An Investigation of Changes in Brain Wave Energy during Hypnosis with Respect to Normal EEG

Golnaz Baghdadi, MSc, and Ali Motie Nasrabadi, PhD

Correlation between different brain waves energy and hypnosis has been investigated in this study. Using empirical mode decomposition algorithm, the EEG signals of 32 subjects with different hypnotizability levels have been decomposed into different frequency bands and then the energy of these frequency bands is calculated using Hilbert transform. Statistical tests show that the effect of the hypnosis suggestion and hypnotizability on brain wave relative energy in delta band is opposite of beta band. It was also resulted that hypnosis is not a sleep and the brain is in conscious state in hypnosis. **(Sleep and Hypnosis 2009;11(2):40-45)**

Key words: Hypnosis, EEG, hilbert transform, EMD, brain wave energy

INTRODUCTION

There are several studies on the relationship of brainwave activity and hypnosis (1)-(9), but we exactly do not have all the answers yet. The situation is more complex by the fact that the brain's activity differs in hypnosis depending on the nature of the induction, for example imaginary perception of subjects, relaxation, etc.

In the research of Morgan, Macdonald and Hilgard (1974) it was showed that high hypnotizable subjects showed higher amplitudes of alpha, however, suggests that the overall production of alpha may be positively related to the particular cognitive style that characterizes the person who is able to experience hypnotic phenomena (1). However, Dumas (1977) found that no alpha-hypnotizability correlation existed in the general population (2). Galbraith, et al (1970), reported that baseline EEG activity in the theta that mean theta power in highly hypnotizable subjects is more than low hypnotizable subjects in frontal, central, and occipital lobes during resting nonhypnotic baseline (4). In addition, Crawford and Gruzeiler (1992) stated that theta activity strongly and positively related to hypnotic susceptibility (5). Graffin, Ray and Lundy (1995) showed that high susceptible individuals displayed a decrease in EEG theta activity whereas the low-susceptible

From Biomedical Engineering Department, Shahed University, Iran

Address reprint requests to: Golnaz Baghdadi
Biomedical Engineering Department, Shahed University, Across Emam Khomeini Holy Shrine, Persian Gulf Highway, Tehran, Iran.
Tel: 00989125077241
Fax: 00982151212021
E-mail: golnaz_baghdadi@yahoo.com

Accepted September 17, 2009

individuals showed an increase in EEG theta activity after hypnosis induction, and similar to theta activity, alpha activity increased as the induction duration continued. In terms of alpha and beta activity, there was a decrease in the entire cortex from the preinduction to the postinduction. Furthermore, high hypnotizable participants displayed more alpha activity than low during the hypnotic induction (6). De Pascalis (1999) implicated in the relationship of 40 Hz activity with high hypnotizability, which is another frequency band associated with intensely focused attention (7). Faber, et al (2000) by a review on frequency band source gravity centers showed that under hypnosis, the source gravity center was more posterior for the delta band, more left for the alpha1 band, more anterior for the beta1 band, more right for the beta2 band and more posterior for the theta band (8). Hammond (2005) in his study on EEG patterns and hypnotizability reported that the dominant brainwave frequency in children is in the theta frequency band. However, between the ages of 13 and 14, a shift in brainwave activity occurs toward the alpha frequency (9).

In the current study, hypnosis EEG and normal EEG were decomposed into five known brainwaves (delta (1-3 Hz), theta (3-7 Hz), alpha (7-12 Hz), beta (12-30 Hz), and gamma (30-80 Hz)), using a data driven decomposition method that is called empirical originally developed as a form of adaptive time series decomposition, used prior to spectral analysis using the Hilbert transform, for non-linear and non-stationary time series data. EMD has several advantages over other spectral techniques, in that it is relatively easy to understand and use, the fluctuations within a time series are automatically and adaptively selected from the time series and it is robust in the presence of non-linear and nonstationary data. After calculating the brain waves energy in different brain's channels, their changes have been investigated along hypnosis induction.

