35th Annual International Conference of the IEEE EMBS
Osaka, Japan, 3 - 7 July, 2013

Measurement of brain activity responded by subjects'own name using EEG

Kaori Tamura , Chihiro Karube, Takaaki Mizuba, Mayumi Matsufuji, Sachio Takashima and Keiji Iramina, *Member, IEEE*

***Abstract*— Sever motor and intellectual disabilities (SMID) patients can't express their feelings with languages. That's why it is important to measure and analyze their brain activity. In this study, we tried to investigate the brain response to hearing subject's own name of healthy people and one patient with SMID by analyzing EEG. The results of time frequency analysis showed the inter trial coherence of a patient with SMID at theta oscillation was higher in response to SON specifically. On the other hand, that of healthy subjects was not so different with that in response to control condition. These results might reflect of the difference of lexical semantic process between the patient and healthy subjects.**

I. Introduction

"Severe motor and intellectual disabilities" (SMID) is a term used to describe a heterogeneous group of disorders with severe physical disabilities and profound mental retardation. The SMID children can show expressions of their feelings, but are unable to use speech to communicate with others. Hence their families or nurses have a problem of communication with SMID people and sometimes they have a difficulty in reading their expression. For example, when their families called the SMID people's name, sometimes SMID people changed their expression. However the family can't determine whether patients recognized it as their own name or not.

In order to support of understanding SMID people's response to hearing their own name, we focused on measuring their brain activities. In previous study, we estimated a passive oddball paradigm including auditory stimuli. One of the auditory stimuli is subject's own name and it was used to measure brain response of hearing one's name and the other words. It has been reported that Novelty p300 was elicited by hearing subject own name comparing with white noise [1]. In our experiments, we tried to analyze the event related potential. In addition, we introduced the time frequency analysis, event related spectral perturbation and inter-trial coherence to measure the change. Using these procedure and methods, we measured the brain activity of one patient with SMID and healthy subjects as a control group.

Kaori Tamura, Chihiro Karube, Takaaki Mizuba and Keiji Iramina are with the Graduate school of System Life Sciences, Kyushu University, 1-1-3 Maidashi Higashiku Fukuokashi, Japan (corresponding author to provide phone: 092-642-6608; e-mail: tamura@ bie.inf.kyushu-u.ac.jp).

Mayumi Matsufuji and Sachio Takashima is with the Yanagawa Institute for Developmental Disabilities, Yanagawa, 284-2, Kamimiyanaga-machi, Yanagawa,Fukuoka, Japan.

II. Material and Method

A. Subjects

As the subjects in the healthy group, eight healthy, right-handed volunteers aged from 21 to 27 years old (2 females), with normal hearing participated in this study. All of the members of this group reported no medical, neurological or psychiatric problems.

We also measured EEG of a patient with SMID (SP), who was in the Yanagawa Institute for Developmental Disabilities. He was 21 years old at measure and his diagnostic is Perinatal brain damage (Peri Ventricular Leukomalacia, PVL) and his focal pathology site was parietal part.

The protocol was approved by the Kyushu University ethics committee.

B. EEG recordings

EEGs were recorded using 22-channels with Ag/AgCl scalp electrodes according to the International 10-20 system. The reference electrode was placed on the earlobes, the ground electrode on the tip of the nose. Electrode impedance was kept below 10kΩ. EEGs were recorded using Neurofax (NIHON KOHDEN). The sampling rate was 500 Hz. A 0.08-300 Hz bandpass analog filter was applied.

C. Procedure

The subjects in the healthy group sat on a comfortable chair and listened to the presented sound stimuli through earphones. They were instructed to watch a silent movie and, not to pay attention to the sound stimuli (Fig.1). The sound intensity was 65dB. SP lied on a wheelchair instead of a chair and listened to the stimuli through same earphones as the healthy subjects. The patients with SMID were not instructed to watch a silent movie.

The stimuli set included three words, the Subject own name (SON) and two control words. Two control words were Japanese noun as same syllables as SON. SON stimuli were recorded using Softalk, a freeware of screen reader. These sound stimuli were edited using STIM (NEURO SCAN,INC). The mean duration of SON was 502.4 msec. (SD = 80.9)

These three words were delivered in a random series with the same probabilities (33%) for presentation. Each sequence consisted of 120 stimuli. Stimulus onset asynchrony was 5 sec.

