Neurofeedback for the Treatment of Schizophrenia: Case Study

Wenya Nan[1], Lanshin Chang[2], Joao Pedro Rodrigues[3], Feng Wan[1], Peng Un Mak[1], Pui-In Mak[1], Mang I Vai[1], Agostinho Rosa[1, 3]
[1]Department of Electrical and Computer Engineering, Faculty of Science and Technology, University of Macau, Macau
[2]Department of Psychology, Faculty of Social Sciences and Humanities, University of Macau, Macau
[3]LaSEEB-System and Robotics Institute, Department of Bioengineering, Instituto Superior Tecnico, Technical University of Lisbon, Portugal

***Abstract*—The paper presents a case report of the therapy by neurofeedback training of a chronic female schizophrenia outpatient. The purpose of the neurofeedback training was to enhance cognition, memory and behavioral performance. We used an intensive approach. All the training sessions were performed during 4 consecutive days. The results showed that the patient learnt to increase individual alpha amplitude and simultaneously decrease beta2 (20-30 Hz) amplitude at P4 site during active state over sessions. The individual alpha increased 74.73% and beta2 decreased 13.73%. The short term memory was enhanced after training. Her mood had positive change and her speech was much clearer than before. She started to associate the meaning of her life and illness. These results support that neurofeedback is not only a feasible therapy for schizophrenia but also positive results could be obtained using a much more intensive training sessions than the one reported in the literature.**

Keywords-neurofeedback; schizophrenia; beta2; individual alpha band; digit span

I. INTRODUCTION

Based on the definition from [1], schizophrenia is a chronic and devastating brain disorder. The patients who are suffering from it normally have significant cognitive, behavioral, and emotional deteriorated functions. The symptoms of affected functions include but are not limited to hallucination and/or delusion in conjunction with impaired social and occupational abilities. It is common to label the symptoms of affected functions into "positive" or "negative" categories. The positive symptoms are the "exaggerated or distorted functions added onto normal functions" such as hearing internal voices, seeing something that no others can see, false beliefs, distorted reasoning, misinterpreted experiences and perceptions, disorganized speech/thinking/behavior, etc. The negative symptoms are the "decreased or flattened functions deducted from normal functions" such as limited facial expression, emotional and verbal communication, body language, and/or no motivation to initiate things, etc. Schizophrenia is typically characterized as a disorder with generalized neurocognitive dysfunction. In schizophrenia research, 7 separable neurocognitive areas have been identified as being of primary interest: attention/vigilance, speed of processing, working memory, verbal learning, visual learning, reasoning and problem-solving as well as social cognition [2].

Even after pharmacological treatments, the patient's symptoms persist and negatively influence the patient's social and professional lives. Reference [3] showed the possibility for schizophrenics to participate in neurofeeback training which may be an additionally potential treatment intervention. In [3], the author applied neurofeedback to a long term hospitalized inpatient with chronic schizophrenia. Before training, this inpatient had high frontal delta activity, low amplitude of posterior alpha, and generalized elevated EEG amplitudes in the left hemisphere while the right hemisphere was very low in amplitude. The training protocol included three phases. Phase 1 was to enhance alpha simultaneously to inhibit fast beta (21-30 Hz) in the right parietal. Phase 2 was to firstly inhibit delta while reinforcing low beta (13-15 Hz) activity, then returned to right parietal enhancement of alpha activity. Phase 3 was the connection and integration: bipolar neurofeedback training (PO4-CP4) as in phase 1, then bipolar training (FC3-Fp1) as in phase 1 and phase 2, and finally treatment returned to the right parietal area (PO4-CP4) for calming for 20 minutes. Following 18 months training, alpha activity in the right parietal area was enhanced, delta activity in the left frontal area was decreased, and fast beta activity decreased at all training sites. The improvement was achieved in cognitive, affective and behavioral patterns. A 2-year follow up found that positive changes were sustained. This study showed strong evidence that neurofeedback is a potential treatment for schizophrenia patients, but the process lasted one and a half years, too long to be followed by an outpatient.

Neurofeedback, also known as EEG biofeedback, is an operant conditioning procedure in which individuals learn to self-regulate their brain activities. During neurofeedback, the EEG is recorded from one or more electrodes placed on the scalp and the relevant components are extracted. The feedback information is presented to the training individuals in the form of audio, visual or combined audio-visual format [4]. An increasing number of studies utilize neurofeedback to enhance performance in healthy individuals. For instance, trained enhancement of the sensory motor rhythm (SMR) has been demonstrated to result in improvements in semantic working memory and focused attention [5] as well as reaction time and spatial rotation [6]; mental rotation ability can be improved by individual upper alpha training [7], [8]; increasing peak alpha frequency by NFT can improve the cognitive processing speed and executive function in the healthy elderly individuals [9].