2. Material and Methods in Data Analysis

2.1. Subjects and EEG Signals

The data includes EEG signals, which have been recorded from 32 right-handed men along hypnosis. The EEG signals have been recorded from subjects, when they are in normal and relax condition (without movement). EEG data have been recorded from 19 channels and are sampled with 256 Hz based on 10-20 system of electrode placement. Hypnosis is normally preceded by a "hypnotic induction" technique. Traditionally this was interpreted as a method of putting the subject into a "hypnotic trance"; however, subsequent theorists have viewed it differently, as a means of heightening client expectation, defining their role, focusing attention, etc. There are enormous variety of different induction techniques used in hypnotism. In this research hypnosis, induction has been done by playing an audiotape based on Waterloo-Stanford criterion (10), so the method and time of hypnosis induction was same for all of the subjects. The first 15 minutes of this tape are related to the hypnosis induction and the following 30 minutes are related to 12-item Waterloo-Stanford group scale (WSGS) of hypnotic susceptibility determined for each subject. The WSGS scores are between 12 and 60. Based on these scores the subjects divided into three groups, low (WSGS scores are between 12 and 22), medium (WSGS scores are between 23 and 41) and high (WSGS scores are between 42 and 60). In our dataset, 4 subjects were low hypnotizable, 18 subjects were medium and 10 subjects were high hypnotizable.

2.2. Empirical Mode Decomposition

EMD method is an adaptive data driven decomposition procedure, which decomposes a time series into a finite and often small number of intrinsic mode functions (IMFs), each of which must satisfy the following definition:

(1) Number of extrema = number of zero-crossings ± 1.

(2) At any point, the mean value of the upper and lower envelope is zero.

The IMFs, $x_i(t)$, of a signal y(t), is found as follow (11):

(1): Compute the mean of upper and lower envelopes of signal, m(t)

(2): Subtract to the signal to obtain $z_i(t)=y(t)-m(t)$.

(3): Check if $z_i(t)$ is an IMF, then $z_i(t)$ is the first IMF of y(t). If it is not an IMF, $z_i(t)$ is treated as the original signal and (1)-(3) are repeated;

(4): Separating $z_i(t)$ from y(t), we get $y_i(t)=y(t)-z_i(t)$. $y_i(t)$ is treated as the original data, and by repeating the above processes, the second IMF of y(t) could be obtained.

The second step is applying Hilbert transform to each IMF, in order to compute the instantaneous frequency and amplitude at each time. X(t) in the following equation is the Hilbert transform of Y(t).

$$X(t) = \text{Hilbert Tranform}\{Y(t)\} = \frac{1}{\pi}\int_{-\infty}^{\infty} \frac{Y(t)}{t-t'}\,dt'$$

Using equation (1), instantaneous frequency, If(t), and instantaneous amplitude, a(t), are defined as (9), (12):

$$a(t) = \sqrt{Y^2(t) + X^2(t)}$$

$$\begin{cases} If(t) = \dfrac{d\theta(t)}{2\pi dt} \\ \theta(t) = \arctan\left[\dfrac{X(T)}{Y(T)}\right] \end{cases}$$

The next step after estimating instantaneous frequency and amplitude is separating each of the considered frequency band along time that is done by computing the sum of the IMFs that belong, at each sample, to the considered frequency band (12). Then the instantaneous energy of each frequency band is calculated by squaring the amplitudes in each time. In this project three type of energy is calculated in various frequency bands, maximum energy, average energy and relative energy. Maximum energy is the greatest energy value in a considered time window. Calculating the mean energy along a time window gives the average energy and relative energy is the ratio of specific frequency band energy to the summation of the other frequency bands energy.

2.3. Statistical Analysis

Comparisons between first and end of hypnosis have been carried out using paired sample t-test (13). The analysis was performed, with the recording values of various frequency bands energy in hypnosis and normal EEG. The differences between different hypnotizable groups along hypnosis suggestion have been investigated using ANOVA (14). These tests were performed, with the recording values of different brain wave energy in different brain's channels in hypnosis EEG and normal EEG. In addition, box plot (15) has been used to access a visual tool for evaluating the differences between beginning and end of the hypnosis induction.

3. Results

The maximum, average and relative energy of different frequency bands in hypnosis EEG with respect to the normal EEG has been investigated along different time windows. Obtained result showed that the effect of the hypnosis on brain waves energy is different in various frequency bands. Statistical analysis showed that hypnosis suggestion and the level of the hypnotic susceptibility have no significant effect on brain wave energy in Theta, Alpha and Gamma bands. But these analyses showed some notable and significant results in the effect of hypnosis on Delta and Beta bands in different hypnotizable groups.

