



Ecstatic epileptic seizures: A potential window on the neural basis for human self-awareness

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ABSTRACT

The anatomical correlate of epileptic seizures with ecstatic auras has not been established. We document precise descriptions of the ecstatic seizures experienced by five patients, all of whom reported intense feelings of well-being and a heightened self-awareness. We propose here that the descriptions by these patients, together with the neurophysiological and neuroradiological evidence, support a theoretical framework for understanding ecstatic states based on hyperactivation of the anterior insula, rather than the temporal lobe. Epileptologists who have access to patients who experience episodic feelings of ecstasy and heightened self-awareness have an opportunity to provide insights that might help clarify the neural basis of consciousness.

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1. Introduction

Ecstasy refers to a trance-like state of joy (and also a widely abused party drug). A period of ecstasy can be considered a state of heightened consciousness in which an individual has a transcendent capacity for exceptional mental clarity and an intensely positive emotional experience. Subjective perception of time, space, and the self may be strongly altered, and the experience can permanently change an individual's world view. The notion of epilepsy with "ecstatic auras" first emerged from the description by Fyodor Dostoevsky of his own seizures [1,2]. However, the existence of ecstatic seizures was initially denied by well-known epileptologists [3,4]. Documentation of ecstatic seizures is difficult, in part because such a "hallucination of emotion" [5] is so abnormal that patients often refrain from explaining it; the experience seems "beyond what can be described in words" [6]. There are thus few descriptions of ecstatic seizures in the clinical literature [6–16] and little documentation of patients' own feelings.

Nevertheless, when encouraged tactfully to provide more details, some patients try to explain what they feel. The present re-

port provides precise descriptions by five patients of the ecstatic seizures they experienced. None of these patients had a concomitant psychiatric disorder. Each patient described an intense feeling of bliss, enhanced well-being, and heightened self-awareness, very similar to the original description by Dostoevsky.

The neural basis of ecstatic seizures has not been established. Each of the five patients observed for this report had neuroradiological and/or electroencephalographic abnormalities in the anterior temporopolar region, similar to previous reports [11,12,15]. Notably, the anterior insular cortex (AIC), which is physically hidden behind the temporopolar region, has recently been suggested to engender a representation of the "sentient self" that underlies all emotional feelings and the evolved capacity of human beings to be aware of themselves, others, and the environment; in other words, the AIC could be the "neural correlate of consciousness" [17]. The close correspondence between the functional characteristics of the AIC and these patients' descriptions of their experiences, which contrast with the symptomatology commonly associated with mesial temporal epileptic seizures [18], suggests the possibility that ecstatic seizures may originate in dysfunction of the AIC. Initial support for this possibility is provided by one ictal single-photon-emission computed tomography (SPECT) image that revealed increased cerebral perfusion in the insula in one patient in the present study.

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2. Case reports

2.1. Case 1

A 53-year-old right-handed female teacher described focal epileptic seizures that began in 2001 as a sensation of warmth filling up her body from her feet to her head. Asked to provide a more precise description of an episode, she explained, "It was something that I have never felt before. It felt as though my body was filling up with a sensation which was quite surreal. The feeling was almost out of this world. This led to a feeling of complete serenity, total peace, no worries; it felt beautiful, everything was great." She added: "During the seizure it is as if I were very, very conscious, more aware, and the sensations, everything, seems bigger, overwhelming me." When asked if it was like an orgasm, she answered, "Maybe the closest sensation that I know would be an orgasm, but what I felt was not at all sexual. I have no religious feeling, but it was almost religious." These episodes influenced her life, "It is a big happening in your life to have these seizures. Thanks to these experiences, I do not fear death anymore. I see the world differently, every sensation is stronger; for instance I see more colours than before, and I have more detailed perceptions, particularly when listening to music." There were no postictal symptoms. Occasionally, these ecstatic seizures were followed by the involuntary repetition of multiplication tables in her head, followed by a secondary tonic-clonic generalized seizure. She also described another very rare type of simple partial seizure in which she could sense a strong smell of pipe tobacco.

Cerebral MRI showed a meningioma in the left temporopolar region with compression of the temporal tip and extensive edema on the same side, involving wide regions of the temporal lobe (mesially and laterally) and extending up to the lenticular nucleus, the external capsule, the posterior arm of the internal capsule, and the anterior insula (Fig. 1). An interictal electroencephalogram (EEG) showed left anterior temporal theta slow waves. After surgical treatment, the patient had two focal seizures during a drug withdrawal trial; however, since reintroduction of antiepileptic drug treatment (levetiracetam 1000 mg/day) she has experienced no seizures in the last 6 years.