This work is supported in part by FCT SFRH/BSAB/1101/2010 and PEst-OE/EEI/LA0009/2011 grants and the Macau Science and Technology Development Fund under Grant FDCT 036/2009/A and the University of Macau Research Committee under Grants RG059/08-09S/FW/FST, RG080/09- 10S/WF/FST and MYRG139(Y1-L2)-FST11-WF.

978-1-4577-1759-8/12/$26.00 ©2012 IEEE

Besides optimal performance, neurofeedback also has shown positive evidence to treat psychiatric disorders such as epilepsy [10], attention deficit hyperactivity disorder (ADHD) [11], substance abuse [12], autism [13] and depression [14].

The prevalence of pharmacological treatment leaves psychosis patients with limited and deteriorated functions. The quality of their lives has dramatically decreased. Therefore, with the new findings of neurofeedback research, sheds a new hope to the doomed psychosis patients. This study attempted to utilize intensive neurofeedback training to a schizophrenic female patient in order to enhance her cognitive and behavioral functions which have been impaired by her psychotic symptoms and medications.

In this work we explored a different methodology by using a rather intensive training and reducing drastically the length of the treatment into 4 days only.

II. METHODS

A. *Subject*

The subject is a single female outpatient in her late forties. She received prominent education with a professional career. Her family members do not have the history of psychosis. She had her first episode of schizophrenia in 2004. Before her first episode she had showed unstable mood symptoms for 3 to 5 years.

B. *Feedback Parameter*

The feedback objectives were to increase alpha amplitude simultaneously to decrease beta2 band (20-30 Hz) amplitude at P4 channel of the "10-20 International System of Electrode Placement". Due to the large inter-individual differences in alpha band, we trained the individual alpha band (IAB) instead of fixed alpha band (8-12 Hz). The calculation of relative amplitude is shown in (1) where band_Amplitude was the amplitude of certain band and EEG_Amplitude was the amplitude from 0.5 Hz to 30 Hz. Here, the feedback parameter is the ratio of relative IAB amplitude to relative beta2 amplitude.

$$rAmplitude = \frac{band\_Amplitude}{EEG\_Amplitude} \qquad (1)$$

C. *EEG Recordings*

Neurofeedback was carried out using a 6-channel EEG amplifier (Sommeil 800 from Meditron Eletromedicina Ltda, SP, Brazil) with the electrode placed at P4 channel of the "10-20 International System of Electrode Placement" and referenced to contra-lateral mastoid (M1). The ground was located at forehead. Sampling frequency was 250Hz and feedback delay was 125 milliseconds. The signals were recorded by Somnium software platform with neurofeedback plugin (Cognitron, SP, Brazil). Before neurofeedback, two EEG epochs of 60 seconds each during the resting period were recorded while the subject had her eyes opened and closed respectively. The recordings of eyes opened and closed provided data for alpha desynchronization and synchronization respectively, which enabled the determination of IAB through amplitude bands crossing.

D. *Neurofeedback Protocol*

The training program had two parts. During the first part, the subject adapted herself to the neurofeedback program and explored the mental activities. The session duration was controlled by the subject and the mental strategy used was annotated. The duration of each session varied from 1 to 15 minutes. The total time of the first part was 12.5 hours in 4 days. The training duration of the first part was 1 hour and 20 minutes in Day 1, 3 hours in Day 2, 4 hours and 40 minutes in Day 3, and 3.5 hours in Day 4. By inspecting the performance during the first part, 6 mental activities were selected as the best strategies for the second part. The second part of the training program was completed in Day 4 after finishing the first part. It was composed of 4 fixed sessions. Each session was composed of 12 successive trials of 60 seconds each and with an interval of 10 seconds between trials. The total duration of the second part was almost 1 hour. The subject applied the best selected 6 cognitive activities to train, but only one was used for each trial. Each strategy was repeated twice in 12 trials.

