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EEG spectral analysis during hypnotic induction, hypnotic dream and age regression

Vilfredo De Pascalis

Department of Psychology, University of Rome 'La Sapienza', Rome, (Italy)

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EEG was recorded monopolarly at frontal (F_3 , F_4), central (C_3 , C_4) and posterior (in the middle of O_1 - P_3 - T_5 and O_2 - P_4 - T_6 triangles) derivations during the hypnotic induction of the Stanford Hypnotic Clinical Scale (SHCS) and during performance following suggestions of hypnotic dream and age-regression as expressed in the before-mentioned scale. 10 low-hypnotizable and 9 highly-hypnotizable and right-handed female students participated in one experimental session. Evaluations were Fast-Fourier spectral analyses during the following conditions: waking-rest in eyes-open and eyes-closed condition; early, middle, and late phases of hypnotic induction; rest-hypnosis in eyes closed condition; hypnotic dream and age regression. After spectral analysis of 0 to 44 Hz, the mean spectral amplitude estimates across seven Hz bands (theta1, 4–6 Hz; theta2, 6–8 Hz; alpha1, 8–10 Hz; alpha2, 10–13 Hz; beta1, 13–16 Hz; beta2, 16–20 Hz; beta3, 20–36 Hz) and the 40-Hz EEG band (36–44 Hz) for each experimental condition were extracted. In eyes-open and -closed conditions in waking and hypnosis highly-hypnotizable subjects produced a greater 40-Hz EEG amplitude than did low hypnotizable subjects at all frontal, central and posterior locations. In the early and middle hypnotic induction highly-hypnotizables displayed a greater amount of beta3 than did low hypnotizables and this difference was even more pronounced in the left hemisphere. With posterior scalp recordings, during hypnotic dream and age regression, high hypnotizables displayed, as compared with the rest-hypnosis condition, a decrease in alpha1 and alpha2 amplitudes. This effect was absent for low hypnotizables. Beta1, beta2 and beta3 amplitudes increased in the left hemisphere during age regression for high hypnotizables; low hypnotizables, in contrast, displayed hemispheric balance across imaginative tasks. High hypnotizables during the hypnotic dream also displayed in the right hemisphere a greater 40-Hz EEG amplitude as compared with the left hemisphere. This difference was even more evident for posterior recording sites. This hemispheric trend was not evidenced for low hypnotizable subjects. Theta power was never a predictor of hypnotic susceptibility, 40-Hz EEG amplitude displayed a very high main effect ($p < 0.004$) for hypnotizability in hypnotic conditions by displaying a greater 40-Hz EEG amplitude in high hypnotizables with respect to lows.

INTRODUCTION

Two major trends can be identified in EEG studies on hypnosis: (a), experiments devoted to evaluating the relationship between waking EEG and hypnotic susceptibility and (b), experiments aiming to distinguish the brain activity of a postulated hypnotic state from that known to characterise waking and sleeping states. The first line of research is mainly represented by studies devoted

to examining the relationship between EEG-alpha rhythm and hypnotic susceptibility.

Investigators of the second trend are more interested in what occurs during hypnosis than in individual differences in hypnotizability. One of their main goals is to obtain objective and independent criteria of ascertaining if, and when, a person is hypnotized. Major theoretical interest has been in examining whether the EEG during hypnosis was comparable to the EEG recorded during sleep. The EEG rhythms commonly studied during hypnosis were alpha and theta, and it was quite clear that hypnosis did not share any specific EEG activity with sleep (Evans, 1979).

Correspondence to: V. De Pascalis, Dipartimento di Psicologia, Via dei Marsi 78, 00185 Roma, Italy.

There are consistent findings supporting the evidence of a decrease in alpha amplitude and a significant increase in beta activity during hypnosis (Bauer and McCanne, 1980; Evans, 1979). Results from other laboratories indicated an enhancement in alpha density during hypnosis, above all among highly hypnotizable subjects (Engstrom, 1973; Engstrom, London and Hart, 1970; Morgan and MacDonald, 1973; Ulett, Akpinar and Itil, 1972; Morgan, MacDonald and Hilgard, 1974). An increase of alpha and beta rhythms during the hypnosis was also observed in depth cerebral electrical activity in man (De Benedittis and Sironi, 1986). Edmonston (1981) did not find changes in alpha activity during hypnosis, although a significant increase of alpha density was observed in the initial stage of the induction period.

A number of studies have supported the hypothesis that hypnosis is characterized by the presence of a low voltage theta (3.5–7.5 Hz) activity (e.g., Sabourin, 1982; Tebecis et al., 1975; Sabourin, Cutcomb, Crawford and Pribram, 1990; Ulett, Akpinar and Itil, 1972; Crawford, 1990a, b). Some authors (e.g., Sabourin and Cutcomb, 1980) derived this hypothesis from the observations that highly hypnotizable subjects with respect to lows usually exhibit a higher ability for imaginative involvement and added further support to the generally accepted assumption that hypnotizability depends on a capacity for imaginative involvement (Hilgard, 1979). This assumption suggests that differences between high and low hypnotizables in EEG theta activity cannot be interpreted as uniquely related to hypnotizability. In a more recent study by Sabourin et al. (1990) the theta-hypnotizability relationship was confirmed. High hypnotizables, with respect to the lows, in eyes-open and eyes-closed conditions, in waking and hypnosis, exhibited significantly greater average theta power at all frontal, and central and occipital locations, with a larger difference in frontal locations. The enhancement of theta activity during post-surgery hypnosis was also found by Chen, Dworkin and Bloomquist (1981).

