CYBERPSYCHOLOGY & BEHAVIOR
Volume 3, Number 3, 2000
Mary Ann Liebert, Inc.

Emotion Spectrum Analysis Method (ESAM) for Monitoring the Effects of Art Therapy Applied on Demented Patients

TOSHIMITSU MUSHA, Ph.D.,[1–3] SHIN KIMURA, M.D.,[3,4] KEN-ICHI KANEKO,[3,5] KIYOKO NISHIDA,[3,5] and KAZUO SEKINE[3,6]

INTRODUCTION

ALZHEIMER'S DISEASE (AD) is a major healthcare problem in all countries with a significant proportion of elderly individuals. Contrary to previous thinking, recent work has shown that AD is a significant cause of dementia in Japan and is currently under-diagnosed in favor of Vascular Dementia (VD).[1,2] Generally speaking, dementia has been treated as an incurable disease. But recently, the idea that dementia being incurable has been erased. The American Psycho-Medical Association has introduced the concept of curative dementia. Matsushita[3] indicated that cerebral problems could not be the sole reason for the onset of dementia because there are psychological factors such as psychological stress, social-environmental factors such as loneliness and isolation, mental factors, and physical factors. Kondou[4] reported on risk factors of the cause of dementia. This shows that there is a possibility for cure and prevention. Kaneko[5] also reported on critical factors for the cause of dementia and indicated the possibility of recovery by cerebral activation in the early stage. Kaneko stressed the importance of early diagnosis and early treatment.

Currently, we don't have a standard method for early diagnosis. The Hamamatsu method of early diagnosis (among many others) was the one of the easiest methods with which to screen the patients. This method was tested through statistical verification. However, the Hamamatsu method includes an active functional questionnaire and task requirements for subjects; it is not suitable for mass screening.

It is known that progress of AD is blocked by cognitive rehabilitation and medication provided it is found in its early stages. Some of the present authors (SK, KK, KN, KS) have been applying active art therapy on demented patients in various levels for the past 3 years, and have observed remarkable improvement of the patients. Active art therapy is aimed at giving the patients an enjoyable time by providing strong interactions between patients and artists. Family members are also invited to join art workshops with the patients so that they can enjoy oneness with the patients. The age of the patients ranges from 50 to 80 years, and the average is 73.2 years. They are classified as mild (20 patients), severe (20 patients), and predementia (1 patient). There are 23 patients diagnosed with senile dementia of Alzheimer's type, 15 patients diagnosed with cerebro-vascular type dementia, and 3 patients diagnosed with pre-senile dementia of Alzheimer's type.

[1]Brain Functions Laboratory, Inc., Kawasaki, Kanagawa-ken, Japan.
[2]Department of Informatics, Teikyo Heisei University, Ichihara, Chiba-ken, Japan.
[3]Kansei Fukusi Research Center, Tohoku Fukushi University, Sendai, Miyagi-ken, Japan.
[4]Ohmiya Medical Association Hospital, Saitama, Ohmiga, Saitama-ken, Japan.
[5]The Institute of Formative Art, Co., Tokyo, Japan.
[6]Mission Aid Christian Fellowship, Tokyo, Japan.

The result of the active art therapy for 1 year is as follows: 34% of the patients were improved (more than a 3-point increase in MMSE score[6]) and 20% inclined (more than 3-point decrease in MMSE score). The families evaluated the patients' improvement. The evaluation performed by the families rated 44% of the patients as improved and 37% of the patients as inclined.

The emotional state of a patient during the active art therapy was visualized by a new technique called ESAM that has been developed by Musha and colleagues through correlation analysis of electroencephalogram (EEG).[7] The emotional state is decomposed in four basic ones, namely, (1) anger/stress, (2) sadness/depression, (3) joy, and (4) relaxation, and it is represented as a locus in the 4-dimensional emotion space that is spanned by these four orthogonal characteristic emotional states. As this is a kind of spectral analysis of emotion, it is called Emotion Spectrum Analysis Method or ESAM. The present article will describe what ESAM is and some of the results that were gained by monitoring the effect of the emotional state of patients during the course of the therapy.

EMOTION SPECTRUM ANALYSIS METHOD (ESAM)

Estimation of the emotional state, in most cases, depends on the statement of a person under test. This is, of course, subjective and has some unreliable characters. In demented patients, a subjective method loses reliability because it is sometimes impossible to require demented patients to describe how they feel. To remove these drawbacks, an objective method for estimation of the emotional state is desired. A dynamic change of the emotional state is almost impossible to trace in every second in a subjective way.