E. *Feedback Display*

The display contains two objects: a sphere and a cube (see Fig. 1 and Fig. 2). The sphere reflects the feedback parameter value. If it reaches the threshold (Goal 1) the sphere color changes. This sphere is constituted by several slices and the more slices it has, the smoother it looks. Initially, the sphere is only constituted by four slices, which is the minimum number, and while Goal 1 is being achieved slices are slowly added to the sphere. When Goal 1 is not achieved, the sphere loose slice slowly until it only has four of them again. The cube height is related to the period of time Goal 1 kept being achieved continuously. If Goal 1 is being achieved continuously for more than a predefined period of time (2 seconds), Goal 2 is accomplished and the cube rises until Goal 1 stops being achieved. Then the cube starts falling slowly until it reaches the bottom or Goal 2 is achieved again. Therefore, the best outcome would be having the cube as high as possible [15].

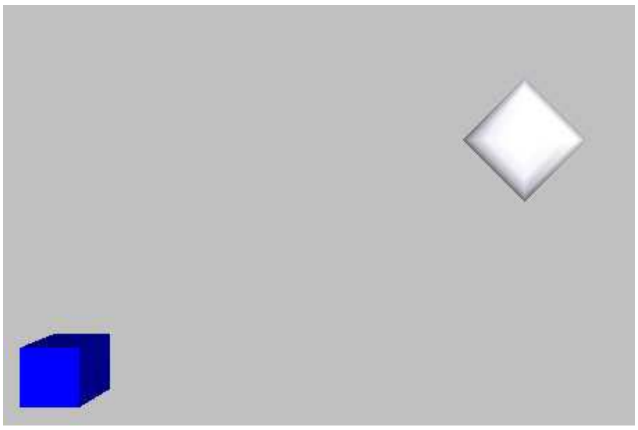

Figure 1. The display when Goal 1 was not achieved.

The threshold was IAB/beta2 and its initial value for the first session was set to 1. After each session, a session report showed the percentage of time the IAB/beta2 was above threshold. If this value exceeded 60%, the threshold was increased by 0.1 in the next session. In contrast, if this value was lower than 30%, the threshold was decreased by 0.1 in the next session.

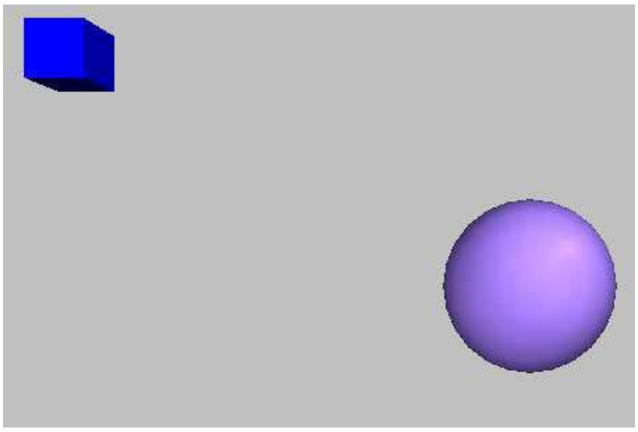

Figure 2. The display when both Goal 1 and Goal 2 was achieved.

F. Cognitive Assessment

The subject performed a short term memory test to assess her cognitive performance before and after neurofeedback. The short term memory test consisted of forward and backward digit span tests. In each test, a series of trials showed random digits at the rate of one digit per second. After all the digits had been shown, the participant was instructed to input the digits with the same order (forward digit span) or with the inverse order (backward digit span) as they were displayed. The last number of digits correctly recollected was the participant's digit span score.

III. RESULTS

A. Behavioral Results

For the memory test before neurofeedback, the forward digit test was 7 and backward digit test was 5. After all training sessions, the forward digit test was 9 and backward digit test was 6.

Before neurofeedback, she spoke very slowly, needed to pause for a few seconds before she spoke, and did not have much facial expression. Her eyes looked blank. After neurofeedback, she maintained a smooth and stable mood when evaluated more than 3 months later. Her depressive mood had decreased. She started to associate the meaning of her life and illness. She was trying to link her illness with possible future responsibilities. Her speech pattern was improved, much clearer and no delays, although still slow. She could response to people very well.

B. EEG Results

In this section, we focus on the first 2 user control sessions and the last 4 fixed sessions. EEG data were analyzed in the frequency domain by means of Fast Fourier Transformation (FFT). Average relative amplitude values for IAB and beta2 are calculated according to (1). IAB amplitude over sessions is shown in Fig. 3. As can be seen in Fig. 3, IAB amplitude was 0.91 in session 1 and 1.59 in the last session; it increased 74.73%, indicating the subject can learn to increase IAB amplitude during sessions.