D. ERP analysis

The EEG data was analyzed using EEGLAB version 11.0.3.1b, which is an open toolbox operated in the MATLAB environment (version 7.50, MathWorks, Natick,

978-1-4577-0216-7/13/$26.00 ©2013 IEEE

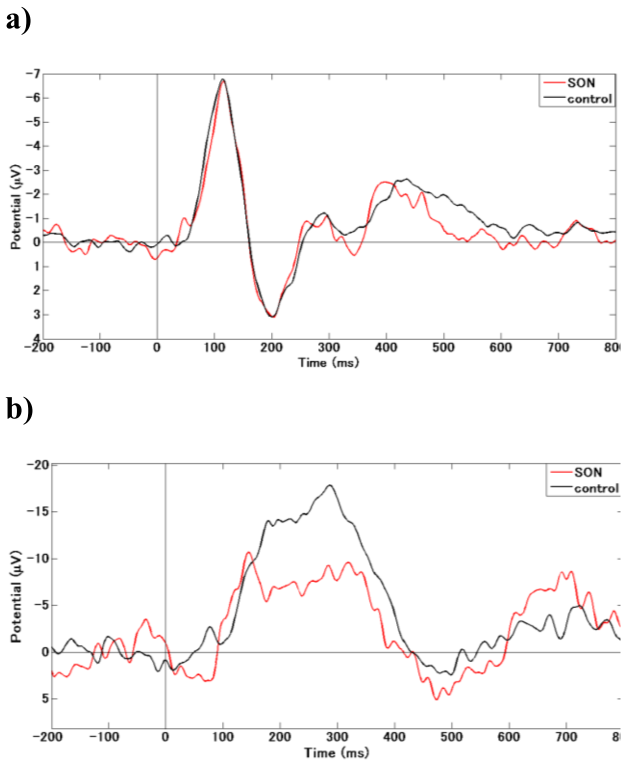

Figure 1. The grand average waveforms of recordings Cz for the healthy subjects (a) and SP (b). The response to control stimuli (black line) and SON stimuli (red line). The X axis is a time scale (ms) and the Y axis represents amplitudes (μV).

MA, USA) [2]. The ERP was averaged for the novels, for an epoch of 1000ms including a pre-stimulus period of 200ms. After averaging, the baseline was corrected according to the mean value of the signal during 200ms prior to the stimulus, and a 0.1-50 Hz bandpass digital filter was applied (Butterworth, 6th order). Some epochs including ± 100μV were rejected. All processed epochs from each subject were assembled and subjected to Infomax independent component (ICA) analysis using the runica algorithm implemented within EEGLAB in Matlab [2][3], with a blind source separation. Then eye blinking components were removed. The ERP data were averaged with the sweep from 200ms before to 800ms after stimulus onset.

E. Time frequency analysis

To measure the mean event related changes in the power spectrum, we introduced event related spectral perturbation (ERSP) [4] using the EEGlab package. ERSPs measure average dynamic changes in the amplitude of a broadband EEG frequency spectrum.

$$ERSP(f,t) = \frac{1}{n}\sum_{k=1}^{n}\left|F_k(f,t)\right|^2 \qquad (1)$$

For *n* trials, $F_k(f,t)$ is the spectral estimate of trial *k* at frequency *f* and time *t*.