2.2. Case 2

A 37-year-old right-handed male electronics assembler who has had focal epileptic seizures since the age of 20 described his auras "as a halo, something pleasant which fills my inner body, wrapping me, with a rapid crescendo. It is a well-being inside, a sensation of velvet, as if I were sheltered from anything negative. I feel light inside, but far from being empty. I feel really present. Something has taken possession of my body, to feel really good ... but I still control my thoughts!" "I feel rooted to the spot with a more developed consciousness. I feel a stronger consciousness of the body and the mind, but I do not forget what is around me". According to the notes the patient made about his feelings during the auras: "My inner body rises from an unalterable bliss. I escape into the time space of my body. It is a moment of fullness in the loophole of time, a return to myself. It is an unconditional, privileged moment of inhaled sensations. My body and my head may interact differently to what every human knows. It is a sensation that is not common, something to discover." He described a feeling of *déjà vu* that was associated with the ecstatic aura. The simple focal seizures, lasting 2–10 seconds, were usually followed by complex focal seizures with gestural automatisms. Postictal recovery of consciousness was rapid. The patient reported that soon after the very first seizures, an anxiety intermingled very rapidly with the bliss sensation, because of the anticipated fear of how he would appear to

other people during his complex focal seizures. However, as the bliss increased, it overcame the associated anxiety.

Cerebral MRI revealed a tumoral mass in the right temporal region centered on the anterior part of the parahippocampal gyrus (Fig. 2A–D), with edema affecting the temporal pole. An interictal EEG including sphenoidal electrodes showed a right temporal slow wave focus with focal spikes maximal in the anterior temporal region; the amplitude of the spikes recorded in the sphenoidal electrodes was lower. Ictal EEGs showed a diffuse flattening, sometimes preceded by right anterior temporal rhythmic 7- to 8-Hz elements and followed by diffuse slow waves and then right temporal delta slow waves. The tumor was resected in 1996 and diagnosed as a pleomorphic xanthoastrocytoma WHO grade II. The resection included the head and the anterior part of the body of the hippocampus. Seizures disappeared postsurgically for several years, under carbamazepine, and then reappeared in 2002 with a similar symptomatology, but at a lower frequency than before surgery. Postsurgical cerebral MRI performed in 2005 and 2008 (Fig. 2H) showed tumor residue in the anterior temporal and mesiotemporal areas, stable over the two examinations. An interictal EEG revealed right anterior temporal spikes. Interictal SPECT using technetium-99m ethyl cysteinate dimer (99mTc-ECD) showed decreased blood flow in the right temporal lobe predominant in its tip (namely the resected area), and ictal 99mTc-ECD SPECT showed increased blood flow that was maximal in the right insula (Fig. 2I).

2.3. Case 3

A 25-year-old right-handed male office worker who has had focal epileptic seizures since the age of 15 described his aura to different neurologists over many years as a feeling of "rising in the head, like bubbles in the head." When we asked for a detailed description of the feelings he had during the seizures, he said, "The sensation was a feeling of pleasure. I felt intensely well in my body. This feeling became stronger and stronger, until it became so strong that it was unbearable and led to a loss of consciousness" (secondary generalization). "It is a physical state, an overload. The feeling is intense, with a sensation of fullness." "The sensation is certainly more intense than could be achieved with any drug." The aura of bliss was usually followed by a sensation of a loss of balance linked to "a difficulty in gaze fixation, with a sensation of eye convergence," and oscillopsia, and then secondary generalization. His first seizure was the most pleasant because the following ones included a feeling of fear and anxiety as he knew they would end in a generalized tonic-clonic seizure.

Cerebral MRI was normal. An interictal EEG showed rare theta slow waves in the left anterior temporal area. Treatment with levetiracetam 2000 mg/day resulted in no further seizures during 1 year of observation.

2.4. Case 4

A 36-year-old right-handed female architect who has had focal epileptic seizures since the age of 18 described an aura consisting of an intensely pleasant feeling. "My head fills with feelings and emotions ... I feel more conscious of myself, more concentrated on myself ... I feel more present from a psychological point of view, with more sensations. It is something very intimate. It is as if I rose a little into the air. ... The pleasure goes crescendo until it reaches a peak. It affects both the cerebral thought, which is very intense and concentrated on itself, and the physique." She described a feeling of relaxation, which she tried to interpret: "Being very conscious of myself, I feel discharged from anything else, although I do not lose consciousness." She described a strong sense