The mental state, on the other hand, is reflected more or less in EEG, and various correlation analyses of EEGs have been tried so far. If successful, it would be reproducible and allow reliable dynamic tracing of an emotional change. Several researchers challenged the development of an objective diagnostic method. Schellberg *et al.*[8] made coherent analysis of fronto-temporal and inter-hemispheric EEGs, and compared the results with subjective ratings of video films. They found that high frequency EEG components were involved in the information processing and low frequency components in the transmission of differential affective information.[8] Hinrichs and Machleidt[9] made coherence-spectrum analysis on the inter-hemispheric coupling of brain activity. They found aggression and joy to be characterized by an increase of alpha-coherence. An alpha-coherence decrease is observed for anxiety and sorrow. Maremmani *et al.*[10] found that EEG asymmetry was attributed to anxiety. Spectral analysis of EEG and dynamical properties of the EEG system orbiting within the attractor were calculated by Aftanas et al.[11] and were found to correspond to the state of brain activity induced by emotionally valenced video stimuli. Field *et al.*[12] observed the effect of music on mood state and associated right frontal activation with chronic depression. These studies show the existence of a relationship between emotional states and EEGs, but nobody has ever tried to numerically evaluate levels of various emotional states by means of EEG analysis.

The state of mind surely influences EEG, and there is a possibility of characterizing it by properly processing EEGs. Musha *et al.*[7] are successful in numerical characterization of the state of mind in terms of cross-correlation coefficients of EEGs recorded at 10 electrode sites (Fp1, Fp2, F3, F4, T3, T4, P3, P4, O1, O2) on the scalp. The result is visualized in every 5.12 seconds or less. There are other possible methods for characterizing EEG, for instance, in terms of power spectrum analysis and channel powers together with linear and nonlinear conversion of these parameters. Musha et al.[7] came to a conclusion that linear conversion of the cross-correlation coefficients is superior to the others because the number of parameters can be made relatively large, which allows the researcher to pick up a large amount of information on brain activity. More specifically, because the number of parameters is independent of time resolution of emotion analysis, linear conversion is the best method of characterizing EEG.

Because EEG is recorded with 10 scalp elec-

trodes, we obtain 45 ($_{10}C_2$) cross-correlation coefficients in every 5.12 sec. They are evaluated for the theta (5–8 Hz), the alpha (8–13 Hz), and the beta (13–20 Hz) frequency bands. Therefore, we totally obtain 135 (45 × 3) parameters, which form a *state* vector. This state vector includes not only emotional states but also other brain activities. Proper linear combination of the 135 parameters characterizes the given basic emotional states if the coordinate transformation is properly made. We have selected anger, sadness, joy, and relaxation as the basic emotional states. Let their levels be denoted as z_{ang}, z_{sad}, z_{joy}, and z_{relax}, and let them be weighted sums of the 135 parameters, c_1, c_2, . . . , c_{135}. In matrix form these relations are described in a compact way as:

$$\begin{pmatrix} z_{ang} \\ z_{sad} \\ z_{joy} \\ z_{relax} \end{pmatrix} = \begin{pmatrix} a_{1,1} & a_{1,2} & \cdots & a_{1,135} \\ a_{2,1} & a_{2,2} & \cdots & a_{2,135} \\ \vdots & \vdots & \vdots & \vdots \\ a_{135,1} & a_{135,2} & \cdots & a_{135,135} \end{pmatrix} \times \begin{pmatrix} c_1 \\ c_2 \\ \vdots \\ c_{135} \end{pmatrix} + \begin{pmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \end{pmatrix} \tag{1}$$

where a_{ij} are weights on the 135 cross-correlation coefficients and form an emotion matrix and $\boldsymbol{d}$ is a constant vector.