Other studies have failed to find a theta-hypnotizability relationship. MacLeod-Morgan (1979)

found that highly-hypnotizable subjects generated more theta in eyes-open, but not in eyes-closed conditions. De Pascalis and Imperiali (1984) found no relationship between temporal and parietal theta power and hypnotizability. Starting from the differentiation of theta rhythm in low (Class I inhibition) and high (Class II inhibition) theta frequency operated by Vogel, Broverman, and Klaiber (1968), Crawford (1990a,b) found that high hypnotizables generated significantly greater spectral power than low hypnotizables in high theta (5.5–7.5 Hz) but not low theta (3.5–5.5 Hz) in both hemispheres across frontal, temporal, parietal, and occipital locations. This result has been interpreted as suggesting that the greater theta power observed in the waking state for high hypnotizables, as compared with lows, may reflect their greater focused attentional and disattentional skills. The greater theta during hypnosis was interpreted as reflecting the enhancement of focused attention and cognitive activity which are characteristics of the hypnosis condition.

A high-frequency EEG activity centered at 40 Hz (36–44 Hz) has been found to be a covariate of focused arousal. A psychophysiological construct of 'focused arousal' has been developed in considerable detail as a functional component of the multi-dimensional attentional process (Sheer, 1988). Focused arousal, its brain circuitry and direct electrical measurement procedure, and its relationship with an EEG activity within a 36–44 Hz frequency band, centering at 40 Hz has been described by Sheer (Sheer, 1970; 1976; 1984).

In a number of studies carried out in our laboratory it was found that 40-Hz EEG activity, either in a waking condition (De Pascalis et al., 1987) or in hypnotic and nonhypnotic conditions (De Pascalis, Marucci and Penna, 1989; De Pascalis and Penna, 1990), reflected differential attentional patterns between high and low hypnotizables during cognitive effort. In particular, we observed that the greater ability of high hypnotizables to recollect positive and negative emotional events was paralleled by the more consistent task-related 40-Hz EEG hemispheric shifts observed for high hypnotizables as compared with the lows.

A psychophysiological working model of hyp-

nosis was proposed by Gruzelier and his collaborators (Gruzelier et al., 1984) wherein experimental evidence is reported of altered cerebral asymmetry under hypnosis in favour of the right hemisphere and the role of left-hemisphere dynamic processes is displayed as fundamental to the induction of hypnosis. This model was further elaborated by Gruzelier (1988), who suggested the importance of an inhibition of frontal lobe functions and an enhancement of posterior functions aside from shifts in activation from left to right hemisphere. More recently, it has been suggested that behavioural differences related to hypnotic susceptibility are expressions of differences in neurophysiological mechanisms (Gruzelier, 1990; Crawford and Gruzelier, 1992). Highly-susceptible individuals show greater cognitive and physiological flexibilities, as expressed by their greater ability to focus attention and to shift from one strategy to another in compliance with instructions. In line with this model, hypnosis may be conceived of as a multi-stage dynamic process, involving in the first stage of the hypnotic induction a greater activity of the left frontal hemisphere, and as the induction proceeds, the inhibition of frontal left-sided functions by releasing posterior functions of the right hemisphere. As posterior functions of the right hemisphere become activated the vivid imagery, disinhibition of affect and retrieval of early memories are facilitated. In the light of the before mentioned model of hypnosis, the purpose of this paper is to look for hemispheric trends during hypnotic induction as well as during a suggested dream and age regression as imaginal tasks. An aim of the study was to extend our previous 40-Hz EEG findings by collecting EEG activity in frontal, central and posterior leads and by using Fast-Fourier spectral analysis in low and high bands of alpha, theta and beta activities.

METHODS

Subjects

19 (9 high hypnotizables and 10 low hypnotizables) between the age of 20 and 28 years were selected from a sample of 80 female psychology

students on the basis of their scores on the Harvard Group Scale of Hypnotic Susceptibility: Form A (HGSHS: A; Shor and Orne, 1962) and, in a separate session, on the basis of their scores on the Stanford Hypnotic Susceptibility Scale: Form C (SHSS: C; Weitzenhoffer and Hilgard, 1962). Subjects were designated as being high hypnotizables when they scored in the 10–12 range on both hypnotic susceptibility scales. Subjects were designated as being low hypnotizables when their scores were in the 0–4 range on both hypnotizability scales.

The subjects were all women since there are suggestions indicating that women are significantly more susceptible to hypnosis than men (Bowers, 1971) and that sex is a moderating variable in the relationship between hypnotic susceptibility and functional brain asymmetry (Gur and Gur, 1974). Moreover, some studies have revealed greater task-induced asymmetries in males than in females (Ray et al., 1976; Glass, Butler and Carter, 1984; Trotman and Hammond, 1979).

Before the placing of electrodes, subjects were administered the State Anxiety Scale, and on another day, the following scales: Trait Anxiety Scale of the State-Trait Anxiety Inventory (STAI, Spielberger, Gorsuch and Lushene, 1970), and the Tellegen Absorption Scale (TAS: Tellegen and Atkinson, 1974). No significant differences in state-trait anxiety scores were found between groups ($p > 0.05$). Subjects were all right-handed. The handedness was evaluated with the Italian version of Edinburgh Inventory Questionnaire (Salmaso and Longoni, 1985). Subjects who had reported neurological or psychiatric disorders were excluded from data analyses. Because menstrual cycle has been known to affect EEG parameters (e.g., Glass, 1968), subjects who claimed to be in a menstrual state were called again on another occasion.

Procedure

The monitoring equipment was shown to the subject and she was told that the aim of the experiment was to obtain EEG recordings during the hypnotic induction of the Stanford Hypnotic Clinical Sale (SHCS; Morgan and Hilgard, 1978, 1979). Subjects were, however, neither informed

about specific experimental hypotheses, nor about their individual level of hypnotizability as previously measured by HGSHS: A and SHSS: C. The experimental session was carried out between 3 and 7 p.m. After the electrodes were attached each subject sat in a comfortable armchair, in a sound-attenuated dimly-lit cubicle. During the EEG recording session the hypnotist and subject were in touch with the experimenter by means of an intercom system. The hypnotist was a woman and she did not know the subjects' susceptibility scores, but she administered to the whole group ($n = 80$), in a preceding session, the SHSS: C. Before the administration of SHCS a 2-min relaxation period was given to the subject during which she was invited to relax, emphasizing muscle relaxation and slow breathing. Two 1-min rest periods (1 min with eyes open and 1 min with eyes closed) were given before beginning the hypnotic induction.

