



EEG activity in Carmelite nuns during a mystical experience

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ABSTRACT

Mystical experiences relate to a fundamental dimension of human existence. These experiences, which are characterized by a sense of union with God, are commonly reported across all cultures. To date, no electroencephalography (EEG) study has been conducted to identify the neuroelectrical correlates of such experiences. The main objective of this study was to measure EEG spectral power and coherence in 14 Carmelite nuns during a mystical experience. EEG activity was recorded from 19 scalp locations during a resting state, a control condition and a mystical condition. In the mystical condition compared to control condition, electrode sites showed greater theta power at F3, C3, P3, Fz, Cz and Pz, and greater gamma1 power was detected at T4 and P4. Higher delta/beta ratio, theta/alpha ratio and theta/beta ratio were found for several electrode sites. In addition, FP1–C3 pair of electrodes displayed greater coherence for theta band while F4–P4, F4–T6, F8–T6 and C4–P4 pairs of electrodes showed greater coherence for alpha band. These results indicate that mystical experiences are mediated by marked changes in EEG power and coherence. These changes implicate several cortical areas of the brain in both hemispheres.

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There is a growing interest in the neural underpinnings of religious/spiritual/mystical experiences (RSMs) [5]. These experiences are commonly reported across all cultures [10,11] and refer to a basic dimension in human existence. For the experiencers, RSMs often lead to major changes such as a sense of purpose, new meaning to life and a more compassionate attitude toward others [5].

RSMs can occasionally be induced by stimulation of the temporal lobe [14]. Based on this finding, it has been proposed that RSMs are evoked by transient, electrical microseizures within deep structures of the temporal lobe [21]. There is some clinical evidence indicating that RSMs sometimes take place during ictal, peri-ictal, and post-ictal seizures related to temporal lobe epilepsy (TLE) [7,17,24]. Particularly, ictal RSMs have been associated with interictal intensification of spiritual feelings [20,29] and religious conversion [8]. Furthermore, in a prior study [22], two patients with TLE together with a group of highly religious volunteers and a non-religious group were shown a list of words, which included sexual, violent, religious and “neutral” terms. Galvanic skin response was utilized to measure the emotional arousal induced by the various

word categories. The non-religious group displayed galvanic skin responses when sexual words were presented. The two TLE patients responded more robustly to the religious words than to the violent and sexual words.

To date, no electroencephalography (EEG) study has been conducted to identify the neuroelectrical correlates of a mystical experience (as understood in a Christian sense—it should be noted, however, that several EEG studies of very deep meditation and absorption states have been carried out during the last decades [1,2,4,14]). From a Christian perspective, the mystical experience is characterized by a sense of union with God. It can also include other aspects such as the sense of having touched the ultimate ground of reality, the experience of timelessness and spacelessness, the sense of union with humankind and the universe, as well as feelings of positive affect, peace, joy and unconditional love [26].

The main objective of this study was to measure EEG spectral power in Carmelite nuns during a mystical experience. This study constitutes a sequel to the functional magnetic resonance imaging (fMRI) study we recently carried out in the same group of nuns [6]. Given that changes in EEG coherence have previously been reported during blissful experiences associated with Sahaja Yoga meditation [1], another objective of this study was to investigate coherence during a mystical experience. EEG coherence is considered to be an index of functional connectivity between two cortical regions [19]. Functional connectivity refers to the integration of information flows across sets of brain regions dynamically interacting with

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one another [30,31]. EEG coherence is a sensitive measure that can reveal subtle aspects of brain network dynamics such as “functional coupling”, “cortico-cortical associations” [28], “information exchange” [23], “temporal co-ordination” [9], and “functional interaction” [3].

Fourteen Carmelite nuns (age range: 23–64; mean age: 49.93, S.D.: 11.70) took part in the study. The average duration of affiliation with the Carmelite order was 18.93 (S.D.: 11.85; range: 2–37). Subjects had no history of psychiatric or neurological disorder. They were not smokers and were not taking psychotropic medications at the time of scanning. Nine subjects were menopausal. All subjects gave written informed consent and the study was approved by the ethics committee of the CRIUGM.