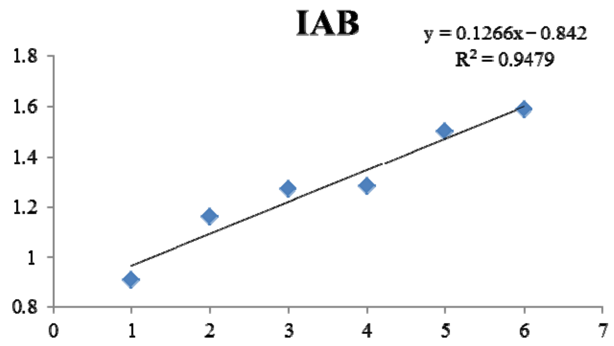

Figure 3. IAB amplitudes over sessions. The horizontal axis represents session number and the vertical axis is the relative amplitudes.

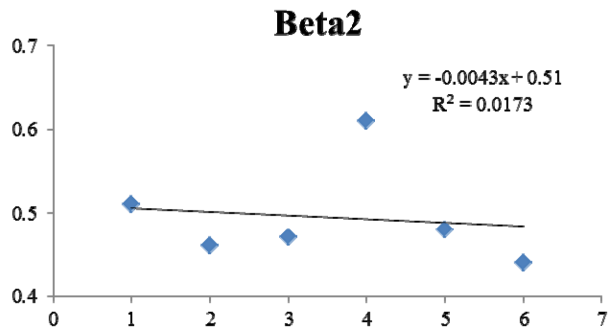

Figure 4. Beta2 amplitudes over sessions. The horizontal axis represents session number and the vertical axis is the relative amplitudes.

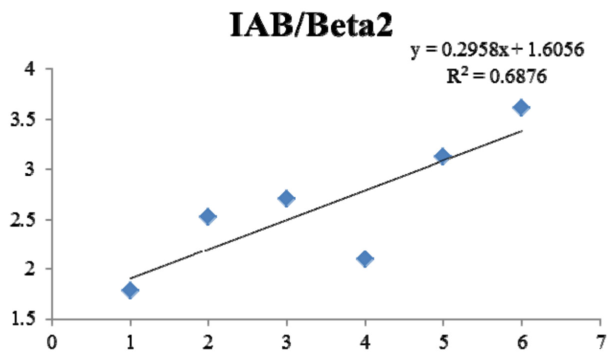

Figure 5. IAB/beta2 over sessions.

Fig. 4 presents the beta2 amplitude over sessions. Beta2 decreased from 0.51 to 0.44, it decreased 13.73%. Therefore, IAB obtained much larger change than beta2, suggesting that IAB amplitude increase was easier than beta2 amplitude decrease for this patient. IAB/beta2 is also presented in Fig. 5. As depicted in Fig. 5, IAB/beta2 increased over sessions; this increase resulted from an increase in IAB amplitude and simultaneous decrease in beta2 amplitude.

With regard to the threshold during training, it increased from 1.0 in the first session to 3.5 in the last few sessions, also suggesting that the patient could learn to increase the IAB/Beta2 over session. The largest percentage time of above threshold 3.5 was 57.64%.

IV. Discussion

The neurofeedback training in this study obtained successful treatment for a schizophrenia patient. Although the subject only had 4 days training, she learnt how to change her brain activity through the feedback display. More specifically, IAB amplitude increased and beta2 decreased over sessions, these changes are in line with our training objectives. Furthermore, her short term memory and mood were also improved after training. In [3], the training lasted for 18 months and the total session number was 130. The patient improved behavioral performance gradually over training time. Compared with [3], our training only lasted 4 days, which also improved the patient performance significantly. One reason is that the patient in [3] was an inpatient that had severe schizophrenia, while the patient in this study was an outpatient whose symptoms were better. Therefore, the less training time can alleviate symptoms. Another important reason is that the training protocol in this study had advantages as follows.

First, the intuitive display of the feedback information encouraged and kept the patient engaged with the training. Also, the threshold can provide challenge to the patient. It was set to the appropriate value for each session. The patient could always feel the challenge but not too much beyond her ability.

In addition, during the user-control function of the first part of neurofeedback training, the subject gained enormous confidence in herself for she had not been acting as an independent person since her first episode.

Finally, a psychologist accompanied the patient for the whole training sessions. The psychologist gave useful guidance and therapy sessions during the neurofeedback training sessions. Such as when the patient could not effectively regulate her own behavior (i.e. similar to ADHD symptoms), the psychologist would apply useful strategies to help the patient to control her behavior. When the patient's mood was not stable (i.e. felt angry and sad when she thought of some unhappy experience), the psychologist would help the patient to release her upset feeling and stabilize her mood. When the patient was distracted by her irrational cognition, the psychologist would help her to unveil the root of her irrational thoughts and the positive strength under all the cloud.