The hypnotic induction was divided into three parts, the early hypnotic induction (eyes open) and the late induction (eyes closed) and the counting period that concludes the hypnotic induction and introduces the hypnosis condition. EEG activity was recorded during the hypnotic induction in order to test whether the relaxation suggestions might differentially affect those who were more or less hypnotizable. After an eyes-closed resting-hypnosis period (1 min), the Dream and Age regression items of the SHCS were then administered to the subject. The session lasted about 1 h. All high-hypnotizable subjects passed the Dream and Regression items. All low-hypnotizable subjects failed to pass these items and it was suggested to them to imagine neutral situations like in a dream.

EEG recordings

EEG recordings were made using Ag/AgCl cup electrodes placed on F_3 and F_4 (anterior sites), on C_3 and C_4 (central sites), and in the middle of O_1 - P_3 - T_5 and of O_2 - P_4 - T_6 triangles (posterior sites). Central recording sites were chosen because they lie over the central sulcus, a region that is known to reflect the activity of motor and sensory cortex (Arezzo and Vaughan, 1980). From posterior and anterior recordings

were obtained four 40-Hz EEG signals. The frontal recording site was chosen because there is experimental evidence that the frontal cortex is mainly involved in the regulation of phasic arousal, the neural substrate for the facilitation of focused arousal in specific sensory circuitry. Posterior recording sites were, on the other hand, chosen because they lie over the parieto-occipital-temporal junction, an area known to be involved in cognitive processes and very specifically associated with a generator facilitating focused arousal (Sheer, 1989). The reference electrode was made by directly linking the earlobes. Subjects were grounded on the forehead. Electrode impedance was maintained below 7 k Ω and balanced across left and right recording sites. EEG was amplified by a 'ERA-9'-OTE Biomedica Italiana neuropolygraph in the 0.1–200 Hz frequency range and tape recorded for off-line analysis on a digit OTE tape recorder. Seven neuropolygraphic channels were used, six of them to record EEG activity and one to record EMG activity from the frontalis muscle.

40-Hz EEG detection system

The amplified (gain = 200 000) anterior and posterior raw EEG signals were sent to a four-channel 40-Hz EEG detection system, built according to Sheer's (1975) method. The restriction of the 40-Hz EEG system to four channels constrained us to detect 40-Hz EEG from frontal and temporo-parieto-occipital cortex because these brain regions have been found mainly involved in the regulation of focused arousal (Sheer, 1989). Since the 40-Hz EEG activity may be contaminated by low-frequency muscle activity, EMG activity was recorded as a control. One EMG recording was obtained from bipolar leads, with both electrodes on the frontalis muscle approx. 25 cm above the eyebrows. To control for muscle artifacts in the four 40-Hz EEG activities, the two frontal 40-Hz EEG (35–45 Hz bandwidth) and frontalis 70-Hz EMG (64–76 Hz bandwidth) signals were first rectified, integrated and then compared. The integrated signals were also analyzed in order to obtain an averaged amplitude level value in different time periods (from 2 s to 3 min). In order to determine the presence of mus-

cle artifacts each of the two 40-Hz EEG signals was separately compared with the 70-Hz EMG signal. To do this an amplitude criterion was first applied by determining an amplitude threshold for each signal. Threshold levels were empirically determined for each subject as the averaged level of each signal as obtained during a baseline period (eyes closed). The amplitude criterion, to reject 40-Hz EEG activity coincident with muscle artifacts, was made operant by three separate Schmidt triggers that served as threshold level detectors. Three adjustable gain potentiometers for both 40-Hz EEG and 70-Hz EMG served to settle previously determined threshold levels as a reference level of the Schmidt trigger. In cases in which one of the EEG or EMG signals was above a previously settled dc threshold level, the threshold level detector switched on. Each output of the two 40-Hz EEG level detectors with the output of the 70-Hz EMG level detector was separately connected to a comparator to control for muscle artifacts. If there was any partial overlap, within a time window of 100 ms (4 cycles of 40-Hz and 7 of 70-Hz signals), of any 40-Hz EEG activity and 70-Hz EMG activity which was exceeding the threshold, any 40-Hz EEG channel was inhibited.

EEG processing

The EEG was continuously monitored on paper. 10 EEG signals were digitized, labelled and stored on a computer disk memory. Four of the EEG signals were 2 for F_3 , F_4 and 2 for posterior raw EEG recordings. The other four were for the 40-Hz EEG as extracted from F_3 , F_4 and posterior raw EEG recordings. The remaining two EEG signals were for C_3 and C_4 recordings. EEG was digitized on-line on 12 bit at 300 samples per second per channel in a 16-channel (Metrabyte Dash-16) interface connected to a IBM PC/AT. Epochs of 3.41 s (1024 points per channel) were recorded on floppy diskettes. Before the beginning of EEG recording the recording system was calibrated by feeding a 10 cycles/s, 100 μ V sinewave into each of the EEG channels. An average peak-to-peak amplitude of the calibration signal was then calculated in order to correct for interchannel differences prior to the

Fast-Fourier Transform (FFT).

First, signal analysis consisted in editing the digitized raw EEG and 40-Hz EEG signals for artifact rejections. The EEG editing was done as follows: the raw EEG paper record and the corresponding digitized epochs were visually scanned by two observers to identify any eye-movement or motor or high-frequency muscle artifact. 40-Hz EEG signals were scrolled on a computer screen and the epoch which displayed a blank (zero potential trace) produced by a muscle artifact was discarded. In the cases in which a muscle or eye-blink artifact was detected, a playback of the EEG record into the analog-to-digital converter was used. Second, FFT on selected EEG epochs, power spectral computation and ensemble averaging of these spectra were carried out. 60 epochs were digitized for each subject. Epochs were then subjected to FFT, in order to transform the time-series into the frequency domain. FFT was implemented by using a Turbo-Basic language program elaborated for this experiment*; a 512-point transform was accomplished, creating a resolution of 0.29 Hz in the resulting spectra. Autospectral estimates were then averaged within each epoch of the eight experimental conditions for each subject, producing smoothed power spectrum estimates for each condition and group.

