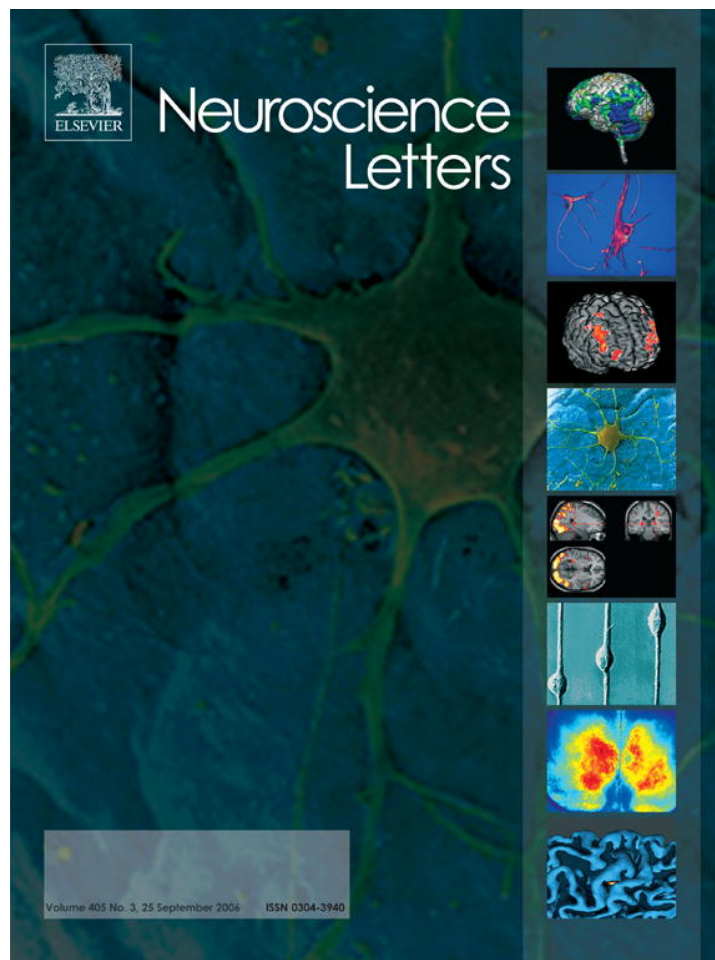


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## Neural correlates of a mystical experience in Carmelite nuns

Mario Beauregard<sup>a,b,c,d,e,\*</sup>, Vincent Paquette<sup>a,c,e</sup>

<sup>a</sup> *Département de Psychologie, Université de Montréal, Montréal, Que., Canada*

<sup>b</sup> *Département de Radiologie, Université de Montréal, Montréal, Que., Canada*

<sup>c</sup> *Centre de Recherche en Neuropsychologie et Cognition (CERNEC), Université de Montréal, Montréal, Que., Canada*

<sup>d</sup> *Centre de Recherche en Sciences Neurologiques (CRSN), Université de Montréal, Montréal, Que., Canada*

<sup>e</sup> *Centre de Recherche, Institut universitaire de gériatrie de Montréal (CRIUGM), Montréal, Que., Canada*

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### Abstract

The main goal of this functional magnetic resonance imaging (fMRI) study was to identify the neural correlates of a mystical experience. The brain activity of Carmelite nuns was measured while they were subjectively in a state of union with God. This state was associated with significant loci of activation in the right medial orbitofrontal cortex, right middle temporal cortex, right inferior and superior parietal lobules, right caudate, left medial prefrontal cortex, left anterior cingulate cortex, left inferior parietal lobule, left insula, left caudate, and left brainstem. Other loci of activation were seen in the extra-striate visual cortex. These results suggest that mystical experiences are mediated by several brain regions and systems.

