The neural mechanisms associated with hypnosis were investigated in a single highly hypnotizable subject by measuring the mismatch negativity (MMN) component of auditory ERP, reflecting the preattentive discrimination of change in stimulus flow, in normal baseline state and under hypnosis. It has been proposed that the frontal inhibition associated with hypnosis can be measured as a decrease in MMN. ERPs were elicited using the passive oddball paradigm with standard and deviant sine tone stimuli of 500 and 553 Hz, respectively. The measurement was repeated in five separate sessions. In hypnosis the MMN was significantly larger compared to baseline. The results indicate that hypnosis can give rise to altered information processing in the brain even at a relatively early, i.e. preattentive level and that the larger MMN measured under hypnosis does not support frontal inhibition theory.

Key words: Altered state of consciousness (ASC); Event related potentials (ERP); Hypnosis; Mismatch negativity (MMN)

Introduction

The hypothesis that hypnotic induction can lead to an altered state of consciousness (ASC) is highly controversial in hypnosis research [1,2]. According to the state theory, hypnosis evokes an ASC with its own characteristic neuropsychological and neurophysiological correlates in highly hypnotizable subjects [3]. The neurophysiological mechanisms behind this altered state have been proposed to be the inhibition of frontal lobe functions [3]. According to the non-state theory, all the psychological, physiological and behavioral changes associated with hypnosis can be explained without assuming any ASC [1].

Recent attempts to resolve this controversy include the use of new brain imaging techniques [4,5] where the subjects are typically given instructions of altering the perception of auditory, visual or somatosensory stimuli [6,7]. So far the results have been rather controversial and it remains unclear whether they imply the existence of any distinctive hypnotic state.

In the present study we approached this question by measuring the changes in ERPs associated with hypnosis. The mismatch negativity (MMN) is a component of the auditory event-related potential (ERP). It is elicited in a passive oddball situation when infrequent (deviant) stimuli are presented in a sequence of frequent (standard) stimuli. MMN is calculated by subtracting ERPs to the standard stimuli from ERPs to the deviant stimuli. This negative wave has been suggested to reflect the function of an automatic preconscious detector of stimulus change [8]. The MMN is considered to be composed of two subcomponents: a sensory-specific one, generated in the auditory cortices, and a frontal component [9]. The sensory-specific mechanism involves preconscious detection of stimulus deviation which then activates frontal mechanisms leading to conscious discrimination of this stimulus deviation and further to an orienting response which is reflected as a P3a wave in the EEG [10]. The scalp distribution of MMN has been found to be asymmetrical with the MMN peaking over the right hemisphere [11].

In this study our aim was to test the frontal inhibition theory and the ASC theory of hypnosis. We chose the MMN component of auditory ERP because it is well documented in the literature, it reflects a preconscious function and it is considered to have a frontal component. The ASC theory would be supported if significant change is found between baseline and hypnosis. The frontal/right frontal diminution of MMN would support the theory of frontal inhibition associated with hypnosis.

Materials and methods

The subject (T.H.) was a 34-year-old right handed female office worker who also performs semi-professionally as a classical singer. In a scale measuring...
hypnotic susceptibility (Stanford Hypnotic Susceptibility Scale, form C; SHSS-C) [12], T.H. scored the maximum of 12 points. The subject displayed all phenomena typically associated with highly susceptible individuals, such as vivid visual and acoustic hallucinations and an immediate re-entry into hypnosis when using a previously given posthypnotic suggestion. T.H. had no history of neurological illness and had normal hearing in both ears. She gave her informed consent to participate in the study.