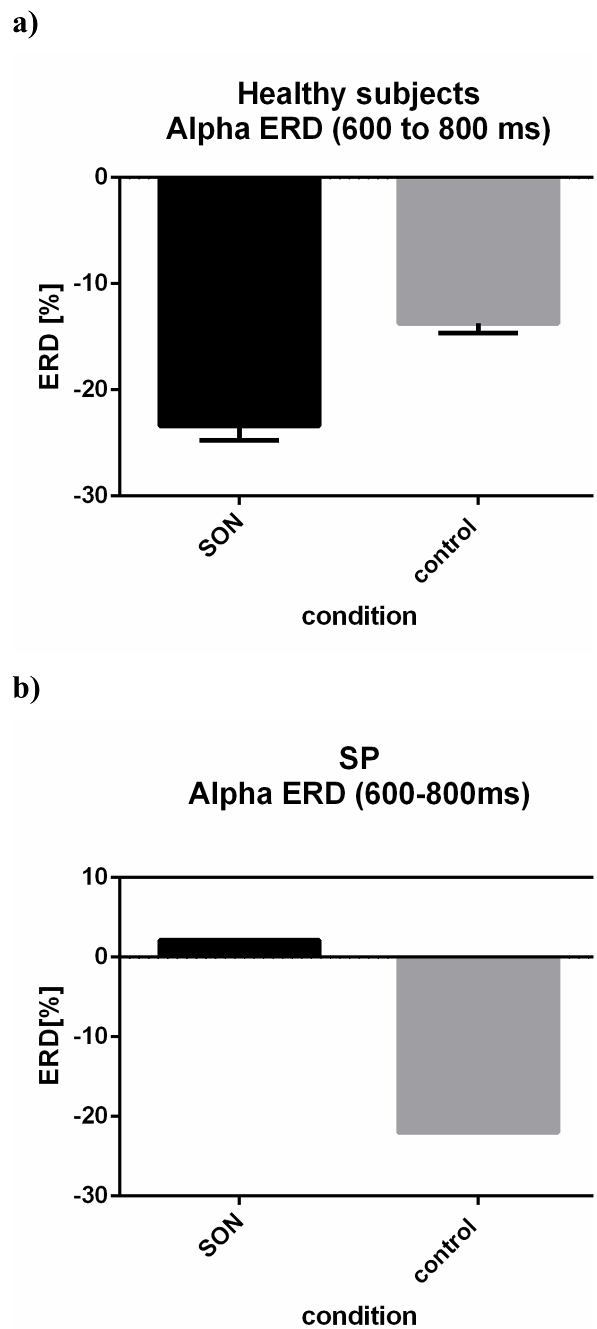

Figure 2. Alpha Event related desynchronization (mean ±SEM) around 600 – 800 msec after stimli at Cz electrode of healthy subjects (a) and SP (b). The Y axis shows the ERD range (%).

A 0.1-50 bandpass digital filter (Butterworth, 6th order) was applied. Then, Morlet wavelet transform (MWT) was used to compute these measures of single-trial EEG responses [5]. The parameters of central frequency (ω) and restriction (σ) in MWT were 5 and 0.2 respectively.

With the obtained wavelet coefficients we calculated event related de-/synchronization (ERD/ERS), reflecting the percentage change in test power with respect to a reference interval [6] according to the formula:

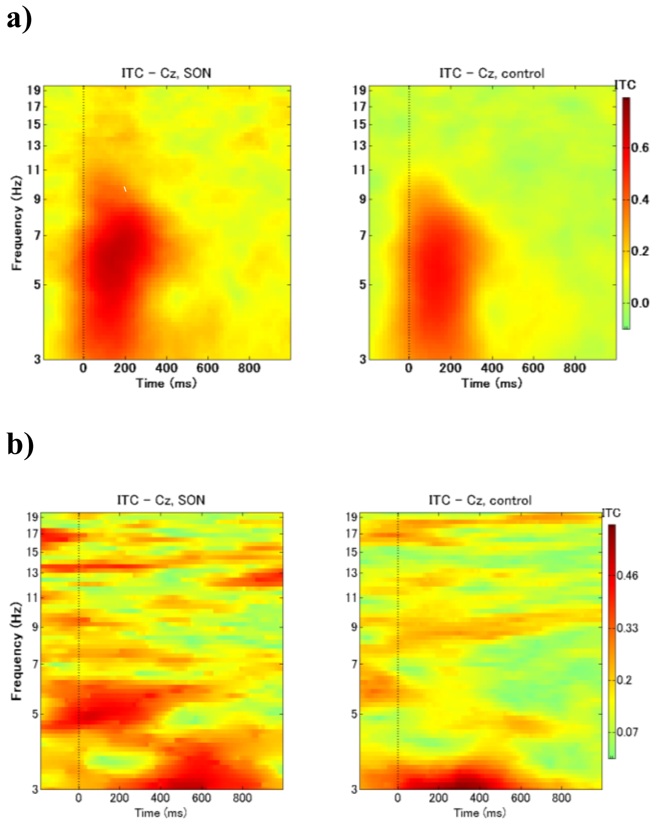

Figure 3. ITC associated with control condition (right) and SON (left) condition at Cz electrode of healthy subjects (a) and SP (b). The X axis shows the time range (msec), and the Y axis shows the frequency (Hz) .The black arrows indicate each peak of ITC at theta oscillations in response to SON (helthy and SP) and control (only healthy subjects).