RESULTS

Statistical data analysis

After spectral analysis of the raw EEG activity (0–44 Hz) recorded from frontal, central and posterior recording sites, the mean spectral amplitudes estimates for seven Hz bands, theta1 (4–6 Hz), theta2 (6–8 Hz), alpha1 (8–10 Hz), alpha2 (10–13 Hz), beta1 (13–16 Hz), beta2 (16–20 Hz) and beta3 (20–36 Hz) for rest and hypnosis conditions were extracted. In order to obtain comparable variables within the EEG activity, the

* The FFT software was implemented by Roberto Pedone, psychology student at the Faculty of Psychology, Università di Roma, 'La Sapienza' (Rome, Italy).

four 40-Hz EEG (36–44 Hz) signals (two for anterior and two for posterior recordings) were also analyzed by FFT and the 36–44 Hz mean amplitude estimate was extracted.

For each of the bandwidths repeated-measures-analyses of variance (ANOVAs) were separately performed by using the GLM procedure of the Statistical Analysis System (SAS): 2 Hypnotizability (high, low) \times 2 Hemisphere (left, right) \times 3 Intrahemispheric Location (frontal, central, posterior) \times Condition. The type-III sums of squares were used for testing statistical effects with an unbalanced design (SAS, 1987). For 40-Hz EEG power scores the central electrode locations were not available and therefore not considered in the analyses.

Three separate analyses of variance (ANOVAs) for each EEG spectral amplitude score were carried out. The first was across three rest-baseline conditions: Waking-Rest (eyes open), Waking-Rest (eyes closed), Hypnosis-Rest (eyes closed). The second ANOVA was across the following conditions: Waking-Rest (eyes open), Waking-Rest (eyes closed), Early-Hypnotic Induction (eyes open), Late-Hypnotic Induction (eyes closed), Counting (the end of hypnotic induction). The third analysis of variance was car-

ried out across Rest-Hypnosis, Hypnotic Dream and Age-Regression conditions.

Significant effects were assessed using the Greenhouse-Geisser epsilon correction for inflated probability of a type-I error (Geisser and Greenhouse, 1958; Vasey and Thayer, 1987; Jennings, 1987). A rejection region with at least a value of $p < 0.05$ was selected and used throughout. Post-hoc comparisons of the means were carried out by Scheffé's Multiple Range Test (Kirk, 1968). Comparisons addressing hypnotizability levels are emphasized. The effects displayed by EE spectral amplitude scores that are considered essential for the explanation of individual differences are reported.

Resting conditions

Theta1 and theta2. No main or interactional effects involving Hypnotizability were found.

Alpha1 and alpha2. No significant effects involving Hypnotizability or hypnosis condition for alpha1 amplitude scores were found. For alpha2 amplitude the Hemisphere \times Location \times Condition \times Hypnotizability interaction was found to be significant ($F(4,68) = 3.00$, $p < 0.03$). This effect showed, for high hypnotizables, a reduction of alpha2 amplitude in the frontal left hemi-

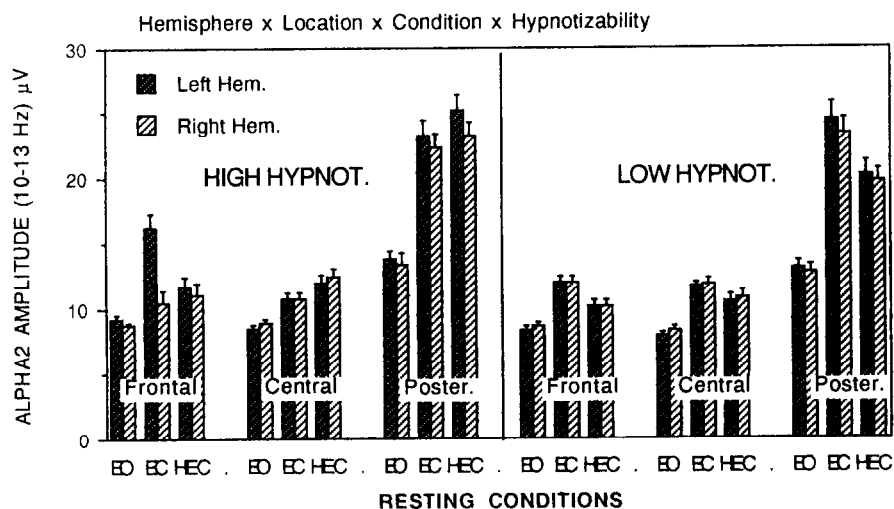


Fig. 1. Alpha2 (10–13 Hz) amplitude in left and right hemispheres across frontal, central and posterior scalp leads during waking-rest eyes-open (EO) and eyes-closed (EC) conditions and a hypnosis-rest eyes-closed (HEC) condition, among high and low-hypnotizable subjects.

sphere during the hypnosis-rest (eyes-closed) condition as compared with waking-rest eyes-closed condition. This interaction might indicate that the left hemisphere preponderance in alpha2 production as observed in waking-rest (eyes closed) was replaced with hemisphere symmetry during hypnosis eyes-closed resting condition (see Fig. 1).

Beta1, beta2, beta3 and 40-Hz EEG. Analyses across beta and 40-Hz EEG scores did not display significant effects except for Condition main effects that were found to be significant for beta1 and beta2 amplitudes. This effect showed parallel trends (beta1 Condition: $F(2,34) = 15.23$, $p < 0.0001$; beta2 Condition: $F(2,34) = 16.60$, $p < 0.0001$) for beta1 and beta2 amplitudes among conditions, i.e., there were greater beta1 and beta2 amplitudes across waking and hypnosis rest eyes-closed periods as compared to a waking-rest eyes-open condition (beta1: 7.0, 8.5, and 7.7; beta2: 7.2, 8.8, and 8.1 μV for waking-rest with eyes open and eyes closed and hypnosis-rest with eyes closed, respectively).