EEG activity was measured inside a dark, soundproof room (isolated acoustically and electromagnetically) during a Mystical condition, a Control condition, and a Baseline condition. An infrared camera enabled the experimenters to observe the subjects continually. In the Mystical condition, subjects were asked to remember and relive (eyes closed) the most intense mystical experience ever felt in their lives as a member of the Carmelite Order. This strategy was adopted given that the nuns told us before the onset of the study that “God can’t be summoned at will”. In the Control condition, subjects were instructed to remember and relive (eyes closed) the most intense state of union with another human ever felt in their lives while being affiliated with the Carmelite Order. The week preceding the experiment, subjects were requested to practice these two tasks. Both Mystical and Control conditions lasted for 15 min. The Baseline condition was a normal restful state (eyes closed, duration: 5 min). The experiment always began with the Baseline condition. The order of the Control and Mystical conditions was counterbalanced across subjects. The intensity of the subjective experience during the Control and Mystical conditions was measured using numerical rating scales ranging from 0 (no experience of union) to 5 (most intense experience of union ever felt). The scales were administered immediately at the end of these two conditions. Self-report data referred uniquely to the experiences lived during these two conditions, not to the original experiences recalled to self-induce the Control and Mystical states. The phenomenology of the mystical experience during the Mystical condition was assessed with 15 items of the Mysticism Scale [12]. This scale, which comprises 32 items, aims at measuring reported mystical experience. Summed scores of 15 or above were considered significant for a given item. In addition, qualitative interviews were conducted after the experiment to obtain additional information regarding the nature of the subjective experiences during the Control and Mystical conditions.

EEG was recorded (Deymed Diagnostic, TruScan 32) from 19 scalp locations (Electro-cap International Inc.) – (FP1/FP2, F7/F8,

F3/F4, FZ, T3/T4, C3/C4, CZ, P3/P4, T5/T6, PZ, O1/O2) – based on the International 10/20 System of electrode placement [13]. A linked-ears reference montage was used. EEG data were acquired and amplified within a bandpass of 0.1–75 Hz (128 samples/s) with a 60-Hz Notch filter. EEG recordings were imported into the software Neuroguide (version 2.4), which calibrated EEG signals coming from the current amplifier. Each participant’s EEG samples were plotted, visually examined and then edited to remove artifacts. Non-overlapping, artifact-free 120 s EEG samples were extracted for all participants (starting from the 11th minute for both Mystical and Control conditions). Split-half reliability (correlation between the first 60 s and the last 60 s) was examined on the edited EEG segments and only records with >95% average reliability were considered in power spectral analysis (PSA). This analysis was performed for the 120 s EEG samples with a fast Fourier transform (FFT). Overall, absolute power (mV^2) was computed in nine frequency bands (delta: 1–4 Hz, theta: 4–8 Hz, alpha1: 8–10 Hz, alpha2: 10–12 Hz, beta1: 12–15 Hz, beta2: 15–18 Hz, beta3: 18–30 Hz, gamma1: 30–35 Hz, gamma2: 35–40 Hz). Power ratios were calculated for the following frequency bands: delta: 1–4 Hz, theta: 4–8 Hz, alpha: 8–12 Hz, beta: 12–30 Hz, gamma: 30–40 Hz. Frequency-domain EEG coherence was computed for all 171 intra-hemispheric and inter-hemispheric pairwise combinations of the 19 channels for each of the 5 frequency bands used to calculate power ratios. EEG activity associated with the three conditions was compared with paired *t*-tests. Due to space constraints, only the results of the contrasts between the Mystical and Control conditions will be presented and discussed.

The average intensity of the subjective experience was 3.10 ± 0.94 (range: 2–5) during the Mystical condition and 3.10 ± 1.00 (range: 2–5) during the Control condition. As for the phenomenology of the subjective experience during the Mystical condition, summed scores of 15 or above were noted for 6 items of the Mysticism Scale [12]: (1) *I have had an experience in which something greater than my self seemed to absorb me*; (2) *I have experienced profound joy*; (3) *I have had an experience which I knew to be sacred*; (4) *I have had an experience which cannot be expressed with words*; (5) *I have had an experience in which I felt that everything in this world is part of the same whole*; (6) *I have had an experience which is impossible to communicate*. During the qualitative interviews conducted at the end of the experiment, several subjects mentioned that during the Mystical condition they felt the presence of God, His unconditional and infinite love, as well as plenitude and peace. They also felt a surrendering to God. All subjects reported that from a first-person perspective, the experiences lived during the Mystical condition were different than the vivid memories of a mystical experience used to access a mystical state. Subjects also reported