$$ERD / ERS[\%] = ((R - A) / R) * 100 \qquad (2)$$

R is the reference power and A is the interested spectral power. As a reference power, the mean power of between -200 to 0 msec was used.

For the investigation of the coherence of interested oscillation, Inter-trial coherence (ITC) values were calculated [7] [2]. It indicates the synchronization at a particular frequency and latency which time locked EEG data over trials. ITC was defined by

$$ITC(f,t) = \frac{1}{n}\sum_{k=1}^{n}\frac{F_k(f,t)}{|F_k(f,t)|} \qquad (3)$$

For n trials, $F_k(f,t)$ is the spectral estimate of trial k at frequency f and time t as ERSP.

F. Statistics

The numerical data of healthy control group was analyzed using non parametric unpaired Mann- Whiteny U test with stimulus type (SON vs. control words) and was performed using GraphPad Prism version 6.00 for Windows, GraphPad Software, La Jolla California USA, www.graphpad.com

III. RESULTS

A. Event related potential

Fig.1a shows the grand average waveform across 8 healthy subjects, in response to subject's own name (SON) and other control words (control). The grand average waveform showed a positive peak around 350msec after stimulus. The peak amplitudes of SON was significantly different from that of control ($p = 0.0391$). It has been reported that this peak was novelty p300 and it was elicited by SON [1]. Fig.1b is the grand average waveform of SP. It was too noisy to find a distinct peak.

B. Event related spectral perturbation

For further investigation of brain activity after hearing of subject's own name (SON), we analyzed the change of EEG power using time frequency analysis.

We found a decrease of alpha power around 600msec to 800msec in response to SON specifically at Cz in the healthy subjects group (Fig.2a). Comparing the decrease in statistically, this alpha power decrease was significantly different from the response to the control stimuli ($p = 0.0002$) (Fig.2a).

Next we analyzed whether the decrease of alpha power was shown in response of SP (Fig.2b). However such a decrease was not shown in response to SON, rather ERD of control condition was larger than that in response to SON.

C. Inter trial coherence analysis

The time frequency analysis of EEG power change is related to the amplitude of the interest oscillation. In order to detect the change of oscillations whose amplitudes were small, we tried to compare the Inter-trial coherence (ITC) [7][2].

Fig.3 shows the time frequency plot of ITC value and we found the high ITC values of theta oscillations around 100msec to 200mse in response to both of stimuli in healthy subjects (Fig.3a).

The ITC increase was also shown in our result from SP and the ITC value in response to SON was higher than that to control condition (Fig.3b).

IV. DISCUSSION

A. Healthy subjects

In the presented study, we found that novelty P300 was elicited using the oddball paradigm including subject's own name (SON). It indicates that SON evoked the Novelty p300 components as a novel stimulus in our procedure. This result suggested that SON stimuli captured an attention in comparison with other control words. It has been reported that novelty P300 was elicited in passive oddball paradigm including subject's own name [1] and our findings were compatible with their results.

Next, we analyzed using two time frequency method. One of them is the Inter-trial coherence (ITC) analysis and the other one is the Event elated spectral perturbation (ERSP) analysis.

From the ITC analysis, we found that the high score of ITC of theta oscillations around 150 msec after stimuli. It was indicative of the increase of coherence in theta band. In previous report, theta oscillations have a relevance to some cognitive process, for example, sustained attention [8][9]. Our results suggested the transition of attention to sound stimuli in our passive oddball paradigm in line with previous reports [8][9].

In ERSP analysis, the results showed the decrease of alpha range power in response to subject's own name specifically. It has well discussed that the decrease of alpha power has a correlation with attention process and long-term memory [10]. It would suggest that some types of long-term memory process occur upon hearing one's name.

