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# Psychic Seizures and Their Relevance to Psychosis in Temporal Lobe Epilepsy

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## 1. Introduction

Psychic seizures are defined as simple partial seizures manifesting themselves as psychic phenomena. Their current classification is neither comprehensive nor rational enough, mainly because psychic seizures are defined as subjective phenomena and not as objective dysfunctions. The high incidence of psychiatric symptoms in patients with temporal lobe epilepsy (TLE) is not only resulted from misdiagnosis but causally linked to psychic seizures. In this article the relationship between psychic seizures and various psychiatric disturbances found in TLE patients is discussed from a clinical viewpoint. Psychosis in TLE patients has historically been of special interest, whose relationship with schizophrenia is still unresolved. In this article the possible effect of psychic seizures on the generation of psychosis in TLE patients is discussed based on the author's own data obtained from magnetoencephalographic localization of psychic seizures and psychosis in TLE patients.

## 2. Psychic seizures and their classification

Psychic seizures have been classified from a practical viewpoint into cognitive, emotional, mnemonic seizures and miscellaneous. In the following, psychic seizures are described according to the current classification (Fish, 1997), and the limitation of the current classification is discussed.

### 2.1 Cognitive seizures

Cognitive (or dyscognitive) seizures indicate disturbances of cognitive functions by seizure activities. Although theoretically disturbances of higher cognitive functions cannot be localized only to temporal lobes, as they are realized by collaboration of many circuits all around the brain, clinically cognitive seizures are most often observed in TLE.

#### 2.1.1 Perceptual illusions

Perceptual illusion are defined as various kinds of illusions in perception in any mode of senses (Penfield & Jasper, 1954). Historically various kinds of perceptual illusions have been described as psychic seizures, for example, increase and decrease of the size of objects

(macropsia and micropsia, respectively), augmentation and diminution of stereoscopy in visual mode. There are also corresponding auditory phenomena, namely, increase and decrease of the volume of sounds and various alterations of hearing sounds.

From the present point of view, these phenomena can be understood as dysfunctions of higher sensory processing, both visual and auditory modes of which are made in the temporal necortex. In this sense, perceptual illusions could be classified as sensory seizures.

Whereas higher cognitive functions in general tend to be disturbed by seizure activities, facilitation is also seen among lower cognitive functions. Thus micropsia, the most often seen phenomenon of this kind, could be either augmentation of distant sight or diminution of near sight.

### **2.1.2 Aphasic seizures**

Sensory and motor aphasia can appear as simple partial seizures, although these disturbances would appear more frequently as postictal symptoms which are observed after complex partial seizures involving the speech-dominant hemisphere. On the other hand, occasionally abundant but empty speech is observed after complex partial seizures involving the non-dominant hemisphere. This is regarded as a release phenomenon rather than a stimulated symptom, whereas aphasia is defective symptoms.

### **2.1.3 Higher cognitive seizures**

Higher cognitive functions in general tend to be disturbed by epileptic seizures, and combinations of disturbances of various cognitive functions bring about the states called complex partial seizures. It is worth remembering that concept of complex partial seizures, characterized by "impairment of consciousness", had implied originally combinations of elementary partial seizures, each of which interferes each of cognitive functions. While "impairment of consciousness" is defined by lacks of responsiveness and memory registration, these two lacks can be caused by disturbances of elementary cognitive functions. For example, combination of sensory aphasia, apraxia and amnesia could hardly be differentiated from impairment of consciousness.

Although it is hard to suppose that any of higher cognitive functions might be facilitated, instead of disturbed, by seizure activities, as higher cognitive functions are thought to be realized by exquisite collaborations of many elementary circuits, there remains the possibility of epileptic facilitation. At least, some patients report subjective sense of transient facilitation of general cognition and it sounds like a mystic experience.

### **2.1.4 Depersonalization and derealization**

Depersonalization and derealization can be caused by seizure activities. These phenomena could be interpreted as weak forms of complex partial seizure or impairment of consciousness. Some patients complain of "absurdity" about the surroundings during the seizure (Penfield & Jasper, 1954), which can be interpreted as some peculiar kind of alteration of perception of the surroundings, presumably similar to derealization.

## 2.2 Emotional seizures

Emotional seizures can basically be epileptic induction of any kind of emotion. In reality, however, this category is almost solely used for ictal fear, namely, fearful or anxious emotion induced by seizure activities. Although there are actually cases showing pleasant emotions as seizure symptoms, their incidence is decisively lower than that of fear, anxiety, sadness or loneliness. The reason why those negative emotions are much more often induced by epileptic seizures than positive ones might be explained that the neural structure relevant to emotions, amygdala, is tend to respond as negative when stimulated grossly, corresponding to an evolutionally lower hierarchy in emotional system.

Incidentally, embarrassment has also been suggested to be a possible type of emotional seizure (Devinsky et al., 1982), which is a social emotion and thought to reside in a rather high hierarchy, presumably anteromedial frontal lobes, although occurring with much lower incidence.

Regarding the possibility that seizure activities inhibit, instead of induce, any of the emotions, there has been no consideration as far as the author knows. Although it is theoretically possible, thought to be very difficult to detect in practice.

## 2.3 Mnemonic seizures

Mnemonic or dysmnestic seizures, which mean seizures causing dysfunction of memory, include amnesia, recollection and reminiscence, déjà vu, jamais vu and experiential hallucination induced by seizure activities. As it is known that temporal lobe is the most important part of the brain for memory function, it is reasonable that seizure activities residing in temporal lobes cause various derangements of memory function.