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**Keywords:** Carmelite nuns; Mystical state; Functional magnetic resonance imaging; Temporal lobes; Prefrontal cortex; Parietal cortex; Spiritual neuroscience

The turn of the new millennium has seen the emergence of “Spiritual neuroscience”, a field of scientific investigation at the crossroads of psychology, religion and spirituality, and neuroscience. The main objective of this novel domain of research is to explore the neural underpinnings of religious/spiritual/mystical experiences (RSMEs). These experiences relate to a fundamental dimension of human existence and are frequently reported across all cultures [18,19]. One of the basic assumptions of spiritual neuroscience is that RSMEs are brain-mediated, as are all other aspects of human experience. With respect to this issue, it is of paramount importance to fully appreciate that elucidating the neural substrates of these experiences does not diminish or depreciate their meaning and value, and that the external reality of “God” can neither be confirmed nor disconfirmed by delineating the neural correlates of RSMEs [40].

It has been hypothesized that RSMEs are evoked by transient, electrical microseizures within the temporal lobes [36]. Anecdotal evidence indicates that RSMEs sometimes occur in conjunction with ictal, peri-ictal, and post-ictal seizure expe-

riences linked to temporal lobe epilepsy (TLE) [14,30,40]. In particular, ictal RSMEs have been associated with interictal intensification of spiritual and mystical feelings [34,43] as well as religious conversion [15]. Moreover, in a previous study [37], two patients with TLE along 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 used to measure the emotional arousal induced by the various categories of words. The non-religious group showed galvanic skin responses when presented with sexual words. The two patients with TLE responded more strongly to the religious words than to the sexual and violent words.

The parietal cortex may also be involved in RSMEs. A recent single photon emission computed tomography (SPECT) study has measured regional cerebral blood flow (rCBF) in Franciscan nuns at prayer involving the internal repetition of a particular phrase [33]. Compared to rest, the prayer state showed increased rCBF in the prefrontal cortex (PFC), the inferior frontal lobes, and the inferior parietal lobule (IPL). In addition, the rCBF change in the left PFC showed an inverse correlation with that in the ipsilateral superior parietal lobule (SPL). Changes in SPL activity were interpreted as reflecting an altered sense of the body schema experienced during the prayer state [32,33].

\* Corresponding author. Tel.: +1 514 343 7651; fax: +1 514 340 3548.  
E-mail address: [mario.beauregard@umontreal.ca](mailto:mario.beauregard@umontreal.ca) (M. Beauregard).

The main goal of this functional magnetic resonance imaging (fMRI) study was to identify the neural correlates of a mystical experience (as understood in the Christian sense) in a group of contemplative Carmelite nuns. Mystical experience is characterized by a sense of union with God. It can also include a number of other elements, 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 [41].

Fifteen Carmelite nuns (age range: 23–64; mean age: 49.93, S.D.: 11.27) took part in the study. The average duration of affiliation with the Carmelite order was 19.27 (S.D.: 11.49; 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.

Blood oxygen level dependent (BOLD) signal changes were measured during a Mystical condition, a Control condition, and a Baseline condition. 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. The Baseline condition was a normal restful state (eyes closed). Resting state has been previously used to identify the neural correlates of different meditative states [20,28,29]. The blocked-design paradigm used was as follows: Resting block (30 s), Control block (duration: 5 min), Resting block (duration: 1 min), Control block (duration: 5 min), Resting block (duration: 1 min), Mystical block (duration: 5 min), Resting block (duration: 1 min), Mystical block (duration: 5 min). Several factors motivated the choice of such a design: (1) Mystical and Control blocks had to be long enough to allow the subjects to experience the target states. About this issue, a previous fMRI study of meditation [27] has demonstrated that it is possible to measure, during relatively long periods of time (e.g., 6 min blocks), BOLD signal changes that can be differentiated from low-frequency noise. Recent work carried out by our group [22] indicates that fMRI findings obtained with a long block design (3 min blocks) are replicable using a short block design (33 s blocks); (2) Psychologically, it was not possible for the subjects to alternate between Mystical and Control blocks. Given this, we decided to present the Control blocks first in order to avoid contamination of these blocks by the Mystical blocks; (3) the duration of Resting blocks was shorter than that of Mystical and Control blocks to reduce the length of the scan and thus avoid fatigue for the subjects. Immediately at the end of the scan, 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): self-report data referred solely 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 [21]. 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.