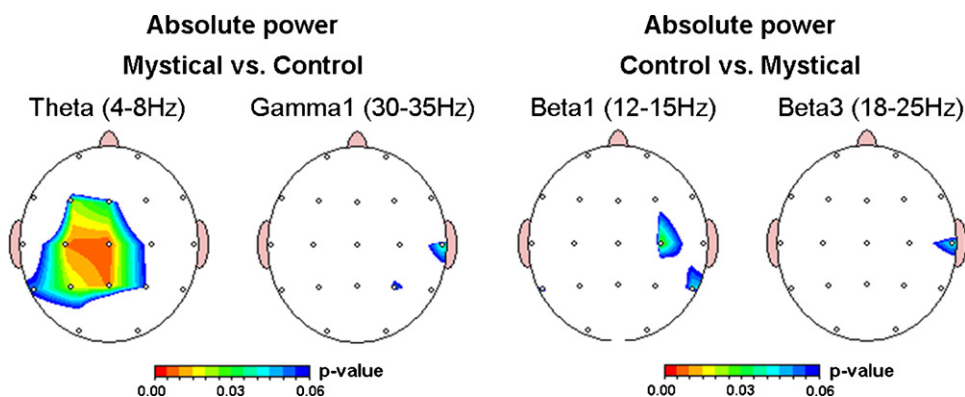


Fig. 1. EEG absolute power for the Mystical vs. Control contrast and the Control vs. Mystical contrast.

the presence of religiously charged visual mental imagery during the Mystical condition.

Electrode sites showed greater theta power at F3 ($P < 0.05$), C3 ($P < 0.01$), P3 ($P < 0.05$), Fz ($P < 0.05$), Cz ($P < 0.01$) and Pz ($P < 0.01$). Greater gamma1 power was detected at T4 ($P < 0.05$) and P4 ($P < 0.05$) (Fig. 1).

Higher beta1 power was measured at C4 ($P < 0.05$) and T6 ($P < 0.05$), and higher beta3 power was recorded at T4 ($P < 0.05$).

A greater delta/beta ratio was noted at F3 ($P < 0.05$), C3 ($P < 0.05$), C4 ($P < 0.01$), T4 ($P < 0.01$), P4 ($P < 0.05$), T6 ($P < 0.05$), Fz ($P < 0.05$), Cz ($P < 0.05$), and Pz ($P < 0.05$). A greater theta/alpha ratio was measured at T5 ($P < 0.05$), P3 ($P < 0.05$), C4 ($P < 0.05$), P4 ($P < 0.05$) and Pz ($P < 0.05$). Last, a greater theta/beta ratio was found at F7 ($P < 0.05$), F3 ($P < 0.01$), C3 ($P < 0.01$), P3 ($P < 0.05$), F4 ($P < 0.05$), C4 ($P < 0.01$), T4 ($P < 0.05$), P4 ($P < 0.01$), T6 ($P < 0.05$), Fz ($P < 0.01$), Cz ($P < 0.001$) and Pz ($P < 0.01$).

FP1–C3 ($P < 0.01$) pair of electrodes displayed greater coherence for theta band while F4–P4 ($P < 0.05$), F4–T6 ($P < 0.05$), F8–T6 ($P < 0.05$) and C4–P4 ($P < 0.05$) pairs of electrodes showed greater coherence for alpha band (Fig. 2).

T5–O1 ($P < 0.01$) pair of electrodes displayed greater coherence for alpha band while FP1–FP2 ($P < 0.05$) pair of electrodes showed greater coherence for beta band.

The collected phenomenological data indicate that the subjects actually experienced genuine mystical experiences (not only vivid memories of a mystical state) during the Mystical condition (according to Stace's definition of a mystical experience and the Mysticism Scale [26,12]). Experientially, the experiences reported during this condition were multidimensional, i.e., they implicated changes in perception (e.g., visual mental imagery), cognition (e.g., representations about the self), and emotion (e.g., peace, joy, and unconditional love). These experiential changes were associated with modifications of EEG spectral power in various regions of the brain. Particularly, theta power increased over left and central frontal and parietal regions, and a greater theta/beta ratio was found over frontal, central, temporal and parietal regions. In addition, gamma1 power increased in the right temporal and parietal regions.

It has been previously shown that emotionally positive “blissful” experience during Sahaja Yoga meditation is accompanied by increased anterior frontal and midline theta activity [1]. It is thus plausible that enhanced theta power over frontal regions was related with the feelings of peace, joy, and unconditional love. Increased theta power has also been reported in frontal areas during a Zen meditation practice called “Su-soku”, which only requires sustained attention and breath control [27]. Therefore, it is also possible that increased theta power in frontal regions during the

Mystical condition reflected focused attention for the contents of the mental experience. As for the increased theta power over parietal cortex, we propose that it was associated with religiously charged visual mental images, based on the evidence suggesting an implication of parietal theta activity in visual mental imagery [32].