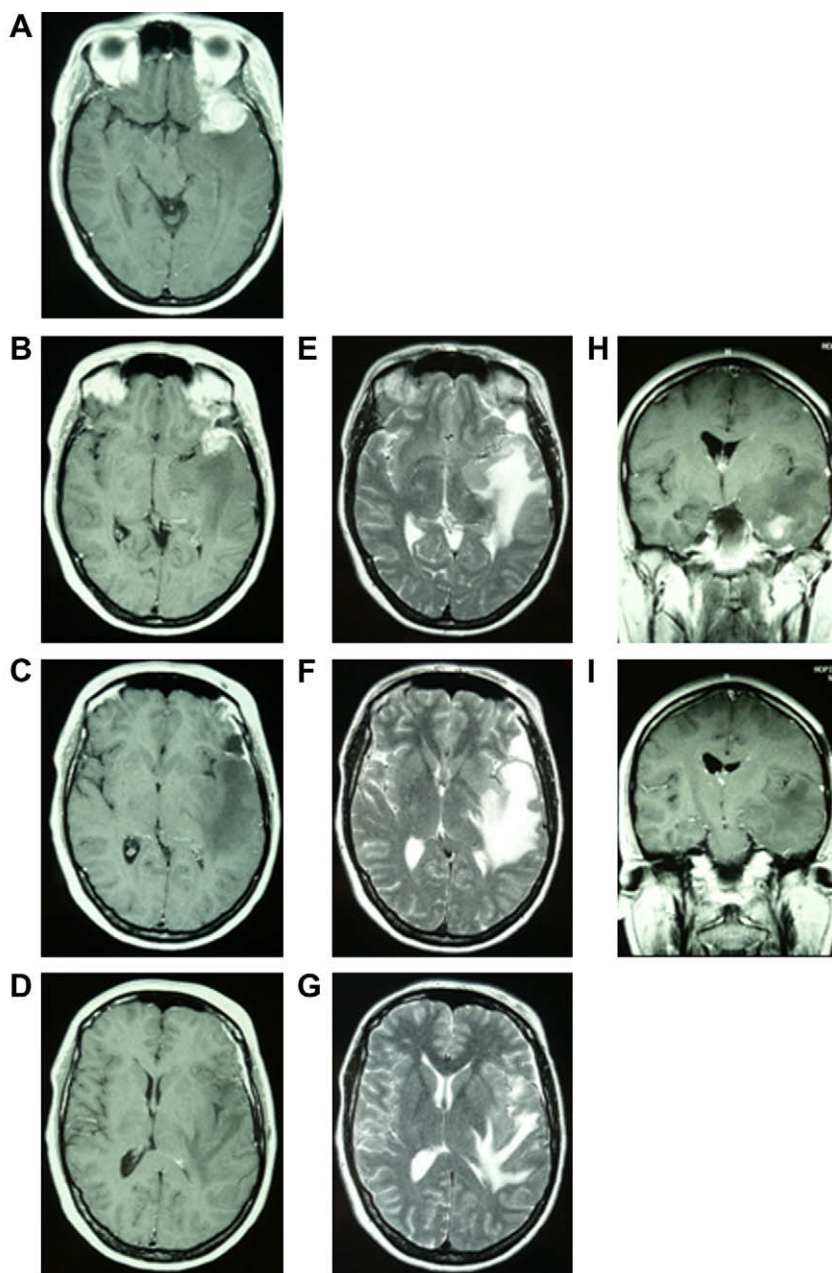


Fig. 1. Cerebral MR image of a 53-year-old woman (case 1) showing a left sphenoidal meningioma within the temporopolar region with extensive edema involving the whole temporal lobe and extending up to the anterior insula. (A–D) Postcontrast T1-weighted axial MR images. (E–G) T2-weighted axial MR images (corresponding respectively to sections B–D). (H–I) Postcontrast T1-weighted coronal MR images.

of concomitant warmth rising in her body up to her head, and a tachycardia.

Cerebral MRI was normal. An interictal EEG showed bursts of left anterior and midtemporal sharp theta slow waves. Treatment with levetiracetam 1000 mg/day resulted in no further seizures for 2 years.

2.5. Case 5

A 64-year-old right-handed woman who has had epileptic seizures with an ecstatic aura described her experiences as a “well-being of almost spiritual consonance” and then a decreased consciousness with jargonaphasia. “The immense joy that fills me is above physical sensations. It is a feeling of total presence, an absolute integration of myself, a feeling of unbelievable harmony of my

whole body and myself with life, with the world, with the ‘All’. I feel very, very, very present at that time; the consciousness of myself is very increased, rather on a psychic point of view. I am one hundred percent concentrated on myself.” “Entirely wrapped up in the bliss, I am in a radiant sphere without any notion of time or space. My relatives tell me that it lasts two to three minutes, but for me these moments are without beginning and without end.” “These experiences brought me confidence. They confirm that there is something that surpasses us.” A joy or a sense of relief can trigger seizures.