Hypnotic induction conditions

Theta1, theta2, alpha1, alpha2, beta1, beta2. No main or interactional effects involving Hypnotizability for these variables in waking-rest, early hypnotic induction, late hypnotic induction and count conditions were found.

Beta3 and 40-Hz EEG. A Hypnotizability main effect for beta3 and 40-Hz EEG amplitudes was found (beta3: $F(1,17) = 4.64$, $p < 0.05$; 40-Hz EEG: $F(1,17) = 4.36$, $p < 0.05$). This effect displayed for high-hypnotizable subjects greater beta3 and 40-Hz EEG amplitudes with respect to the low hypnotizables (beta3: 3.9 vs. 3.4 μV ; 40-Hz EEG, 1.8 vs. 1.4 μV for high vs. low hypnotizables, respectively). The Hypnotizability \times Hemisphere \times Condition interaction was found to be significant for beta3 amplitude ($F(4,68) = 10.30$, $p < 0.0001$). This effect indicated, for high hypnotizables, a greater beta3 amplitude in the left hemisphere as compared to the right during the early hypnotic induction and a hemispheric balance during the late hypnotic induction period. This hemispheric difference, observed for the highly hypnotizables, was found to be also

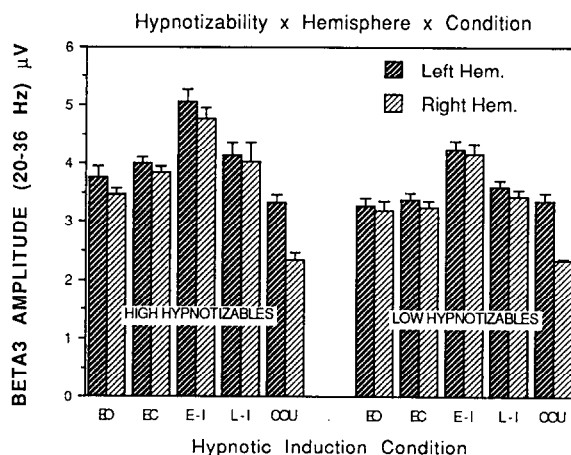


Fig. 2. Beta3 EEG spectral amplitude (20–36 Hz) in high and low-hypnotizable subjects during rest eyes-open (EO), rest-eyes-closed (EC), early induction (E-I), late hypnotic induction (L-I) and counting (COU) conditions of the SHCS.

pronounced in the waking-rest (eyes-open) condition (see Fig. 2). Condition and Hemisphere \times Condition effects were also significant (Condition: $F(4,68) = 15.29$, $p < 0.01$; Hemisphere \times Condition: $F(4,68) = 10.80$, $p < 0.0001$). The condition effect indicated a marked Beta3 increase during the early hypnotic induction as compared with the other conditions. The Hemisphere \times Condition effect indicated a marked hemisphere asymmetry of Beta3 amplitude in favour of the left hemisphere as compared with the right during a counting condition (see Fig. 2).

Resting, dream and age-regression conditions

Theta1 and Theta2. No main or interactional effects involving Hypnotizability or hypnotic condition for theta1 and theta2 amplitudes were found.

Alpha1 and alpha2. Common to both variables were the significant effects for Location (Alpha1: $F(2,34) = 25.72$, $p < 0.0001$; Alpha2: $F(2,34) = 58.50$, $p < 0.0001$) and for the Location \times Condition \times Hypnotizability interaction (Alpha1: $F(4,68) = 3.88$, $p < 0.03$; Alpha2: $F(4,68) = 4.96$, $p < 0.01$). Post hoc multiple comparisons with Scheffé's test indicated for alpha1 and alpha2 amplitudes that over posterior recordings, during hypnotic dream and age regression, high hypnoti-

zables displayed a decrease in alpha2 and even more in alpha1 amplitudes with respect to a hypnosis resting condition, while the opposite

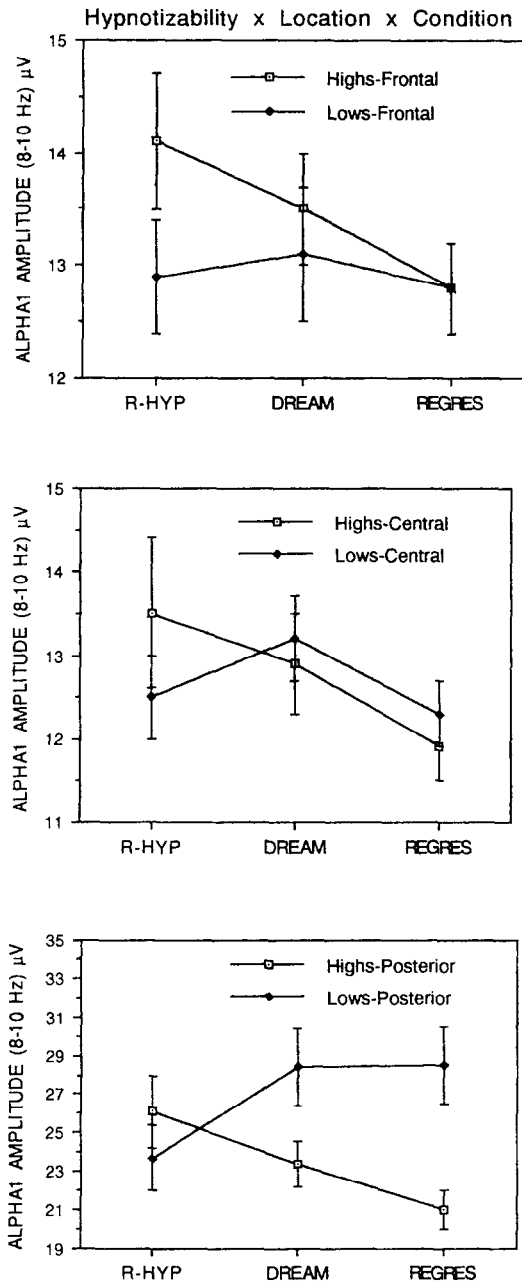


Fig. 3. Alpha1 (8-10 Hz) amplitude across frontal, central and posterior scalp leads for high and low-hypnotizable subjects.