Learning derives the emotion matrix in the following way. A subject is instructed to keep an image of anger and 35 state vectors are calculated in 3 minutes (5.12 × 35 ≅ 180 seconds or 3 minutes in total), and these state vectors are substituted in Eq. (1) as $z_{ang} = 1$, $z_{sad} = 0$, $z_{joy} = 0$, and $z_{relax} = 0$. As a next step, this subject makes an image of sadness to get 35 state vectors, which again are substituted in these equations as $z_{ang} = 0$, $z_{sad} = 1$, $z_{joy} = 0$, and $z_{relax} = 0$. Then this subject makes an image of joy, and the calculated 35 state vectors are substituted in these equations as $z_{ang} = 0$, $z_{sad} = 0$, $z_{joy} = 1$, and $z_{relax} = 0$. Similarly for imaging of relaxation, we require $z_{ang} = 0$, $z_{sad} = 0$, $z_{joy} = 0$, and $z_{relax} = 1$. The value of 1 is just for normalization. These simultaneous equations are numerically solved to obtain the emotion matrix and the constant vector.

Once this emotion matrix has been obtained, the emotional state of this subject is well estimated. This emotion matrix does reasonably estimate the emotional state of this particular subject, but does not always correctly estimate the emotional state of other subjects because EEG characteristics of the basic emotional states for different subjects are not the same. To obtain a *universal* emotion matrix that is applicable to an unspecified subject, state vectors of many different subjects (in the present case seven subjects) corresponding to these four basic emotional states are mixed up and substituted in Eq. (1). Numerical solutions give an emotion matrix. This universal emotion matrix is characterized by the common nature of the four basic emotional states over the subjects who were involved in preparing the universal emotion matrix. The universal emotion matrix we have now has given mostly reasonable results.

When a subject has anger in mind, index of anger z_{ang} increases. However, when the index of anger is increased, it does not always mean that the subject is angry but means that he/she acquires mental stress or excitation. Therefore, this index is often denoted as *N1* to avoid misunderstanding. Similarly, the index for sadness generally specifies depression and, hence, it is named *N2*. Indices for joy and relaxation are denoted as *P1* and *R*. When a subject has a strong interest in a task or has curiosity on it, *N1* and *P1* become larger simultaneously. Mental fatigue results in elevation of *N1* and *N2* simultaneously. Thus, complex emotional states are expressed as a linear combinations of the four indices. By means of the multiple recursive technique on which levels of these basic emotional indices are compared with psychological statements of subjects, we can make the dynamic display of the emotional state in more general terms.

More electrodes would not allow a larger number of basic emotional states to be discriminated because the additional emotional state is difficult to be made orthogonal to the four. For instance fear is not completely orthogonal to anger or stress. To our experience, it is difficult to find one orthogonal to the four. The present method is named *Emotion Spectrum Analysis Method (ESAM)* because the complex emotional state is expressed as a spectrum of the four basic emotional states.

An example of ESAM is shown in Figure 1 where a subject is listening to music. This subject likes Mozart (*Eine kleine Nacht Musik*) better than *Enka* (a style of Japanese songs *Onna no Yume*). It is clearly seen that the subject showed lower *N1* (stress level) index and higher *R* (relaxation) index as compared with when he was listening to *Eine kleine Nacht Musik* than listening to *Enka*.

THE ACTIVE ART THERAPY

ESAM is now being applied to evaluate the effect of active art therapy that has been initiated by some of the present authors (SK, KK, KN, KS). They selected 41 patients who had received this treatment for 1 year. These 41 patients were chosen out of a group of 118 patients who have difficulty in their daily lives because of dementia symptoms. All of the patients in this group had been diagnosed with dementia by the Hamamastu method[5] and DSMV-R by the American Psycho-Medical Association. The treatments were both counseling for families as well as treatment for the patients. For the patients, they provided creative art for recovery of communication and identity. The purpose of the creative art is not to make wonderful masterpieces but rather to give encouragement to the patients to think, make images by themselves, and give them an enjoyable time in which strong interactions are provided between the patients and artists. The family members joined the artwork with the patients so that they enjoyed some kind of oneness with the patients. The family members had 2-hour counseling sessions called "Family Care" once a month to share compassionate support with one another. The 1-year treatment was evaluated in terms of the MMSE score as well as through a questionnaire that was sent to families of the patients.