It has been proposed that the gamma frequency band plays a central role in brain mechanisms underlying conscious experience [16] and states of consciousness [15]. Previous work [4] has revealed that this brainwave band represents an important feature of EEG activity during meditation. With respect to this issue, given that gamma activity in the right middle temporal gyrus has been shown during a self-reconstitution meditation [15] and that clinical data suggest an involvement of the temporal lobe in RSMEs [7,8,14,17,20–22,24,29], it is conceivable that the increased gamma activity over the right temporal region during the Mystical condition was related with the subjective impression of union with God. Since the right parietal lobe is involved in the spatial perception of self [18], the increased gamma activity over the right parietal region during the Mystical condition might reflect a modification of the body schema associated with the impression reported by the participants of being absorbed by something greater than self.

Coherence measures the phase consistency between pairs of EEG signals in specific frequency bands [19]. This index of functional brain connectivity reflects long range or global synchrony between spatial-distributed cortical areas (10–25 cm) [19]. EEG coherence is deemed to be essential for network formation and integration. High levels of coherence are thought to reflect functional co-ordination and information exchange [23] along local and/or distant cortico-cortical projections. Here, increased coherence during the Mystical condition was noted for the theta band at FP1–C3. In addition, long-distant alpha connectivity was seen between F4–P4, F4–T6, F8–T6 and C4–P4. Interestingly, theta connectivity between frontal and posterior association cortices in the left hemisphere has been proposed to be related to positive emotional experience [1]. The finding of increased theta connectivity between left frontal and central areas during the mystical experience seems to support this view. Regarding enhanced long-distant alpha connectivity in the right hemisphere, it is noteworthy that the notion of alpha synchronization reflecting cortical inactivity (“cortical idling”) does not appear tenable any longer [2]. In contradistinction to this notion, alpha synchronization has been demonstrated to indicate the active inhibition of sensory information during internally directed attentional tasks [25]. The increased long-distant alpha connectivity in the right hemisphere between right frontal and temporal as well as parietal regions, and between right central and parietal regions

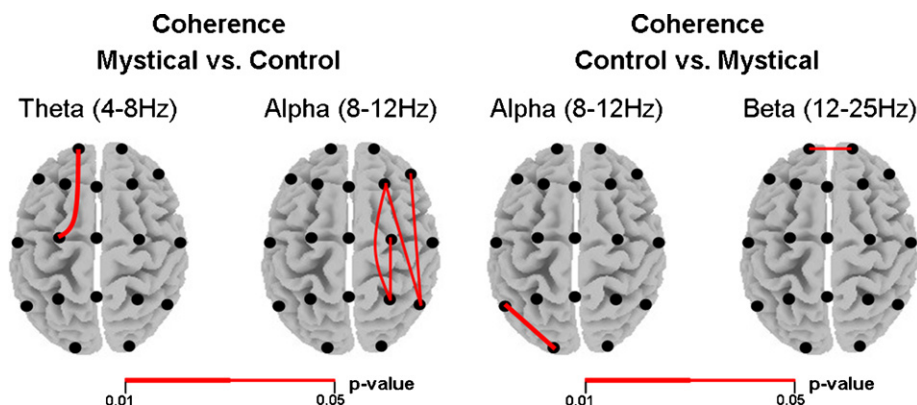


Fig. 2. Topography of EEG coherence for the Mystical vs. Control contrast and the Control vs. Mystical contrast.

might be related with a reduction of sensory processing during the Mystical condition.

The main methodological limitation of this study is the fact that the subjects were asked to remember and relive a mystical experience rather than actually try to achieve one. Such a strategy was used because the subjects told us a priori that they were not able of reaching a mystical state at will. We contend that this limitation does not represent a major problem since the phenomenological data reveal that the subjects actually experienced genuine mystical experiences during the Mystical condition. Importantly, these mystical experiences felt subjectively different than the memories used to access a mystical state.

In summary, we have demonstrated that the subjective changes occurring during the mystical experience were associated with theta power increases over left and central frontal and parietal regions, and gamma1 power increases in the right temporal and parietal regions. Increased theta connectivity between left frontal and central areas, and enhanced long-distant alpha connectivity in the right hemisphere between right frontal and temporal as well as parietal regions, and between right central and parietal regions were also found during the mystical experience. These results indicate that mystical experiences are mediated by marked changes in EEG power and coherence. These changes implicate several cortical areas of the brain in both hemispheres.

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