The ERPs to frequency differences were measured with repetitive tones, based on the oddball paradigm. Pure sine tones (standard 500 Hz and deviant 553 Hz, SPL 70 dB) were used as stimuli. A total of 1000 standards and 200 deviants (duration 100 ms, interstimulus interval from offset to onset = 400 ms) were delivered in a block which lasted 10 min. The stimuli were presented binaurally through insert headphones (Eartone ABR, 10 \text{kHz}). EEG was recorded using 20 Ag/AgCl scalp electrodes arranged according to the 10/20 system of electrode placement. Two EOG electrodes, one at the upper canthus of the right eye and the other at the lower canthus of the left eye, were used for eye movement detection. All electrodes were referenced to the linked ears and the impedance of recording electrodes was held below 5 k\text{\Omega}. Continuous EEG was recorded using the NeuroScan 386 Scan 3.0 acquisition system with a Braintronics CNV/ISO-1032 amplifier having a frequency band of 0.3–70 Hz. The analysis epoch was 450 ms (50 ms before and 400 ms after the onset of each stimulus). The ERP components were measured, analyzed and edited with the NeuroScan equipment (Neuro Soft Inc., USA). All epochs showing significant (>50 \text{\mu V}) eye movements were automatically rejected. A prestimulus baseline of 50 ms was used. Each difference wave (standard-stimulus subtracted from deviant-stimulus) was analyzed by an independent blind referee who manually marked the onset and offset latencies of each difference wave. The MMN peak amplitude was measured from the zero baseline to the highest peak in the difference wave. We also measured the MMN area, which was numerically integrated from the onset to the offset point between the MMN waveform. As a baseline we used the line between the onset and the offset points.

The EEG recording was executed on five different days over a period of 14 months. During each recording session the subject received two identical stimulus blocks: one in the baseline state and one in hypnosis. The sequence of different states of consciousness was varied so that hypnosis started the session two times (second and fourth session) and a baseline recording preceded hypnosis in three sessions.

The subject had previously been given a posthypnotic suggestion about entering hypnosis or waking when hearing the experimenter say certain Finnish words. During the experiment the hypnotic state was induced with this technique and a break of 5 min separated the two recordings from each other. The suggestibility before each hypnosis recording was tested with an arm catalepsy test and an acoustic hallucination test (both from SHSS-C). The tests measuring suggestibility were all passed before each hypnosis session and failed before each baseline session. The subject was instructed to concentrate on a voiceless video program (The family of the Moomins) and not to pay attention to the tone pips which would be delivered through insert headphones. The instructions were verbatim identical in both baseline and hypnosis situation. No other information about the aims or purpose of the study was given.

**Results**

The data were analyzed for normality using the Kolmogorov-Smirnov test and could be considered normally distributed. Student’s t-test was used to compare the baseline and hypnosis results. The grand average difference waveforms of the evoked potentials were mainly compared in the fronto-central electrode (Fz) where the effect was largest and where the maximal amplitude of the MMN is typically found [9].

The MMN peaked at about 170 ms. It was seen all over the scalp and was largest in the frontal area (Fig. 1). The mean (± s.d.) peak amplitude in baseline was $-4.33 ± 0.91$ \text{\mu V} and in hypnosis $-6.38 ± 1.81$ \text{\mu V}; ($t(4) = 3.37, p < 0.05$). The MMN area in hypnosis was also significantly larger (baseline $357 ± 117$ ms \times \text{\mu V} and hypnosis $602 ± 175$ ms \times \text{\mu V}; $t(4) = 3.2, p < 0.03$). The mean MMN onset latencies were rather similar and no statistically significant difference was found (baseline $77 ± 14$ ms; hypnosis $62 ± 12$ ms).

The order of the blocks seemed to affect the results so that when baseline preceded hypnosis, the mean amplitude nearly doubled from $-3.4 ± 1.0$ \text{\mu V} (baseline) to $-6.7 ± 2.6$ \text{\mu V}, (hypnosis). When hypnosis preceded baseline the difference was smaller but still to the same direction ($-4.4 ± 0.6$ \text{\mu V}; hypnosis $-5.5 ± 0.2$ \text{\mu V}).