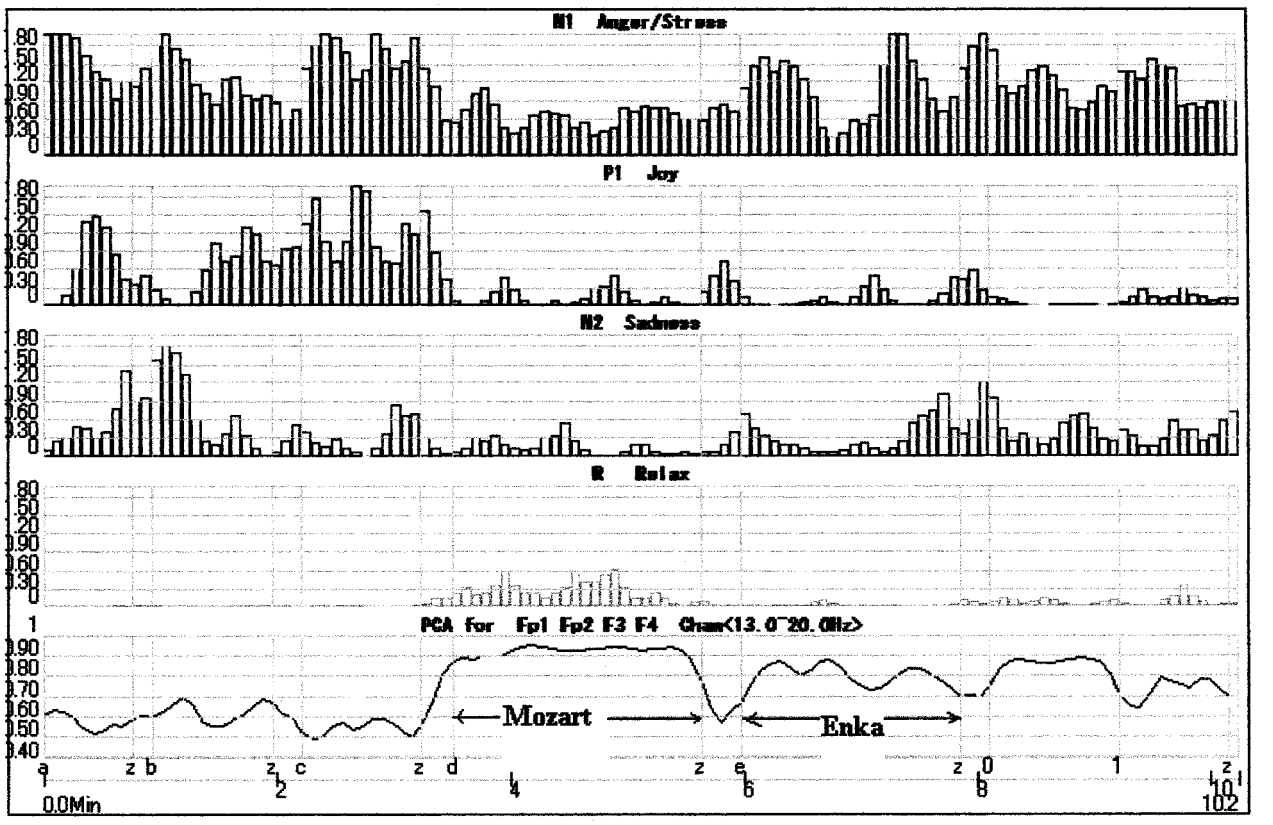

FIG. 1. Emotion spectrum when a subject is listening to Mozart's music in the first section and after 20 seconds of listening to *Enka* (Japanese song). Index refers, from top to bottom, to N1, P1, N2, and R. The bottom index below the emotion spectrum is the percent of contribution to the primary component of the principal component analysis on the frontal four channels (mental load lowers this index). Mozart's music (*Eine kleine Nacht musik*) lowers the stress, increases the relaxation, and lowers the mental load as compared with *Enka* because this patient likes Mozart better. The horizontal axis denotes time where duration of each index is 5.12 seconds.

Pre-dementia refers to an MMSE score of 24–30, mild to 15–23, and severe to 0–14. When the MMSE score increased more than three points, it is judged as improvement, and decreases of the score that were more than three points lead to a judgment of deterioration; otherwise it means no change.

For 16 patients of mild dementia who live with their families, the MMSE score indicated 44% improved and 25% declined. The evaluation from the families of these 16 patients indicated 44% improved and 38% declined. The cases of mild dementia patients who do not live with their families were omitted as there were only four cases. In 20 patients of severe dementia, 30% showed improvement and 15% showed decline. Prevention against declining of dementia was effective in 85%. For the severely demented patients, compared to the mild dementia patients, the rate of improvement was not as high, but improvement rate made by the family evaluation was higher. In the 16 patients with terminal dementia living with their families, improvement was found in 25% and decline was found in 13%. According to the evaluation by the families, improvement was found in 50% and decline was found in 38%.