Cerebral MRI revealed a meningioma in the left temporal pole region. An interictal EEG showed left anterior temporofrontal epileptiform activity. After resection of the meningioma, seizures became less frequent but persisted despite the continuation of carbamazepine. Many years later, a new cerebral MR image

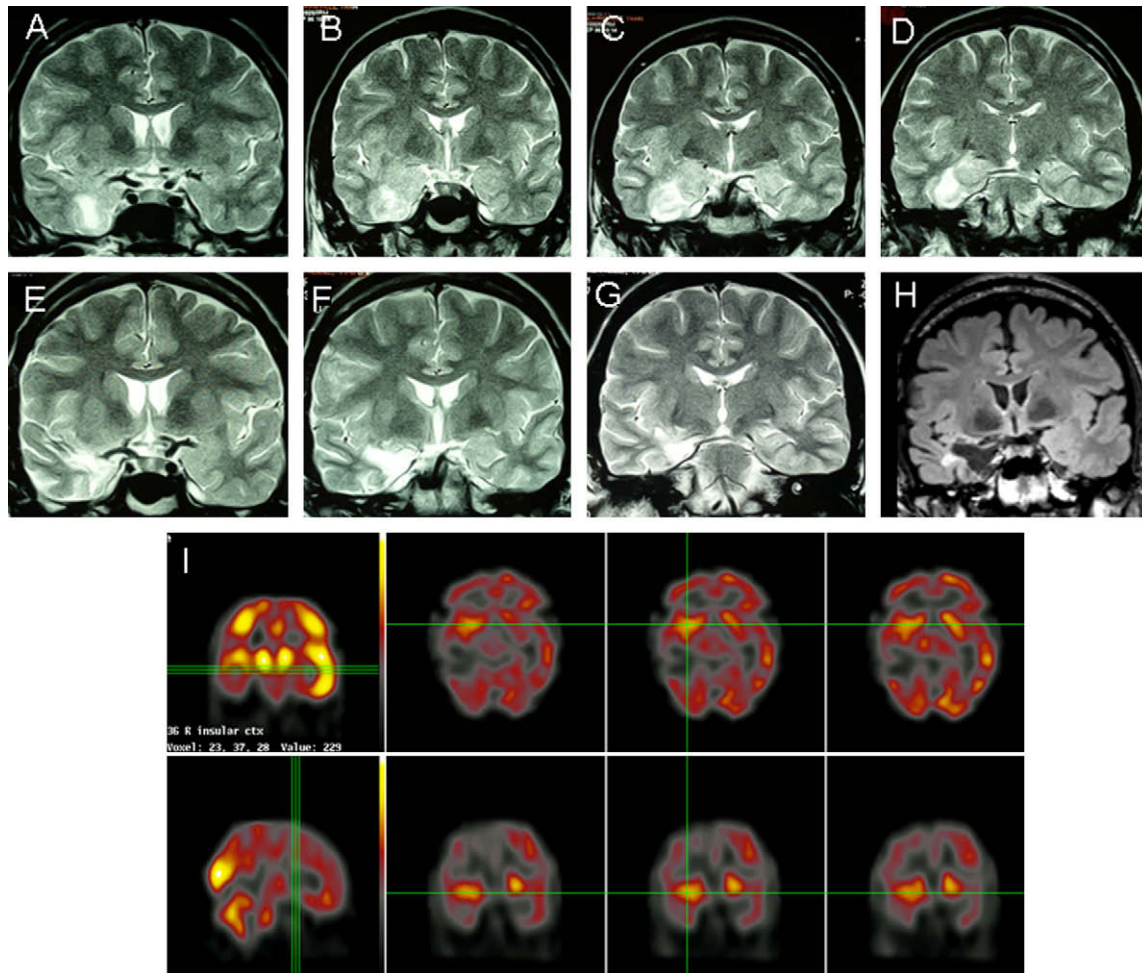


Fig. 2. Cerebral MR and ictal SPECT images of a 37-year-old man (case 2). (A–H) Cerebral MR images. (A–D) Presurgical T2-weighted coronal MR images (1996) showing a right temporal lobe tumor in the parahippocampal gyrus. The fringe of the tumor is close to the inferior part of the anterior insula. (E–G) T2-weighted coronal MR images (1997) after resection of the tumor, diagnosed as a xanthoastrocytoma. The gliosis reaches the anterior insula. (H) FLAIR coronal MR image, 12 years after the resection (2008). (I) Ictal SPECT image of the same patient using technetium-99m ethyl cysteinate dimer (^{99m}Tc -ECD), with axial (top) and coronal (bottom) images, showing increased blood flow maximal in the right anterior insula. Ictal SPECT was performed postsurgically (2005) during a seizure with an ecstatic aura. The analysis program BRASS (Brain Registration and Analysis Software Suite) was used for automatic fitting of brain perfusion scans and quantification and localization of abnormal perfusion regions.

obtained after an increase in seizure frequency showed a recurrence of the meningioma, with gliosis and/or edema reaching the temporal operculum, impinging on the anterior insula (Fig. 3). An interictal EEG showed rare delta slow waves and frequent brief sequences of 8-Hz theta rhythm in the left anterior temporal region.