Echoplanar images (EPI) was acquired on a 3 T system (Magnetom Trio, Siemens Electric, Erlangen, Germany). Twenty-eight slices (5 mm thick, voxel size = 3.4 mm × 3.5 mm × 5 mm) were acquired every 2 s in an inclined axial plane. These T2\* weighted functional images were acquired using an EPI pulse sequence (echo-space time = 0.8 ms, TE = 30 ms, Flip = 90°, FOV = 215 mm, Matrix = 64 × 64). Following functional scanning, high-resolution anatomical data were acquired using a gradient echo pulse sequence. Earpad foam cushions surrounding the head of the subjects and earplugs were used to significantly reduce perception of the noise generated by the MRI scanner.

Data were analyzed using Statistical Parametric Mapping software (SPM2). The images for all subjects were spatially normalized into an MRI stereotactic space [42]. Using a “random-effects model”, paired Student’s *t*-tests were performed to compare the brain activity associated with the various conditions. A total of 100 volumes were acquired for the Baseline condition. Given this, the last 50 volumes of the two blocks belonging to either the Mystical condition or the Control condition (150 volumes were acquired for each type of block) were concatenated to perform these comparisons with an equal number of volumes (100) for each condition (Mystical, Control, Baseline). The volumes belonging to the last portion of the Mystical and Control blocks were selected. Given the highly exploratory nature of this study, a whole-brain post hoc analysis was performed. Height threshold was set at  $P < 0.001$ , uncorrected for multiple comparisons. Only clusters showing a spatial extent of at least 10 contiguous voxels were kept for image analysis.

The average intensity of the subjective experience was  $3.06 \pm 0.93$  (range: 2–5) during the Mystical condition and  $3.04 \pm 0.80$  (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 three items of the Mysticism Scale [21]: (1) *I have had an experience in which something greater than my self seemed to absorb me* (average score: 15); (2) *I have experienced profound joy* (average score: 22); (3) *I have had an experience which I knew to be sacred* (average score: 20). 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. All subjects reported that from a first-person perspective, the experiences lived during the Mystical condition were different than those used to self-induce a mystical state. Subjects also reported the presence of visual and motor imagery

Table 1  
Mystical condition

Region	Brodmann area	Talairach coordinates (mm)			Z-statistic
		x	y	z	
<b>Mystical vs. Baseline</b>					
R MOFC	11	2	46	-14	6.60
R MTC	21	49	-12	-14	6.24
L IPL	7	-32	-79	38	6.06
R IPL	40	36	-76	30	5.46
R SPL	7	26	-67	46	5.38
L caudate		-6	8	3	5.17
R MOC	18	26	-96	0	5.15
L MOC	19	-35	-91	8	4.67
L MPFC	10	-11	52	13	4.50
R caudate		7	5	8	4.25
R LG	18	2	-88	3	4.17
L brainstem		-3	-38	-42	3.90
L insula	13	-35	20	3	3.88
L ACC	32	-1	40	7	3.69
<b>Mystical vs. Control</b>					
R MOFC	11	4	43	-14	4.91
L IPL	40	-51	-56	36	4.33
R MTC	21	47	-15	-14	3.79
L SPL	7	-35	-56	55	3.58
R MPFC	10	4	46	10	3.41
R ACC	32	2	43	5	3.34

L: left; R: right.

during both the Mystical and Control conditions. In addition, the subjects experienced a feeling of unconditional love during the Control condition.

**Mystical versus Baseline:** Significant loci of activation were noted in the right medial orbitofrontal cortex (MOFC) (Brodmann area [BA] 11), right middle temporal cortex (MTC) (BA 21), right IPL (BA 40) and SPL (BA 7), right caudate, left medial prefrontal cortex (MPFC) (BA 10), left dorsal anterior cingulate cortex (ACC) (BA 32), left IPL (BA 7), left insula (BA 13), left caudate, and left brainstem. A few loci of activation were also seen in the extra-striate visual cortex (Table 1, Fig. 1).