Art therapy does not use medicine, and its goal is for patients to live in society as well as with their families at home. Our active art therapy consists of three dimensions: (1) early diagnose of dementia, (2) creative art activity of the patients, and (3) family care counseling.

In art therapy, seven or eight patients gather as a group to paint, carve, create ceramic art, cast, work on paper craft, and make expressive art with various materials. A wide range of the creative arts are covered according to the curriculum. Active art therapy is an effective means of communication for those who are not able to speak, who are not well enough for use of a language, and those who want to communicate. The process of spending time together for creative artwork is very important, and artwork will activate brain creativity and encourage patients to express unconscious thought or imagination of the mind. It will give the patients joy and happiness while they do artwork. Such an idea has been proved by the result of ESAM, and a typical example is given in Fig. 2. Enhancement of joy is observed while

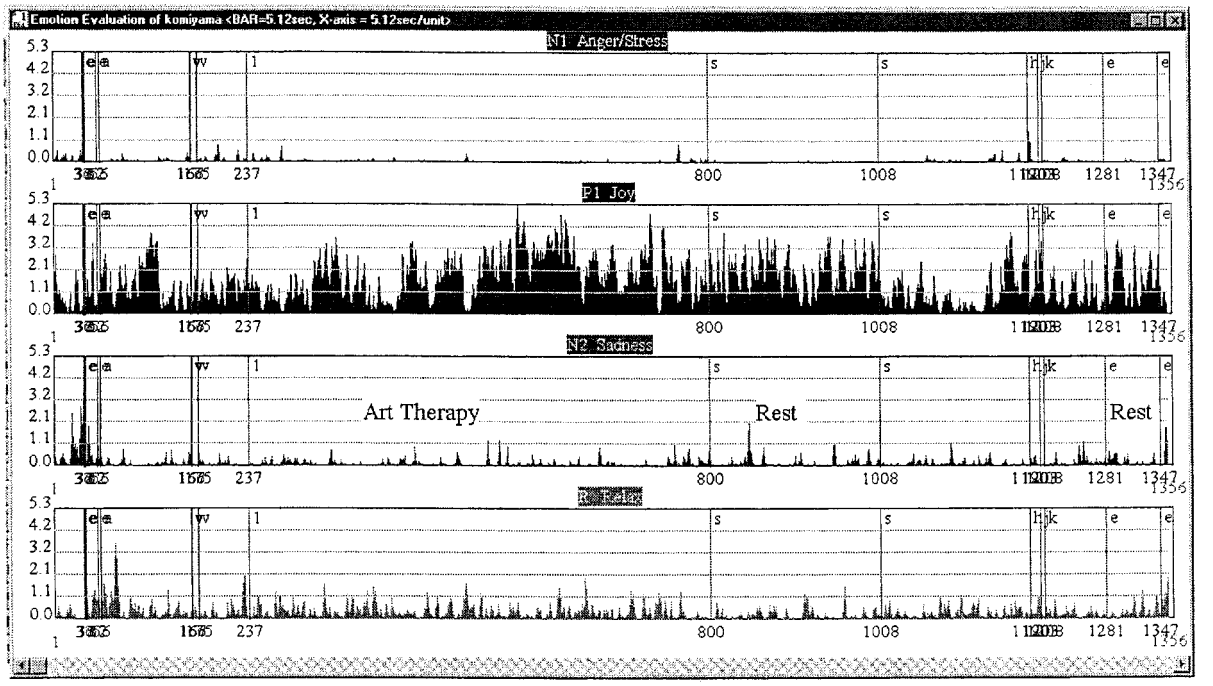

FIG. 2. Emotional response of a demented patient. She feels joy during the active art therapy. After the therapy, the artist gives positive comments on the artwork of each of the patients to encourage them. This patient showed joy before and during the comment session. Enhancement of joy is one of the aims of the active art therapy, and ESAM allows researchers to monitor the dynamic change of emotional responses of the patient to the treatment.

being involved in creative painting. After the artwork, the artist gives comments to each of the artworks made by the patients. The artist tries to find good points and encourages all the patients. It is observed that patients showed high level of joy before and during the comment session. We did not expect such emotional activation in the comment session, but it is really effective.