B. the patient with SMID

To evaluate his brain response, we applied the same methods to one patient with SMID (SP) to analyze his EEG.

The ERP components or event related desynchronization of alpha oscillations were not shown in response of SP, which was found in healthy subjects. One possible reason of these results was less EEG amplitudes of the patient. He has injured his brain so that his EEG amplitudes were very low and the signal/noise ratio was higher than ordinary EEG. From this reason, it was suggested that ERP analysis and time frequency analysis depending on EEG amplitude were not suitable for such a patient.

Comparing with these methods, ITC was robust against noise because it was normalized and it didn't depend on EEG amplitudes. That's why it was proposed that ITC analysis can detect changes of brain activity of patients with SMID.

From our result of ITC of the patient, the increase of ITC at theta oscillation in response to SON was shown at similar latency as healthy subjects. It was higher than that in response to control condition.

It has been reported that in semantic tasks that a theta phase-locked activity was shown and it was revealed that an increase of theta power is related to lexical-semantic processing in healthy subjects [11]. This report indicated that the difference between the results of the patient and healthy subjects caused from whether they understood the meanings of control words. The patient hasn't learned language because he injured his brain perinatally. On the contrary, it was supposed that his own name was something meaningful word for him because he heard his name frequently.

In conclusion, we found three types of EEG change in response to subject's own name; ERP response, the Inter-trial coherence of theta oscillation and the decrease of alpha oscillation in response of healthy subjects. Moreover it was suggested that ITC analysis was more suitable to analyze brain activities of patients with SMID. We are going to investigate the brain response of more patients with SMID.

ACKNOWLEDGMENT

This work was supported in parts by Grant-in Aids for Scientific Research, Ministry of Education, Science, Sports, Culture and Technology, Japan (No.23650267, 25560287).

REFERENCES

[1] I. Holeckova, C. Fischer, M.H. Giard, C. Delpuech and D. Morlet, "Brain responses to a subject's own name uttered by a familiar voice." Brain Res. 1082, 142–152. January, 2006

[2] A. Delorm and S. Makeig, "EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics including independent component analysis." J Neurosci Methods. 134:9–21. October, 2003

[3] A. Delorm, C. Sejnowski and S. Makeig "Enhanced detection of artifacts in EEG data using higher-order statistics and independent component analysis." Neuroimage. 15; 34(4): 1443–1449. February, 2007

[4] S. Makeig, "Auditory event-related dynamics of the EEG spectrum and effects of exposure to tones" Electroencephalogr. Clin. Neurophysiol. 86 , 283-293. November, 1992

[5] A. Mouraux and G. Iannetti, "Across-trial averaging of event-related EEG responses and beyond." Magn. Reson. Imaging 26, 1041–1054. January, 2008

[6] G. Pfurtscheller and A. Aranibar "Event-related cortical desynchronization detected by power measurements of scalp eeg." Electroencephalogr. Clin. Neurophysiol. 42:817—826. December, 1976

[7] C. Tallon-Baudry and O. Bertrand, C. Delpuech, and J. PernierR. "Stimulus Specificity of Phase-Locked and Non-Phase-Locked 40 Hz Visual Responses in Human." 16(13):4240–4249, July, 1996

[8] P. Sauseng, W. Klimesch, W.R. Gruber and N. Birbaumer, "Cross-frequency phase synchronization: a brain mechanism of memory matching and attention." NeuroImage , 40, 308–317. November, 2007

[9] M.P. Deiber, P. Missonnier, O. Bertrand, G. Gold, L. Fazio-Costa, V. Ibanez and P. Giannakopoulos, "Distinction between perceptual and attentionalprocessing in working memory tasks: a study of phase-locked and induced oscillatory brain dynamics." Journal of Cognitive Neuroscience, 19, 158–172. January, 2007

[10] W. Klimesch, P. Sauseng and S. Hanslmayr, "EEG alpha oscillations: The inhibition–timing hypothesis", Brain Research Review, 6 3 – 8 8, 2007

[11] A.J. Shahin, T.W. Picton, L.M. Miller, "Brain oscillations during semantic evaluation of speech.", Brain and Cognition. 70 259–66, 2009.