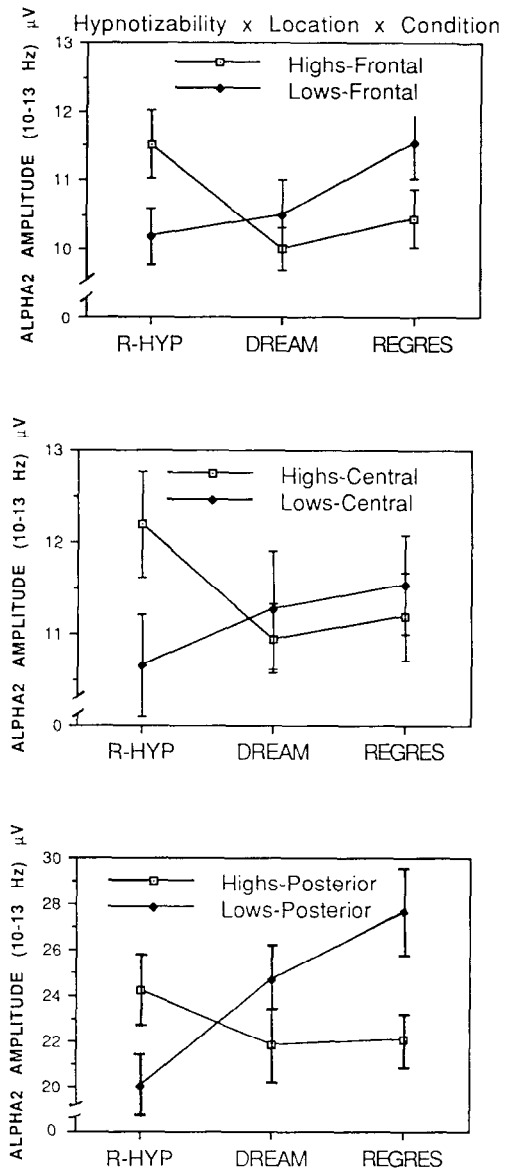


Fig. 4. Alpha2 (10-13 Hz) amplitude across frontal, central and posterior scalp leads for high and low-hypnotizable subjects.

trend was exhibited for both alpha1 and alpha2 amplitudes in low hypnotizables (see Figs. 3 and 4). As an example of the analyses carried out in this study, a complete table of ANOVA for alpha1 amplitude in Resting, Dream and Age-Regression conditions is presented in Table 1.

Beta1, beta2, beta3. All these variables displayed a significant effect for the Hemisphere \times Condition \times Hypnotizability interaction (Beta1: $F(2,34) = 6.14$, $p < 0.005$; Beta2: $F(2,34) = 3.92$, $p < 0.03$; Beta3: $F(2,34) = 7.59$, $p < 0.003$). This effect displayed parallel trends across beta variables by showing a left hemisphere prevalence compared with the right for beta1, beta2 and beta3 amplitudes during age-regression condition

and a hemisphere balancing during dream condition across high-hypnotizable subjects. Low hypnotizables, by contrast, displayed a hemispheric balance across imaginal tasks (see Fig. 5).

40-Hz EEG. There were a number of significant effects for this variable. The first effect was for hypnotizability ($F(1,17) = 11.24$, $p < 0.004$) which showed a significantly greater 40-Hz EEG amplitude for high hypnotizables as compared

TABLE I

Analysis of variance (ANOVA-SAS system) across Alpha1 amplitude scores during hypnosis

Experimental design: 2 Hypnotizability (High, Low) \times 2 Hemisphere (Left, Right) \times 3 Location (Frontal, Central, Posterior) \times 3 Condition (Resting, Dream, Age-regression).

Source of variation	df	Type III SS	Mean square	F	Pr > F	Greenhouse-Geisser Adj Pr > F	Greenhouse-Geisser epsilon
HYPNOTIZABILITY	1	61.5066	61.5066	0.05	0.8274	–	
Error	17	21 315.3513	1 253.8442				
HEMISHERE	1	2.7552	2.7552	0.10	0.7608	–	
HEM. \times HYPN.	1	4.0191	4.0191	0.14	0.7132	–	
Error(HEM.)	17	489.2330	28.7784				
LOCATION	2	11 557.3978	5 778.6989	25.72	0.0001	0.0001	
LOC. \times HYPN.	2	210.3917	105.1958	0.47	0.6301	0.5071	
Error(LOC.)	34	7 639.0157	224.6769				0.5115
CONDITION	2	59.0609	29.5304	0.42	0.6579	0.6202	
COND. \times HYPN.	2	231.4600	115.7300	1.66	0.2050	0.2104	
Error(COND.)	34	2 368.7433	69.6689				0.8246
HEM. \times LOC.	2	47.7124	23.8562	1.07	0.3556	0.3177	
HEM. \times LOC. \times HYPN.	2	26.8649	13.4325	0.60	0.5544	0.4523	
Error(HEM. \times LOC.)	34	760.9103	22.3797				0.5108
HEM. \times COND.	2	0.0948	0.0474	0.02	0.9788	0.9770	
HEM. \times COND. \times HYPNOT.	2	1.8981	0.9491	0.43	0.6550	0.6499	
Error(HEM. \times COND.)	34	75.3242	2.2154				
LOC. \times COND.	4	36.6664	9.1666	0.56	0.6940	0.5694	
LOC. \times COND. \times HYPN.	4	254.8839	63.7210	3.88	0.0068	0.0328	
Error(LOC. \times COND.)	68	1 117.3239	16.4312				0.4757
HEM. \times LOC. \times COND.	4	2.6410	0.6602	0.32	0.8649	0.7281	
HEM. \times LOC. \times COND. \times HYPN.	4	2.8387	0.7097	0.34	0.8487	0.7112	
Error(HEM. \times LOC. \times COND.)	68	141.1127	2.0752				0.4963