In our therapy, we don't analyze the artwork of the patients. Rather we value the works as tools for communication; we encourage the patients to enjoy, and encourage them to do things by themselves. The leader of this creative activity needs to have the ability to communicate with the patients through their artwork, and he or she has to know the joy of creative art personally. The leader needs to be a professional creative artist who actually practices the creative art. The artist can aim for the essence of the art, which artists have been aiming at since ancient times. Invalid psychological analysis of the artwork would damage the patients, and it would be a hindrance for treatment. The report we presented above indicated that 34% of patients improved and 20% of patients declined according to MMSE.

CONCLUSIONS

We have developed a new technique, ESAM, to visualize a dynamic change in a state of mind in terms of mental stress, depression, joy, and relaxation. This technique has been successfully applied to the effect of music therapy on senile demented patients. This time, we applied it to the active art therapy, and we are able to see how the patient responds to the therapy. We find that demented patients also have joy when their artworks received positive comments by the artist. Furthermore, they show expectation to have such a joyful time after finishing the artwork. We are now trying to find which kind of art therapy gives the best emotional influence on each of the patients.

ACKNOWLEDGMENT

This research is partly supported by a project of "Interdisciplinary Life Science Research on the Relationship between Human Sensitivity and the Human environment" ("The Promotion of New Academic Frontiers" directive of the Ministry of Education, 1998) of Kansei-Fukushi Research Center of Tohoku Fukushi University.

REFERENCES

1. Asada, T., Yamagata, Z., Kinoshita, T., Kinoshita, A., Kariya, T., Asaka, A., & Kakuma, T. (1996). Prevalence of dementia and distribution of ApoE alleles in Japanese centenarians: An almost-complete survey in Yamanashi Prefecture. *Jap. J. Amer. Geriat. Soc.* 44:151–155.
2. Morimatsu, M. (1997). Dementia—Causes, diagnosis, treatment, and care. *Nippon Ronen Igak kai Zasshi. Jap J of Geriatr.* 34:93–98.
3. Matsushita, M. (1995). Syndrome of dementia (in Japanese). *Nichii Zasshi* 114:56–62.
4. Kondou, K. (1998). Life style and senile dementia (in Japanese). *Nichii Zasshi.* 119:935–941.
5. Kaneko, M. (1991). Screening test for dementia (in Japanese). *Rounenki Chihou* 5:41–48.
6. Folstein, M.F., Folstein, S.E., & McHugh, P.R. (1975). Mini-mental state. A practical method for grading the cognitive state of patients for the clinician. *J. Psych. Res.* 12:189–198.
7. Musha, T., Terasaki, Y., Haque, H.A., & Ivanitsky, G.A. (1997). Feature extraction from EEG associated with emotions (Invited Paper). *Art. Life Robotics* 1:15–19.
8. Schellberg, D., Besthorn, C., Klos, T., & Gasser, T. (1990). EEG power and coherence while male adults watch emotional video films. *Int. J. Psychphys.* 3:279–291.
9. Hinrichs, H., & Machleidt, W. (1992). Basic emotions reflected in EEG coherence. *Int. J. Psycho-physiol.* 3:225–232.
10. Maremmani, I., Bonanni, E., Pieraccini, F., Santerini, G.C., Murri, L., & Castrogiovanni, P. (1992). Emotivity, personality and task-dependent EEG asymmetry. *Phys. Behavior* 6:1111–1116.
11. Aftanas, L.I., Lotova, N.V., Koshkarov, V.I., Pokrovskaja, Popov, S.A., & Makhev, V.P. (1997). Nonlinear analysis of emotion EEG; calculation of Kolmogorov entropy and the principal Lyapunov exponent. *Neurosci. Lett.* 1:13–16.
12. Field, T., Martinez, A., Nawrocki, T., Pickens, J., Fox, N.A., & Schanberg, S. (1998). Music shifts frontal EEG in depressed adolescents. 129:109–116.

Address reprint requests to:
Toshimitsu Musha
Brain Functions Laboratory, Inc.
KSP Bldg. E211, Sakado, Takatsu-ku
Kawasaki-shi, Kanagawa-ken
Japan 213-0012

E-mail: musha@net.ksp.or.jp