**Mystical versus Control:** Significant loci of activation were detected in the right MOFC (BA 11), right MPFC (BA 10), right

Table 2  
Control condition

Region	Brodmann area	Talairach coordinates (mm)			Z-statistic
		x	y	z	
<b>Control vs. Baseline</b>					
R SPL	7	12	-64	39	3.93
L caudate		-6	17	6	3.79
L SPL	7	-22	-64	41	3.75
R IOC	18	28	-96	-3	3.74
L ACC	32	-11	20	40	3.53
L brainstem		-3	-32	-42	3.52
<b>Control vs. Mystical</b>					
L putamen		-19	8	5	3.61

IOC: inferior occipital cortex.

dorsal ACC (BA 32), right MTC (BA 20), left IPL (BA 40), and left SPL (BA 7) (Table 1).

**Control versus Baseline:** Significant loci of activation were measured in the right SPL (BA 7), right inferior occipital cortex (IOC) (BA 18), left dorsal ACC (BA 32), left SPL (BA 7), left caudate, and left brainstem (Table 2).

**Control versus Mystical:** A significant locus of activation was noted in the left putamen (Table 2).

The present results suggest that several brain regions and systems mediate the various aspects of mystical experiences. This conclusion should not come as a surprise given that these experiences are complex and multidimensional, that is, they implicate changes in perception (e.g., visual mental imagery), cognition (e.g., representations about the self), and emotion (e.g., peace, joy, unconditional love) [41]. The results of the Mystical versus Baseline comparison and the Mystical versus Control comparison suggest that there was some specificity in terms of the brain regions activated in the Mystical condition relative to the Control condition. Interestingly, when the Control and Mystical conditions were contrasted against Baseline, the recall and reexperiencing of two distinct types of socioemotional memories were associated with relatively different regional patterns of brain activation. This finding is very intriguing since one could

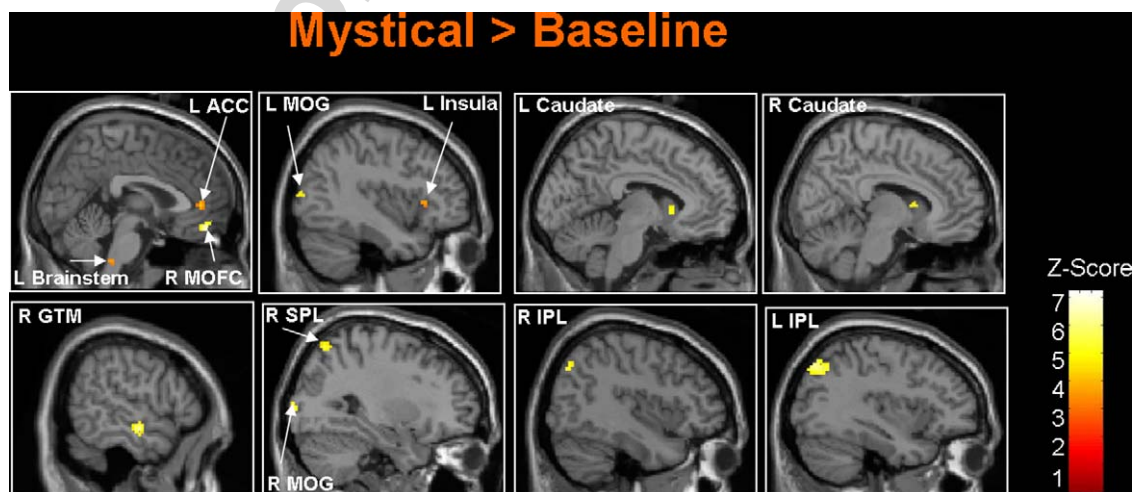


Fig. 1. Statistical activation maps during the Mystical condition. Images are sagittal sections for the data averaged across subjects. L: left; R: right.



have expected that the neural systems supporting the recall and reexperiencing of a state of union with a “divine” other would be largely the same as the neural systems supporting the recall and reexperiencing of a state of union with another human.