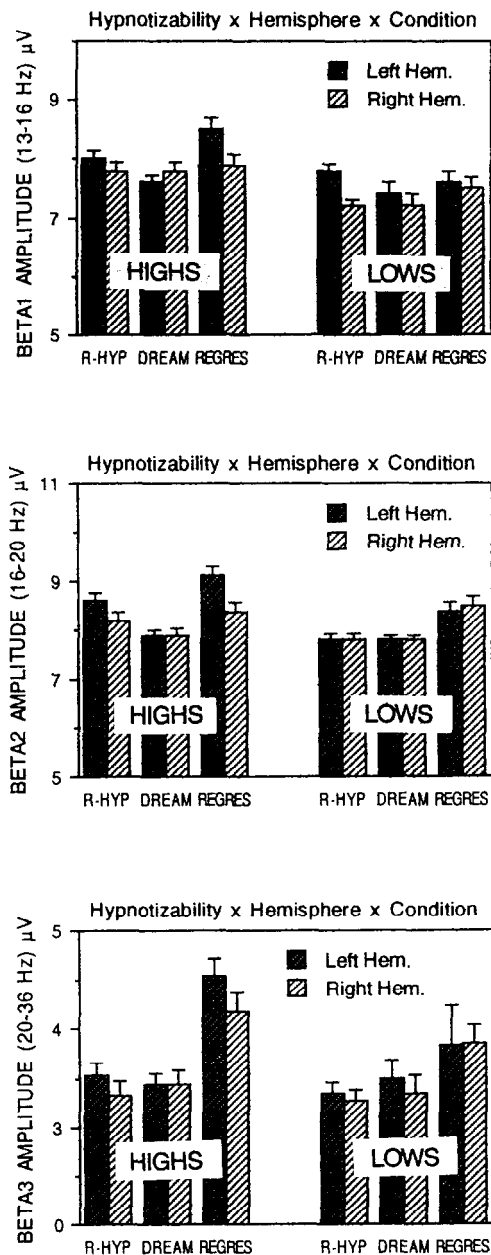


Fig. 5. Beta1 (13–16 Hz), Beta2 (16–20 Hz) and Beta3 (20–36 Hz) amplitudes in left and right hemispheres during rest in hypnosis (R-HYP), hypnotic dream (DREAM) and hypnotic regression (REGRES) conditions of the Stanford Hypnotic Clinical Scale.

with lows (1.8 vs 1.2 μV , for high vs low hypnotizables). The second effect was the Hemisphere \times Condition interaction ($F(2,34) = 5.19$, $p < 0.01$). The third effect was the Hemisphere \times Condition \times Hypnotizability interaction ($F(2,34) = 4.29$, $p < 0.02$). The last effect was the significant Hemisphere \times Location \times Condition \times Hypnotizability ($F(2,34) = 6.23$, $p < 0.005$) interaction. Post hoc comparisons of the means with Scheffé's Multiple Range Test indicated that high hypnotizables during hypnotic dream displayed in the right hemisphere a greater 40-Hz EEG amplitude as compared with the left hemisphere. This difference was even more evident for posterior recording sites. This hemispheric trend was not evidenced for low-hypnotizable subjects (see Fig. 6).

DISCUSSION

Theta1 and theta2 amplitudes

This study failed to show any relationship between hypnotizability or hypnosis and theta1 and theta2 amplitudes. This negative result is in contrast to a number of previous findings (e.g., Sabourin, 1982; Sabourin et al., 1990; De Pascalis and Imperiali, 1984). The reason for the lack of the theta vs. hypnotizability/hypnosis relationship is unknown. We cannot exclude, however, that this relationship may be the result of complex interactions among personality, subject selection, situation-specific factors and hypnotizability.

Alpha1 and alpha2 amplitudes

Alpha2 amplitude (but not alpha1 amplitude) was found to interact with hypnotizability and hypnosis. The hemispheric preponderance for alpha2 amplitude observed in the frontal left hemisphere during a waking-rest eyes-closed condition was replaced with hemispheric symmetry balancing during the hypnosis resting condition. An obvious increase in alpha2 amplitude across central and even more posterior recordings was also observed in resting eyes-closed waking and hypnosis conditions. Moreover, the reduction of alpha1 and alpha2 amplitudes for high-hypnotizable subjects during hypnotic dream and age re-

gression indicated the greater reactivity in alpha amplitude of these subjects while they engaged in the tasks. These results appear in agreement with our previous waking state findings (De Pascalis, Silveri and Palumbo, 1988; De Pascalis and Palumbo, 1986) and support the idea of a functional two-dimensional existence of alpha rhythm (Coppola and Cassy, 1986; Coppola, 1986; Herrmann, 1982).

Beta1, beta2 and beta3

Spectral amplitudes in the beta range were found to be sensitive to individual differences during task performance in the hypnosis condition. High-hypnotizable subjects showed a left-hemisphere prevalence in all the beta bands while

they were executing an age regression suggestion. These subjects also showed hemispheric balance while they were engaged in a hypnotic dream conditions. Beta3 amplitude was also found to be greater among high hypnotizables as compared with lows. Among high hypnotizables, beta3 amplitude in the early hypnotic condition was greater in the left hemisphere as compared to the right and as the hypnotic induction proceeded hemisphere balancing, with reduced beta3 amplitude, was displayed. This result appears in agreement with the predictions of the neurophysiological model proposed by Gruzelier et al. (1984) and Gruzelier (1988) as well as with other studies in which beta rhythm was found to discriminate performances between high and low hypnotiz-