V. Conclusion

Following the neurofeedback treatment, the patient showed evidence of improved performance in short term memory, mood stability, and speech clarity. Meanwhile changes in the EEG patterns were also observed during training. In conclusion, these results support that neurofeedback is not only a feasible therapy for schizophrenia but also positive results could be obtained using a much more intensive training sessions than [3]. The number of sessions and total duration of the treatment is effective and affordable for outpatients. Although this is a case report, it showed promising potentials deserving further exploration with a full scale study. In addition, we will observe the long-term effects and follow-up outcomes on this patient.

References

[1] American Psychiatric Association. *Diagnostic and Statistical Manual of Mental Disorders,* 4th ed, Text Revision, Washington, DC, American Psychiatric Association, 2000.

[2] K. H. Nuechterlein, D. M. Barch, J. M. Gold, T. E. Goldberg, M. F. Green, and R. K. Heaton, "Identification of separable cognitive factors in schizophrenia," Schizophrenia research, vol. 72, no. 1, pp. 29-39, 2004.

[3] A. S. Bolea, "Neurofeedback treatment of chronic inpatient schizophrenia," Journal of Neurotherapy, vol. 14, no. 1, pp. 47-54, 2010.

[4] D. J. Vernon, "Can neurofeedback training enhance performance? An evaluation of the evidence with implications for future research," Appl. Psychophysiol. Biofeedback, vol. 30, no. 4, pp. 347-364, Dec. 2005.

[5] D. Vernon, T. Egner, N. Cooper, T. Compton, C. Neilands, A. Sheri, and J. Gruzelier, "The effect of training distinct neurofeedback protocols on aspects of cognitive performance," Int. J. Psychophysiol, vol. 47, no. 1, pp. 75-85, Jan. 2003.

[6] M. Doppelmayr and E. Weber, "Effects of SMR and Theta/Beta neurofeedback on reaction times, spatial abilities, and creativity," Journal of Neurotherapy, vol. 15, no. 2, pp. 115-129, 2011.

[7] S. Hanslmayr, P. Sauseng, M. Doppelmayr, M. Schabus, and W. Klimesch, "Increasing individual upper alpha power by neurofeedback improves cognitive performance in human subjects," Appl. Psychophysiol. Biofeedback, vol. 30, no. 1, pp. 1-10, Mar. 2005.

[8] B. Zoefel, R. J. Huster, and C. S. Herrmann, "Neurofeedback training of the upper alpha frequency band in EEG improves cognitive performance," Neuroimage, vol. 54, no. 2, pp. 1427-1431, Jan. 2011.

[9] E. Angelakis, S. Stathopoulou, J. L. Frymiare, D. L. Green, J. F. Lubar, and J. Kounios, "EEG neurofeedback: a brief overview and an example of peak alpha frequency training for cognitive enhancement in the elderly," Clin. Neuropsychol, vol. 21, no. 1, pp. 110-129, Jan. 2007.

[10] M. B. Sterman and T. Egner, "Foundation and practice of neurofeedback for the treatment of epilepsy," Appl. Psychophysiol. Biofeedback, vol. 31, no. 1, pp. 21-35, Mar. 2006.

[11] P. N. Friel, "EEG biofeedback in the treatment of attention deficit hyperactivity disorder," Altern. Med. Rev, vol. 12, no. 2, pp. 146-151, June 2007.

[12] T. M. Sokhadze, R. L. Cannon, and D. L. Trudeau, "EEG biofeedback as a treatment for substance use disorders: review, rating of efficacy, and recommendations for further research," Appl. Psychophysiol. Biofeedback, vol. 33, no. 1, pp. 1-28, Mar. 2008.

[13] R. Coben, M. Linden, and T. E. Myers, "Neurofeedback for autistic spectrum disorder: a review of the literature," Appl. Psychophysiol. Biofeedback, vol. 35, no. 1, pp. 83-105, Mar. 2010.

[14] A. M. Dias and D. A. van, "A new neurofeedback protocol for depression," Span. J. Psychol, vol. 14, no. 1, pp. 374-384, May 2011.

[15] J. P. Rodrigues, D. G. Migotina, and A. C. da Rosa, "EEG training platform: Improving Brain-Computer Interaction and cognitive skills," IEEE HIS, 2010, pp. 425-429.