A number of studies suggest the existence of a relationship between RSMEs and TLE [15,30,40]. In particular, ictal experiences have been associated with religious conversion [14,15] and interictal intensification of spiritual and mystical feelings [34,43]. Based on these findings, we hypothesize that the right middle temporal activation noted here during the Mystical condition was related with the subjective impression of contacting a spiritual reality.

The caudate nucleus has been systematically activated in previous functional brain imaging studies implicating positive emotions such as happiness [11], romantic love [3], and maternal love [4]. It thus seems possible that the caudate activations found here during the Mystical condition were related with the feelings of joy and unconditional love. With regard to the brainstem, there is some empirical support to the view that certain brainstem nuclei map the organism’s internal state during emotion [10]. Given this it is conceivable that the activation in the left brainstem was linked to the somatovisceral changes associated with the feelings of joy and unconditional love. As for the insula, this cerebral structure is richly interconnected with regions involved in autonomic regulation [8]. It contains a topographical representation of inputs from visceral, olfactory, gustatory, visual, auditory and somatosensory areas and is proposed to integrate representations of external sensory experience and internal somatic state [1]. The insula has been seen activated in several studies of emotional processing and appears to support a representation of somatic and visceral responses accessible to consciousness [9,10]. It is plausible that the left insular activation (BA 13) noted here was related to the representation of the somatovisceral reactions associated with the feelings of joy and unconditional love. In addition, we propose that the left MPFC activation (BA 10) was linked with conscious awareness of those feelings. Indeed, the results of functional neuroimaging studies suggest that the MPFC is involved in the metacognitive representation of one’s own emotional state [25]. This prefrontal area receives sensory information from the body and the external environment via the OFC and is heavily interconnected with limbic structures such as the amygdala, ventral striatum, hypothalamus, midbrain periaqueductal gray region, and brainstem nuclei [2,6]. In other respects, brain imaging findings [24,26] support the view that the activation of the left dorsal ACC (BA 32) reflected that aspect of emotional awareness associated with the interoceptive detection of emotional signals during the Mystical condition. This cortical region projects strongly to the visceral regulation areas in the hypothalamus and midbrain periaqueductal gray [35]. Lastly, as for the MOFC, there is mounting evidence that this prefrontal cortical region codes for subjective pleasantness [23]. The MOFC has been found activated with respect to the pleasantness of the taste or smell of stimuli [12,38] or music [5]. It has reciprocal connections with the cingulate and insular cortices [6,7]. The right MOFC activation (BA 11) noted here was perhaps related to the fact that the experiences lived during

the mystical state were considered by the subjects emotionally pleasant.

Given that the right SPL is involved in the spatial perception of self [31], the activation of this parietal region (BA 7) during the Mystical condition might reflect a modification of the body schema associated with the impression that something greater than the subjects seemed to absorb them. Moreover, there is evidence that the left IPL is part of a neural system implicated in the processing of visuospatial representation of bodies [16]. Therefore, the left IPL activation in the Mystical condition was perhaps related to an alteration of the body schema. In keeping with this, there is some evidence indicating that the right IPL is crucial in the process of self/other distinction [39]. However, the IPL plays an important role in motor imagery [13]. It is thus possible that the activations in the right (BA 40) and left (BA 7) IPL were related to the motor imagery experienced during the Mystical condition. With regard to the loci of activation found in the extra-striate visual cortex during this condition, it has been previously shown [17] that the MOC and LG are implicated in visual mental imagery. It is likely that the voxels activated in these occipital regions were related to the visual mental imagery reported by the subjects during the Mystical condition.

The main limitation of this study was 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 capable of reaching a mystical state at will. In our view, this does not represent a major problem since the phenomenological data indicate that the subjects actually experienced genuine mystical experiences during the Mystical condition. These mystical experiences felt subjectively different than those used to self-induce a mystical state.

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