3.1. The Results in Delta Band

The most significant result in delta band was obtained using the following ratio (R1):

$$R1=\frac{\text{Relative Energy in Hypnosis EEG in Channel C3}}{\text{Relative Energy in Normal EEG in Channel C3}}$$

Investigating the effect of hypnosis induction on delta band energy (R1) shows that hypnosis suggestion makes decrease in delta band energy (R1). This investigation is done by performing paired sample t-test between the values of the first and end of hypnosis and the null hypothesis in this test is rejected by the p-value of 0.049. In the other word the delta band relative energy in channel C3 at the end of hypnosis reduces in regard with the first of hypnosis see figure1.

One-way analysis of variance shows that hypnotizability has significant effect on this ratio (R1), too. The obtained p-value in this test was about 0.046, which makes the rejection of null hypothesis and means that the delta band relative energy in various groups and the values of the medium subjects is less than the lows, at both the beginning and end of the hypnosis induction. So we can result hypnosis suggestion and also increasing the hypnotizability make decrease on the values of delta band relative energy in channel C3.

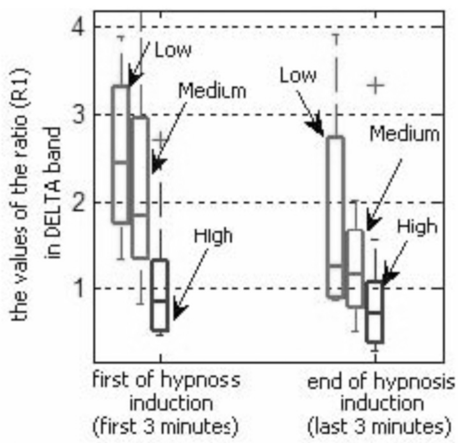

Figure 1. The distribution of the ratio (R1) in Delta band in different hypnotizable groups at first and at the end of hypnosis suggestion.

3.2. The Results in Beta Band

The other frequency band that in statistical analysis showed significant result was beta band, considering the mentioned ratio (R1). Paired sample t-test was used for comparing the values of this ratio in beta band at first and at the end of hypnosis suggestion. Obtained p-value in this test was about 0.0499, which makes the rejection of null hypothesis at 0.95 of confidence interval and means that hypnosis induction has significant effect on the values of the beta band relative energy in channel C3. This effect shows itself by increasing the values at the end of hypnosis induction with respect to the first (figure 2).

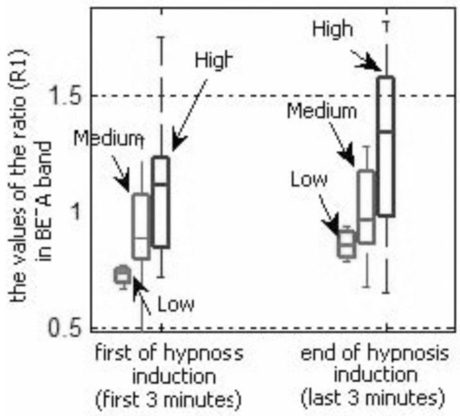

Figure 2. The distribution of the ratio (R1) in Beta band in different hypnotizable groups at first and at the end of hypnosis suggestion.

Using one-way analysis of variance, it is also obtained that the level of this ratio (R1) in beta band is different in three hypnotizable groups (the null hypothesis is rejected by the p-values of 0.046). Investigating the values in three hypnotizable groups showed that the values of (R1) in high hypnotizable groups are more than other groups and the values of the medium subjects is more than the lows, at both the beginning and end of the hypnosis induction (see figure2). Finally, we can result that hypnosis suggestion and increasing the hypnotizability make increase on the values of beta band relative energy in channel C3. It should be mentioned that in this research no significant results were observed in the other channels and in the other frequency bands.

