Pain 112 (2004) 27–36

PAIN

www.elsevier.com/locate/pain

Perception and modulation of pain in waking and hypnosis: functional significance of phase-ordered gamma oscillations

Vilfredo De Pascalis*, Immacolata Cacace, Francesca Massicolle

Department of Psychology, University of Rome, 'La Sapienza', 5, Piazzale Aldo Moro, Via dei Marsi 78, 00185 Rome, Italy

Received 31 January 2004; received in revised form 3 May 2004; accepted 6 July 2004

Abstract

Somatosensory event-related phase-ordered gamma oscillations (40-Hz) to electric painful standard stimuli under an odd-ball paradigm were analyzed in 13 high, 13 medium, and 12 low hypnotizable subjects during waking, hypnosis, and post-hypnosis conditions. During these conditions, subjects received a suggestion of Focused Analgesia to produce an obstructive hallucination of stimulus perception; a No-Analgesia treatment served as a control. After hypnosis, a post-hypnotic suggestion was given to draw waking subjects into a deep hypnosis with opened eyes. High hypnotizables, compared to medium and low ones, experienced significant pain and distress reductions for Focused Analgesia during hypnosis and, to a greater extent, during post-hypnosis condition. Correlational analysis of EEG sweeps of each individual revealed brief intervals of phase ordering of gamma patterns, preceding and following stimulus onset, lasting approximately six periods. High and medium hypnotizable subjects showed significant reductions in phase-ordered gamma patterns for Focused Analgesia during hypnosis and post-hypnosis conditions; this effect was found, however, more pronounced in high hypnotizable subjects. Phase-ordered gamma scores over central scalp site predicted subject pain ratings across Waking-Pain and Waking-Analgesia conditions, while phase-ordered gamma scores over frontal scalp site predicted pain ratings during post-hypnosis analgesia condition. During waking conditions, this relationship was present in high, low and medium hypnotizable subjects and was independent of stimulus intensity measures. This relationship was unchanged by hypnosis induction in the low hypnotizable subjects, but not present in the high and medium ones during hypnosis, suggesting that hypnosis interferes with phase-ordered gamma and pain relationship.

Keywords: Pain; Hypnosis; Analgesia; Subjective experience; EEG gamma oscillations; 40-Hz

1. Introduction

The present study examined the relationship between pain perception and EEG responses within the gamma band (38–42 Hz) by measuring stimulus evoked phase-ordered gamma patterns with a correlational method recently developed by Maltseva et al. (2000).

Gamma activity is thought to play an integral role in information processing (Karakas and Basar, 1998). Among different types gamma activity: spontaneous, evoked, induced and emitted (Galambos, 1992), the evoked gamma activity has been widely studied. This activity occurs after stimulus presentation as a phase-locked activity in the early time window of 0–150 ms. It is thought to reflect early processing of stimulus information (e.g. Basar et al., 1987; Basar and Demiralp, 1995; Galambos et al., 1981; Llinas and Ribary, 1992; Pantev et al., 1991). But there is experimental evidence that synchronized gamma activity is also involved in selective attention. Evoked gamma activity (peaking at about 30 and 100 ms) was also found to increase during task requiring to direct attention to tones presented in one ear while ignoring tones being presented to the other ear (Tiitinen et al., 1993, 1997).

Recently, spatio-temporal dynamics of the event-related oscillations in different EEG bands between painful and non-painful somatosensory stimulation was studied by Chen and Hermann (2001). Later, Babiloni et al. (2002), using fine spatial-analysis of the EEG oscillations, has evidenced that galvanic painful stimulation, compared to non-painful stimulation, increased phase-locked theta to gamma band

* Corresponding author. Tel.: +39-6-4991-7643; fax: +39-6-4991-7652.
E-mail address: v.depascalis@caspur.it (V. De Pascalis).

0304-3959/$20.00
doi:10.1016/j.pain.2004.07.003

responses in the contralateral hemisphere and decreased the phase-locked beta band response in the ipsilateral hemisphere. Tecchio et al. (2003), using somatosensory neuromagnetic fields, provided experimental evidence that neural synchronization in somatosensory cortex (S1) may vary in frequency as a function of the stimulated finger (i.e. increments of beta (20–32 Hz) event-related coherence after little finger stimulation and of gamma (36–44 Hz) after the thumb stimulation).