3. Discussion

Reports of “ecstatic seizures” are rather rare. Ecstatic seizures were apparently first mentioned by Dostoevsky [1,2]. Some authors have referred to “epilepsy with ecstatic seizures” as “Dostoevsky’s epilepsy” [6,10,13], and several papers depicted Dostoevsky’s epilepsy [4,7,19–21]. However, in 1978 Gastaut rejected the existence of ecstatic auras, claiming that Dostoevsky’s creativity and literary genius led him to embellish a psychic state he felt at seizure onset, and that physicians could not find such descriptions by other patients [3]. Dostoevsky described his seizures to a friend and also to a great mathematician (Sofia Kovalevskaya) as a feeling of enhanced well-being, “a contentedness which is unthinkable under normal conditions and unimaginable for those who have not experienced it”; a feeling of being “in perfect harmony with himself and with the entire universe”; and a sensation of height-

ened awareness, “perception is so clear,” “the sense of life, the consciousness of self, are multiplied 10 times at these moments.” He also reported a subjective time dilation: “I cannot say if this bliss lasts seconds, hours or months.” In his novel *The Idiot*, his hero who had epilepsy presented an aura identical to the ones he experienced himself, described as a state of “hypersensitivity and heightened awareness, and, by consequence, a higher state of being” [1].

These characteristics are entirely consonant with the precise descriptions of ecstatic seizures experienced by the five outpatients with epilepsy described in this report, which converge to indicate a state of heightened self-awareness coupled with feelings of enhanced well-being and intense positive emotion. There have been precise descriptions by a few other patients with ecstatic seizures [6–14,16]. One patient pointed out that for him the sense of total bliss could qualitatively be compared only with sensations evoked by music [6]. Another stated that it is much better than sex [10]. Several of the 11 patients with ecstatic seizures reported by Asheim et al. [13] described the feelings they experienced as erotic sensations or sensory hallucinations, whereas others reported a “religious” experience (or a “sensed presence” [22]). The fact that the sense of time disappears during ecstatic seizures was underlined by one of the two patients described by Subirana

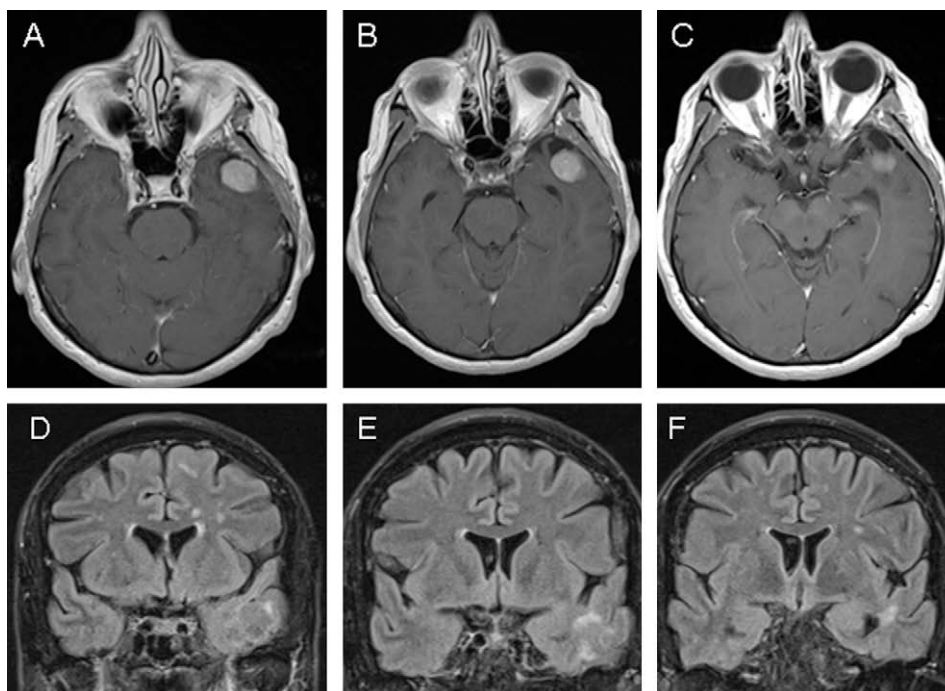


Fig. 3. Cerebral MR image of a 64-year-old woman (case 5) showing the recurrence of a meningioma in the left temporal pole. (A–C) Postcontrast T1-weighted axial MR images. (D–F) FLAIR coronal MR images showing that the edema and/or gliosis reach the temporal operculum, impinging on the anterior insula.