4. Discussion and Conclusion

In our investigation, we have found significant changes in the delta and beta band relative energy in channel C3. But the results of the statistical analysis show that the changes of the energy in the other frequency bands and also in the other channels are not significant. Channel C3 locates in parietal brain lobe, which controls movement. In this study the subjects were relax and have no movement during hypnosis induction process and as only effect on the obtained results. Investigating the results of the previous studies on the effect of hypnotizability on different brain waves appearance shows that their findings have not been consistently replicated either. Fingelkurts, et al (2007) state that these highly inconsistent observations suggest that there are no systematically reproducible patterns of readily observable EEG changes specifically associated with hypnosis (16). In accord with the current study's results, it was seen that brain wave activity in high frequency band (beta) and in high hypnotizable subjects is more than low frequencies (delta). In addition, the relationship between three hypnotizable groups in low frequency band (delta) is opposite of high frequencies (beta). It is approximately resulted that increasing the time of the hypnosis induction makes increase in the ratio of the high frequency band's (beta) relative energy in hypnosis EEG with respect to normal EEG. However, it is nearly observed that hypnosis induction makes decrease in this ratio in low frequency band (delta). Therefore, we can state that the effect of the hypnosis induction and hypnotizability on brain wave energy in low frequency band (delta) is contrary to high frequency band (beta). Delta is the wave of deep sleep and unconsciousness (17). The beta brainwave state is associated with a heightened state of alertness and focused concentration. When your mind is actively engaged in mental activities, listening and thinking during analytical problem solving, judgment, decision making, processing information, the dominant brainwave state will be beta (17)-(18). Increasing the activity of the high frequency band (beta) and decreasing the activity of the low frequencies (delta) after hypnosis induction, especially in high hypnotizable groups suggest that in hypnosis, the brain is not in deep attitude like different mental activities such as solving an analytical problem. Therefore, the result is evidence on this concept that hypnosis is not a sleep.

REFERENCES

1. *Morgan AH, Macdonald H, Hilgard ER. EEG Alpha: Lateral Asymmetry Related to Task, and Hypnotizability. Psychophysiology 1974; 11(3): 275-282.*
2. *Dumas RA. EEG Alpha-Hypnotizability Correlations: A Review. Psychophysiology 1977; 14(5): 431-438.*
3. *Galbraith GC, London P, Leibovitz MP, Cooper LM, Hart JT. Electroencephalography and hypnotic susceptibility. Journal of Comparative and Physiological Psychology 1970; 72: 125-131.*
4. *Sabourin ME, Cutcomb SD, Crawford HJ, Pribram K. EEG correlates of hypnotic susceptibility and hypnotic trance: Spectral analysis and coherence. International Journal of Psychophysiolog 1990; 10(2):125-142.*
5. *Crawford H, Gruzelier J. A midstream view of the neuropsychophysiology of hypnosis: Recent research and future direction. Contemporary Hypnosis Research 1992; pp. 227-266*
6. *Graffin NF, Ray WJ, Lundy R. EEG Concomitants of Hypnosis and Hypnotic Susceptibility. Journal of Abnormal Psychology 1995; 104(1): 123-131.*

7. *Pascalis VD. Psychophysiological correlates of hypnosis and hypnotic susceptibility. International Journal of Clinical & Experimental Hypnosis 1999; 47(2):117–143.*

8. *Faber PL, Gianotti LRR, Wohlgemuth P, Lehmann D. Frequency domain EEG source locations during arm levitation under hypnosis: a pilot study. ISBET 2000, Millennium, November 16-19, Frankfurt on the Main, Germany.*

9. *Hammond DC. EEG Patterns and Hypnotizability. Biofeedback 2005; pp35-37*

10. *Carvalho C, Kirsch I, Mazzoni G, Leal L. Portuguese Norms for the Waterloo-Stanford Group C (WSGS) Scale Of Hypnotic Susceptibility. Intl. Journal of Clinical and Experimental Hypnosis 2008; 56(3): 295–305.*

11. *Huang NE, et al. The empirical mode decomposition and the Hilbert spectrum for nonlinear and non-stationary time series analysis. Proc. Royal Soc. London A 1998; 454: 903-995*

12. *Sharabaty H, Martin J, Jammes B, Esteve D. Alpha and Theta Wave Localisation Using Hilbert-Huang Transform: Empirical Study of the Accuracy. Information and Communication Technologies, 2006. ICTTA '06. 2nd, pp. 1159- 1164.*

13. *Norusis M, SPSS 16.0 Guide to Data Analysis, Prentice Hall, second edition, 2008.*

14. *Johnson RA, Wichern DW. Applied Multivariate Statistical Analysis, Pearson Education, first edition, 2001*

15. *Massart DL, Smeyers-Verbeke J, Caprona X, Schlesier K. Visual Presentation of Data by Means of Box Plots. LC•GC Europe 2005; 18(4): 215-218*

16. *Fingelkurts AA, et al. Cortex functional connectivity as a neurophysiological correlate of hypnosis: An EEG case study. Neuropsychologia 2007; 45: 1452–1460*

17. *Young C. Brain Waves, Picture Sorts, and Branding moments. Journal of Advertising Research 2002; pp.42-53*

18. *Douillard J. Perfect Health for Kids: Ten Ayurvedic Health Secrets Every Parent Must Know. North Atlantic Books 2003; p.306*