0.224	0.245	-0.201	-0.191	0.386	0.448	0.393	0.233	-0.100	-0.099
7	0.558	0.487	0.427	0.299	0.150	0.151	0.426	0.342	0.310	0.193	0.106	0.122
8	-0.035	0.047	0.128	0.239	-0.460	-0.442	0.344	0.434	0.417	0.272	-0.243	-0.226
9	0.632	0.529	0.426	0.200	0.397	0.381	0.343	0.211	0.187	0.141	0.168	0.177
10	0.430	0.432	0.408	0.214	0.045	0.046	0.441	0.423	0.369	0.128	0.128	0.141
11	0.113	0.108	0.113	0.155	-0.103	-0.098	0.259	0.293	0.236	0.154	0.011	0.010

On the other hand, in the MMSE problem 2, the left hand shows more correlations than the right hand. The problem 2 is about space orientation. The right hemisphere is dominant about space orientation. This affects the difference between the left hand and the right hand about the MMSE problem 2.

V. CONCLUSION

This paper aimed to estimate the MMSE evaluation value from the measurement value obtained by the motor control function measurement method as a measure to evaluate the medical condition of dementia. Initially, correlation between each item of MMSE and various evaluation values obtained from the measurement experiment of the motor control function evaluation method was obtained.

Some of the partial tasks that make up MMSE seemed to be irrelevant to motor control. The results show that some MMSE partial tasks using brain functions required for the motor control function evaluation method had high correlation with the evaluation value obtained from the motor control function evaluation method.

In the MMSE partial item considered to be unevenly distributed in the left and right brains of the cognitive function, the motor control function of the opposite hand controlled by the corresponding hemisphere shows much more correlation.

Various evaluation values obtained from the motor control function evaluation method have about three significant digits, and it is possible to capture the fluctuation of minute cognitive function that cannot be captured by MMSE.

The number of effective subjects in the experiment conducted in this study is as small as 32 and it is unknown whether the trend obtained in this paper is a general tendency or not, and a larger scale measurement experiment is necessary.

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