[15]. Nevertheless, without precise patient descriptions and a more detailed understanding of the neural underpinnings, it remains unclear whether patients who report pleasant feelings as a result of some other experience, such as a sensed presence, hearing a non-existent melody, or experiencing an orgasm, are experiencing ecstatic seizures similar to those of Dostoevsky.

The link between ecstatic seizures and heightened self-consciousness, which was clearly reported by these patients (and by Dostoevsky), has not been mentioned before in the scientific literature. Modern neurobiological evidence suggests that the concomitant feelings of heightened self-awareness, enhanced well-being, and intense positive affect described by patients with ecstatic seizures can be explained by activation of the AIC, rather than the temporal lobe. It has recently been proposed that the AIC has a fundamental role in self-awareness [17]. In this view, primary interoceptive representations in the human posterior insula that provide a sense of the physiological condition of the entire body are re-represented in a polymodal integrative zone in the midinsula and again in the AIC, which contains an ultimate representation of all of one's feelings, providing an image of the physical self as a feeling (sentient) entity. The integration in the insula of afferent activity that produces the feelings from the body is considered to provide the basis for a sense of subjective, physical well-being [23]. In a functional MRI (fMRI) study of an interoceptive task where subjects judged the timing of their heartbeats, Critchley et al. showed that the right anterior insula mediates explicit awareness of internal bodily processes and provided evidence that the insula constitutes a neuroanatomical substrate for subjective feeling states that may underlie a conscious representation of self [24]. Various functional imaging studies have demonstrated that the AIC is uniquely activated during all bodily feelings and all emotional feelings, and in direct correlation with subjective awareness of one's body and its movements [24–26], with recognition of one's own image [27], with one's subjective visual and auditory perceptions [26,28,29], and even with one's inner mental processes [30]. Similarly, the patients' descriptions of ecstatic seizures encompass a physical dimension of enhanced well-being and an emotional

dimension of bliss, along with a heightened awareness of all feelings and of the self. In his “somatic marker” hypothesis, Damasio expanded on the classic James–Lange theory of emotion by suggesting that the regions forming the basis of “the mental self” are those that map the condition of the body, that is, the organism's own structure and internal state, in relation to all stimuli [31]. As the “body-sensing” brain does not change in terms of the kind of object it represents, it could be the source of the sense of continuous being that anchors the mental self. This concept fits with the evidence that a posterior-to-mid-to-anterior sequence of re-representations of the physiological condition of the body in the insula provides the basis for the image of the sentient self in the AIC that is involved in all feelings [17]. Thus, the coupling of bodily feelings and intense emotional feelings with enhanced self-awareness in the ecstatic seizures of these five patients is consistent with the functional characteristics of the AIC.

This hypothesis is also supported by the remarkable anatomoclinical finding that degeneration of a particular type of neuron, the Von Economo neuron, in the AIC and the anterior cingulate is directly linked to the loss of self-awareness and self-conscious behaviors in patients with frontotemporal dementia [32,33]. Such neurons are found selectively in the AIC and the anterior cingulate of hominid primates in phylogenetically increasing number [34,35]. Their functional role is unknown.

The patients' reports of an altered sense of time during ecstatic seizures could also be explained by the involvement of the AIC. The AIC is crucial to human time perception (for references, see [17]); from the present perspective, it is most striking that the AIC is increasingly activated as awareness is focused on a single instant of time [36]. The model of the AIC's role in awareness that has been proposed suggests that it contains a cinematic representation of the sentient self across time that advances at a frame rate of ~8 Hz [17,37]. During a period of high emotional salience, this model predicts that the neural instantiations of feelings are rapidly filled with salient information and thus increase in number, producing subjective time dilation and the perception that time in the real world “stands still.” This certainly resembles the

descriptions of ecstatic seizures by these patients. Thus, the strong enhancement of oscillatory EEG activity at approximately 8 Hz or less that is particularly characteristic of mesial and inferior temporal ictal discharge [38,39] potentially provides an electrophysiological explanation for both the heightened self-awareness and the altered sense of time described by patients with ecstatic seizures, because it could indicate phase-locked recruitment within the AIC at 8 Hz [17]. Interestingly, accumulated evidence indicates that the AIC also has a crucial role in the emotional enjoyment of music (which emerges directly from the cinemascopic model of the sentient self [17]), and thus the spontaneous comment by one patient (case 1) indicating enhanced musical enjoyment is also consistent with this hypothesis.