Croft et al. (2002) conducted a study in which EEG spectral power (8–100 Hz range) was measured to painful electric stimuli delivered using an odd-ball paradigm. Gamma activity (32–100 Hz) over prefrontal scalp sites predicted subject pain ratings in the control condition. This relation was found unchanged by hypnosis in low hypnotizables while it was lacking during hypnosis and hypnotic analgesia in high hypnotizable subjects, suggesting that hypnosis interferes with this pain-gamma relationship.

In the present study, measures of phase-ordered gamma patterns, evoked by painful standard electric stimuli, and perceived stimulus intensity were obtained while subjects were engaged in a somatosensory oddball task. The study used a Focused Analgesia protocol requiring to produce an obstructive image of incoming stimuli that, in previous studies, was proved to be effective in pain relief (De Pascalis et al., 1999, 2001; Zachariae and Bjerring, 1994). This treatment was suggested in waking, hypnosis and a post-hypnotic suggestion conditions. Aim of the study was to determine whether: (1) phase-ordered gamma oscillation is a reliable indicator of pain sensation; (2) individual differences in hypnotic susceptibility reliably account for more pronounced pain reduction during hypnotic analgesia; (3) pain reduction is paralleled by reduction in the degree of phase-ordered gamma responses.

2. Methods

2.1. Subjects

The subjects were 38 right-handed undergraduate students (20 women and 18 men; age range 19–30 yr) pre-selected for high ($N=13$; 7 women and 6 men), medium ($N=13$; 7 women and 6 men), and low ($N=12$; 6 women and 6 men) levels of hypnotic susceptibility. The subjects were tested using the Stanford Hypnotic Susceptibility Scale, Form C (SHSS:C; Weitzenhoffer and Hilgard, 1962). The participants were categorized as being high hypnotizable subjects ($N=13$, $M=9.9$, SD $=0.86$) when their scores on SHSS:C were 1 SD above the group mean of a larger sample of 78 subjects tested in our department ($N=48$ women and 30 male, $M=6.0$, SD $=2.96$); an equivalent but opposite deviation designated the low hypnotizable subjects ($N=12$, $M=2.8$, SD $=1.47$). The moderately hypnotizable group was formed with subjects who showed hypnotizability scores 1 SD within the group mean ($N=13$, $M=6.1$, SD $=0.9$). Three different female hypnotists and one male hypnotist carried out the assessment of hypnotic susceptibility about 1 month prior to the second session. During this session, hypnosis was induced by one of the four hypnotists who did not know the hypnotizability level of the subject. All subjects were unacquainted with their hypnotic ability and care was taken to ensure that they had no awareness of the relevance of hypnotic ability to their participation in the experiment. Women who were in a menstrual period were invited for EEG recordings in another occasion, because menstrual cycle has been known to affect EEG activity (e.g. Glass, 1968). Subjects were admitted to participate in the experiment only if they reported an absence of medication use (e.g. psychoactive drugs, antihistamines, and anti-inflammatory medications) or medical conditions that might interfere with pain sensitivity (e.g. high blood pressure, diabetes mellitus, heart diseases, asthma, Raynaud's syndrome, frostbite, arthritis, post trauma to hands).

2.2. Procedure

The subjects were seen individually in the lab and upon arrival they were informed about the nature of the painful electric stimulation. Written consent was obtained if they agreed to continue with the study that was conducted according to the ethical norms of the Italian Association of Psychology (AIP). On this occasion, hypnosis was induced for the second time using the Stanford Hypnotic Clinical Scale (SHSC; Morgan and Hilgard, 1978–1979). The subjects were all naïve volunteers and not informed about their hypnotizability level during the EEG recording session.

2.2.1. Pain treatment conditions

The subjects were engaged in five pain treatment conditions: (1) Awake-Pain; (2) Focused Analgesia in waking state; (3) Hypnosis-Pain; (4) Focused Analgesia in hypnosis; and (5) Post-hypnosis suggestion of analgesia. At the end of hypnosis condition, the subject received a suggestion that during waking state after hypnosis, he/she will enter again in hypnosis with opened eyes after that the experimenter will have knocked two times on the wall. Both waking and the hypnosis conditions were counterbalanced across subjects in order to avoid possible sequence effects or habituation. However, within waking and hypnosis conditions, task order was not varied and painful condition was always administered first. Between waking and hypnosis conditions a resting period of 15 min was given. In each treatment condition (lasting about 5 min), painful stimuli were applied to the subjects and, at the end of each condition, they were asked to rate any pain and distress experienced for standard stimuli on two separate 10 point numeric rating scales (NRS; Jensen et al., 1986). On the left and right sides of the NRS-sensory scale, there were,