In order to find lateral differences the grand average peak amplitudes of left side electrodes (F7, F3, T3, C3, T5, P3 and O1) were compared with the right side electrodes (F8, F4, T4, C4, T4, P4, T6 and O2). At the baseline situation the MMN was peaking over the right hemisphere ($t(6) = 3.9, p < 0.01$).
but in hypnosis there was no significant difference between the hemispheres ($t(6) = 0.77$, $p = 0.47$).

The right frontal electrodes (F4, F8) and the left frontal electrodes (F3, F7) were compared in baseline and hypnosis in order to find out differences in the frontal area. On the left side (F3, F7) the mean amplitudes were $-2.7 \pm 1.1 \mu V$ in baseline and $-4.8 \pm 1.7 \mu V$ in hypnosis. On the right side the difference was smaller; baseline $-2.9 \pm 0.9 \mu V$ and hypnosis $-4.6 \pm 1.5 \mu V$. The difference was not statistically significant.

An orientational response to the stimuli typically

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FIG. 1. (a) Grand average frontal (Fz) ERPs to standard stimuli and deviant stimuli in baseline and hypnosis conditions. (b) Grand-average difference wave (standard-stimulus subtracted from deviant-stimulus) of the five sessions in baseline and hypnosis condition over whole scalp. (c) The fronto-central (Fz) electrode.
elsits a positive wave (P3a) around 300 ms [13]. The P3a wave was analyzed in order to control for possible changes in orientation to the stimuli. This wave was small and almost indiscernible in both baseline (2.1 ± 0.8 μV) and hypnosis (1.1 ± 0.3 μV) and no statistically significant differences were found.

While analyzing the data we noticed a clear difference in T.H.’s eye-blink frequency between baseline and hypnosis. A post-hoc analysis showed a significant difference between the blocks (baseline 86.6 ± 14.9 blinks/block and hypnosis 6.8 ± 0.44 blinks/block; t(4) = 2.5, p < 0.001).

Discussion

In a very highly susceptible subject, pure hypnosis without any further suggestions can give rise to an altered way of information processing in the brain. These changes are difficult to explain by referring to any social–psychological concepts such as implicit or explicit expectations [14] or complying [15] since MMN is considered to be the result of a preattentive process [9]. Since there are no behavioral or neurophysiological criteria for a hypnotic state, it is impossible to present any absolute proof of the subject being in hypnosis during the registration. The subject invariably passed the tests measuring susceptibility after being given the hypnotic induction and failed them in the absence of such induction. The eye-blink frequency also diminished during hypnosis which is a finding previously reported by Tada [16]. However, these are merely signs associated with hypnosis and not evidence of any altered state.

The frontal source of MMN is located in the right hemisphere, reflecting the frontal process related to the orienting response. Whereas the increase of the MMN in hypnosis could partially be a result of the sensory-specific component in the auditory cortices, the MMN is, however, very sensitive to changes in orientation to the stimuli. This is however not likely since this attend condition also typically results in a P3a wave which was practically absent in both baseline and in hypnosis.

Our findings are opposite to a previous study [17], where MMN decreased with high susceptibles progressively from the baseline to hypnosis. The MMN is, however, very sensitive to changes in vigilance and the amplitude also tends to decrease when a monotonous recording session lasts over an hour [18]. It is possible that the different result here can be explained by the very short induction in our study, eliminating a possible fatigue caused by a long induction procedure.

Conclusions

The result suggests that hypnosis can give rise to an altered way of information processing in the early, preattentive level of auditory processing. This is reflected by an enlargement of the MMN. Hypnosis thus may involve an altered state of consciousness in which automatic auditory discrimination processes are enhanced but at the same time their ability to engage attentional orientation seems to be diminished. This disconnection between the automatic orienting mechanisms and the focus of attention may be the neurocognitive basis of the absorption considered to be characteristic of the hypnotic state of consciousness. The present result does not support the frontal inhibition hypothesis.

References


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