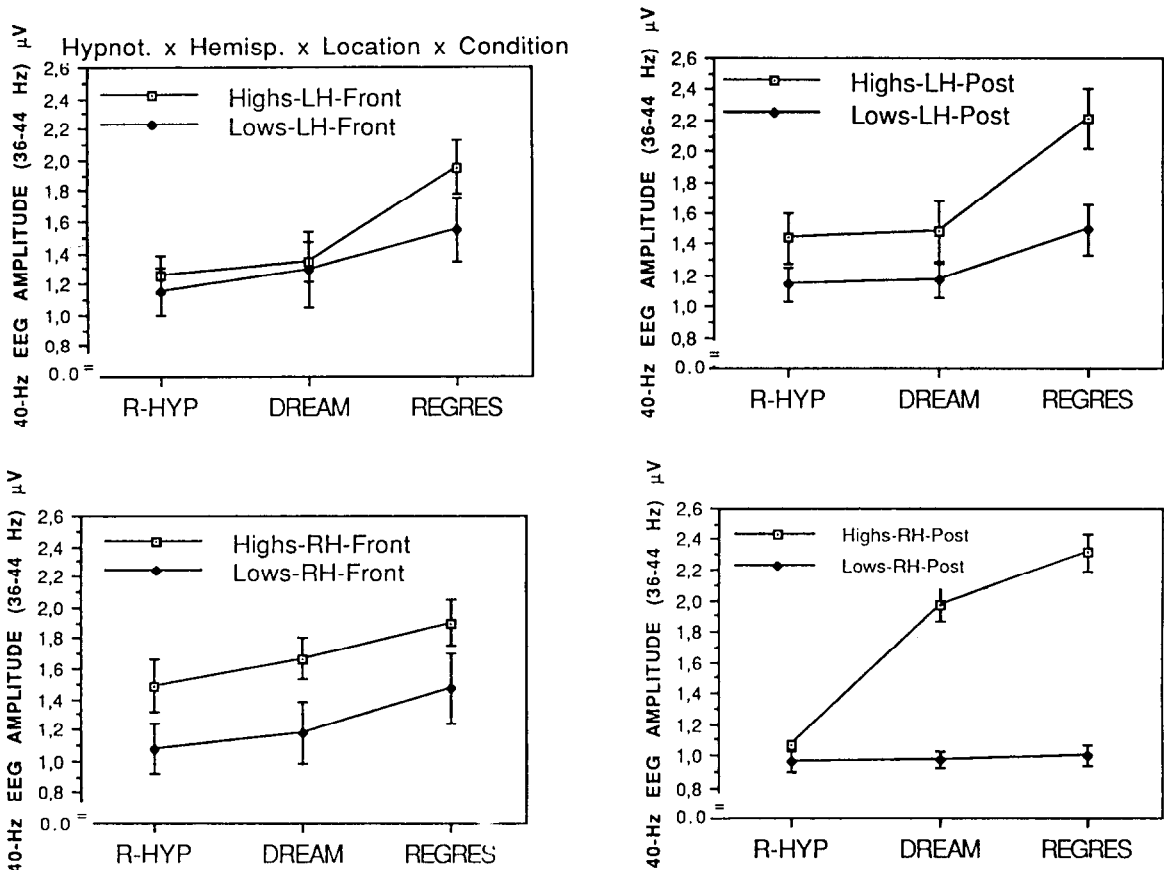


Fig. 6. 40-Hz EEG amplitude across left- and right frontal (Front) and posterior (Post) regions in high and low hypnotizable subjects during rest in hypnosis (R-HYP), hypnotic dream (DREAM), and hypnotic regression (REGRES) conditions of the Stanford Hypnotic Clinical Scale.

ables (e.g., Meszaros et al., 1986, 1989; Sabourin et al., 1990).

40-Hz EEG amplitude

During both hypnotic induction and hypnosis performances, 40-Hz EEG amplitude was also found to be greater in highly-hypnotizable subjects than in lows. Moreover, during the hypnotic dream and especially across posterior recordings, high hypnotizables displayed a greater 40-Hz EEG amplitude in the right hemisphere than in the left. This pattern of hemispheric activation may be interpreted as an expression of the greater right-hemisphere activation and of the release of posterior cortical functions during the hypnotic dream and is compatible with the predictions of the Gruzelier model of hypnosis, however, the results obtained in this study for 40-Hz EEG amplitude failed to reveal an inhibition of the left-hemisphere activity with the progress of the hypnotic induction. In a previous study, however, (De Pascalis and Penna, 1990), the hemispheric trend of 40-Hz EEG density during a standard hypnotic procedure was in agreement with the Gruzelier (1988) model of hypnosis, i.e., as the model suggested, highly hypnotizables in the early hypnotic induction showed an increase of 40-Hz EEG density in both hemispheres, but as the induction proceeded they showed an inhibition of activity in the left and an increase in the right. In this experiment the beta3 amplitude was the only variable that displayed a hemispheric trend that was in agreement with Gruzelier's model. In fact, we observed a decrease in this activity across both hemispheres and this reduction was greater in the left hemisphere than in the right. For high hypnotizables the dream condition showed a greater right-hemisphere activation as expressed by the 40-Hz EEG amplitude, but no hemispheric differences for low hypnotizables. The opposite hemispheric trend was observed for high subjects during age-regression suggestion for spectral amplitudes in the beta range.

The 40-Hz EEG rhythm, which according to Sheer (1976) is the physiological representation of focused arousal, appeared to discriminate between differential patterns of high and low hypnotizables. Both during hypnotic induction and

during hypnotic dream and age regression highly hypnotizables exhibit greater 40-Hz EEG amplitude with respect to the lows. These findings support the validity of the assumption that hypnosis is characterized by a state of focused attention (Hilgard, 1965) and that 40-Hz EEG activity reflects differential attentional patterns among subjects high and low in hypnotizability. On the basis of these findings it would appear that 40-Hz EEG and beta3 spectral amplitudes may prove to be useful measures of individual hypnotizability.

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