Among these five patients, three suffered from a cerebral lesion located in the anterior part of the temporal lobe (left, two cases; right, one case), either within or close to the temporal pole, with consonant EEG abnormalities. In the two MRI-negative patients, EEG abnormalities were located in the left anterior temporal region. According to the above-mentioned functional characteristics of the AIC, we suspect an insular symptomatic zone in our patients, that is, an ecstatic symptomatology related to the spreading of the seizure activity from the temporal region into the AIC. A mesial temporal symptomatic zone seems unlikely for several reasons. These five patients do not present the classic ictal symptoms observed in mesial temporal lobe epilepsy, which are mostly an epigastric ascending sensation, fear (second most common type of aura), and, more rarely, déjà vu, dreamy state, micropsia, macropsia, olfactory hallucinations, and feeling of depersonalization, as well as the highly characteristic oroalimentary automatisms during complex partial seizures [18]. (Interestingly, the appearance of emotional symptoms such as fear in mesial temporal lobe epilepsy has been previously associated directly with ictal propagation from the mesial temporal lobe to the anterior insula [40]). Only one of our patients experienced déjà vu (case 2); however, the déjà vu persisted postsurgically along with the ecstatic symptoms despite a resection that included the major part of the mesiotemporal region (the whole entorhinal cortex and the head and anterior part of the body of the hippocampus), suggesting that both these symptoms originated in other cerebral regions. One other patient (case 1) had rare seizures consisting of olfactory hallucinations, but these seizures included no sense of bliss and probably corresponded to a propagation of the ictal discharge different from that of her usual seizures. Furthermore, a neocortical temporal symptomatic zone seems unlikely because the classic clinical features of neocortical temporal seizures, namely, auditory and visual illusions and hallucinations, vertiginous auras, early contralateral dystonic posturing, and early loss of contact [41], were absent in our patients. Specific symptoms of temporal pole seizures are not known except for an earlier occurrence of loss of consciousness in temporopolar seizures than in mesial temporal lobe seizures [42]; however, our patients did not present with an early loss of consciousness. Orbitofrontal propagation also seems unlikely; such seizures are described as a sudden loss of contact and more or less elaborated automatisms (bizarre gesticulations and often violent movements mimicking fearful behavior with autonomic signs) [43].

Temporopolar ictal activity propagates preferentially to the superior temporal gyrus and to the periopercular cortex, whereas mesial temporal lobe seizures are said to propagate most often to the basotemporal and lateral temporal cortex [42]. By comparison, easy spreading of ictal activity from the temporal pole toward the insula is indicated by recordings of synchronous spikes within the temporal pole and the insula in some patients with epilepsy [44]. Ictal discharges can propagate directly from the temporal neocortex to the insular cortex without a mesiotemporal relay [44].

Corroborating the hypothesis of the involvement of the AIC in the ecstatic symptoms, an ictal SPECT carried out in one of our patients showed increased blood flow predominantly in the insula. Additionally, Isnard et al. [45] studied the clinical manifestations of insular lobe seizures using depth stereotactic EEG (SEEG) recordings and identified seizures that originated in the insula itself in 5 (of 50) patients, one of whom described a feeling of mirth and clairvoyance at seizure onset. The concomitant SEEG recording showed an epileptic discharge confined to the anterior and posterior inferior quadrants of the right insula, without any spread to other explored cortical structures, notably to mesiotemporal structures. Nonetheless, electrical stimulation of the insular cortex has not elicited pleasant feelings in several studies [45–49], which suggests that the generation of feelings of ecstatic symptoms might require the activation of a distributed network. However, stimulations of the most antero-inferior part of the insula (insular pole) have hardly ever been performed.

In the prior reports of single or small series of patients with ecstatic seizures, a temporal lobe origin was usually suspected, yet no precise localization has ever been demonstrated [6–16]. Some cases of primarily ecstatic seizures displayed characteristics suggestive of the involvement of the anterior temporal region, such as the finding of a right anterior temporal tumor [11] or of left anterior temporal interictal EEG discharges [12,15]. In several cases in which a mesial temporal origin was suspected, we note that the reported characteristics seem inconsistent with this hypothesis: in one case of ecstatic seizures with calcifications found in the hippocampus, the ecstatic symptom occurred much later than other ictal symptoms [9]. In another case, the ecstatic seizures disappeared after the treatment of an occipital arteriovenous malformation despite the fact that an associated homolateral gliotic hippocampus remained in place [10]. In a third case, from the series of Asheim et al. (patient 5) [13], the semiology of the seizures changed after surgery for mesial temporal sclerosis and included the appearance of ecstatic auras, suggesting that the ecstatic symptom originated outside the mesial temporal region. Lastly, in the case of Dostoevsky, one article described a laryngeal aura (spasm of the throat) [20], a symptom that has been clearly associated with the insula [45].

Cerebral laterality of activity associated with emotions is a matter of ongoing debate. One model of forebrain emotional asymmetry associates the left hemisphere with positive affect (approach behavior) and the right hemisphere with negative affect (avoidance behavior) [50–52]. This model is supported by asymmetric EEG activity in relation to affective style [51,52] and music [53], by the effects of barbiturate injection in the left and right carotid arteries in the Wada test [54,55], by the emotional consequences of lateralized cerebral lesions [56–58], by changes in heart rate variability while viewing lateralized film presentations [59], and by regional cerebral activity during positive and negative feelings [37,50]. Most significantly, functional imaging studies indicate that the left AIC is selectively activated by intense positive feelings similar to the ecstatic feelings described by these five patients with epilepsy, such as joy, maternal and romantic love, and even “a state of union with God” [60–62], as well as seeing or making a smile, listening to pleasant music, or hearing happy voices (for references, see [17]). A recent study of electrical stimulation of the right and left amygdala in patients with epilepsy reported a similar lateralization of emotional valence [63]: stimulation of the right amygdala evoked negative emotions in all cases whereas stimulation of the left amygdala evoked positive emotions in at least half of the cases. Nevertheless, it seems likely that there is an opponent organization with mutual inhibition between the AIC on the right and left sides, so that the balance between the two sides may be crucial, as shown in other cerebral regions [14,50,64–66]. This might explain cases in which alternating unpleasant and ecstatic feelings have been

reported and, perhaps, the varying laterality in patients with ecstatic seizures [5,14]. Previous reports of ecstatic seizures did not reveal a preferential laterality; taken together, there were 14 cases with apparent left abnormalities and 11 with right abnormalities [6,8,10–15]. In the present study, four of the five cases had abnormal cerebral activity on the left side, which offers potential support for the hypothesis that the left hemisphere is predominantly associated with positive emotions. Further evidence is clearly needed in a larger sample of patients with primarily ecstatic seizures (i.e., consisting of a feeling of bliss not related to any other sensory symptom).

We note the likelihood that the frequency of cases with ecstatic seizures has been underestimated because of the difficulties patients have in describing and discussing them. As Williams reported, patient descriptions of epileptic episodes with emotional disturbances depend on the individual's intelligence, vocabulary, and power of introspection [5]. Some patients have trouble finding the words to describe symptoms that seem surreal, and they simplify the description, for example, "a pleasant ascending sensation" or "bubbles in the body up to the head," as reported in the medical files of two of our patients. People may be more reluctant to reveal an overwhelmingly pleasant sensation than a sensation of fear or anxiety. The apprehension of a secondary complex partial or generalized tonic-clonic seizure could also partially mask reports of ecstatic symptoms. A recent content analysis of the subjective emotional experiences of 27 patients during partial epileptic seizures revealed that ictal joy or delight was reported only three times less often than fear and anxiety [67], although ecstatic seizures were not classified in that study. It is also conceivable that patients with photosensitive absence seizures who admit to self-inducing a feeling of intense pleasure or "paradise" by slow eye closure with upward deviation [68–70] might produce hyperactivation of the AIC.

We wish to underline the similarities between the feelings reported during ecstatic seizures and the feelings described under the effect of stimulant addictive drugs. Stimulant drugs of abuse, such as amphetamine, cocaine, and ecstasy (3,4-methylene-dioxy-methamphetamine), may induce a feeling of enhanced introspective lucidity, inner peace, and extreme bliss, together with a heightened physical and spiritual awareness of the surroundings. Amphetamine and cocaine act by increasing brain levels of dopamine and noradrenaline, whereas the effects of ecstasy are mediated by serotonin, dopamine, and possibly noradrenaline [71]. Interestingly, comparative data suggest that the AIC may be a site of high dopamine utilization [72,73] that is important for antinociception [74] and for drug craving [75,76]. The psychoactive ayahuasca tea, a central element of Amazonian shamanism that has stimulatory effects and produces enhanced introspective attention and euphoria, generates bilateral activation of the AIC and the inferior frontal gyrus, perhaps by way of serotonergic mechanisms [77]. The involvement of the AIC in both epileptic seizures with ecstatic auras and the effects of stimulant addictive drugs could underlie the similarity of symptoms.

We conclude that patients' verbal descriptions of ecstatic seizures match the functional characteristics of the AIC and support the proposal that ecstatic seizures can be explained by ictal hyperactivation of the AIC. Future studies of individual patients with modern neuroimaging and depth EEG recording methods could provide deep insights into the mechanisms underlying the role of the AIC in subjective feelings, time perception, musical enjoyment, and human consciousness.

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