### 2.3.1 Amnesia

The simplest effect of seizure activities on memory functions is a negative one, namely, amnesia. Although clinically it is difficult to differentiate from complex partial seizures with impairment of consciousness, there are actually “pure amnesic seizures” in some TLE patients with seizure activities confined within hippocampus (Palmini et al., 1992).

### 2.3.2 Experiential hallucination

Experiential hallucination is defined as hallucination of any mode of sense which is related to the patient's personal experiences and can be regarded as reappearance and projection of memorized images (Penfield & Jasper, 1954). Each mode of sense is involved either solely or in combination resulting in appearance of audiovisual images just like fragments of movies. The mode most frequently involved is auditory. Patients often report the voices calling their name at the time of the first attack in their childhood.

Experiential hallucination of only olfactory or gustatory mode is hard to be discerned, because hallucination of these primitive modes of sense easily evoke associated memory recall with multiple sensory images, and associated images could hardly be separated from the initial ictal hallucination.

### 2.3.3 Recollection and reminiscence

Ictal recollection is autonomous remembrance of past experiences induced by seizure activities. Contrasted to experiential hallucination, sensuous property of recollection is not strong, and its content is confined within the inner space, not projected to the outer. Emotions accompanying the past experience are often revived. The content of recollection is ordinarily limited to the same every time, although it may change in course of time, in the time scale of years. The content is occasionally the scene that the patient experienced the first attack, apparently resembling traumatic recollection. This resemblance is not only coincidental, because the patient's impression of the first attack is thought to be very strong and therefore memorized particularly strongly, that is comparable to traumatic memory.

Reminiscence is a weaker form of recollection, which does not make any concrete image within the inner space and is experienced only as a feeling of remembering something.

### 2.3.4 Déjà vu

Déjà vu (or déjà vécu) is a paradoxical feeling of knowing things that is never known by the subject. It is not rare in healthy people and therefore not necessarily a pathological phenomenon. Ictal déjà vu tends to be, however, stronger and longer than healthy ones. Emotion accompanying ictal déjà vu is often nostalgic and pleasant, but some patients feel uncanny and uneasy. Penfield suggested that ictal déjà vu should be caused by incomplete recollection and mixed perception of the present environment and the past one (Penfield & Jasper 1954). Whereas, Gloor suggested that déjà vu should be caused by misidentification resulted from deterioration of matching mechanism by seizure activities (Gloor 1990). Recent studies suggested that déjà vu is appearance of a special sense of familiarity separable from either recollection or identification, whose neural substrate is supposed to be parahippocampal gyri (Spatt 2002).

### 2.3.5 Jamais vu

Jamais vu (or jamais vécu) is thought as the opposite of déjà vu, namely, a feeling of not knowing things that is already known by the subject. It is, however, much more difficult to understand the mechanism than déjà vu. Ictal jamais vu is much rarer than ictal déjà vu and seems hard to induce by electrical stimulation. In addition, practically jamais vu is hard to be differentiated from derealization. Emotion accompanying ictal jamais vu is usually anxiety or uneasiness, with rare exception of pleasant freshness.

### 2.3.6 Prescience

There is a special kind of psychic seizure called "prescience", which indicates a sense of knowing what is going to happen from now on (Sadler et al., 2004). While it is theoretically difficult to take prescience as a disorder of memory, which is bound only to the past and never to the future, practically prescience is frequently seen in combination with déjà vu. It seems necessary to clarify what is the common between déjà vu and prescience, which may be the clue to understand the mechanism of déjà vu.

## **2.4 Miscellaneous**

There are various kinds of psychic phenomenon evocated by seizure activities, which are difficult to be classified under any rubric of cognitive, emotional and mnemonic. Here are described only some of them.

### **2.4.1 Forced thinking**

Forced thinking is a comparatively often found type of psychic seizure. It is an autonomous appearance of a fixed thought induced by seizure activities. Apparently it resembles obsession, but it does not necessarily evoke anxiety as obsession does. Some patients take the thought as a gift from the god and develop religious delusion.

### **2.4.2 Changes of time perception**

Some TLE patients report changes of time perception, namely, increase or decrease of the speed in which surroundings proceed. They are experienced just like quick motion or slow motion of the movies. While these phenomena are usually reported only in visual mode without corresponding changes in auditory mode, some patients complain of feeling that others' speeches abruptly change into being too quick to understand.

### **2.4.3 Autoscopy and out-of-body experience**

Autoscopic phenomena have been reported as manifestations of temporal, parietal and occipital lobe epilepsies (Devinsky et al., 1989). Autoscopic hallucinations, in which a mirror image of the patient is seen, is supposed to originate from the parieto-occipital lobes preferentially of the right side (Maillard et al., 2004). Dramatic type of autoscopy, in which the patient see himself/herself act independently from his/her will, just as seeing a movie, is reported mainly as hallucinations appearing during postictal confusional states of TLE. Out-of-body experience, in which the patient feels like seeing himself/herself from the outside of his/her body, is reported to originate from temporo-parietal junctions (Blanke et al., 2004). These autoscopic phenomena induced by seizures could be understood as distortion of body scheme, although the displacement of the viewpoint in out-of-body experiences is hard to explain.

### **2.4.4 Feeling of a presence**

Feeling of a presence is a hallucinatory feeling as if someone is nearby. This phenomenon is most often observed in TLE patients and seemingly related to ictal fear. It is also interesting from the viewpoint of the similarity to a type of psychotic hallucination observed in schizophrenia.

## **2.5 Problems in the classification of psychic seizures**

The essential difficulty in the classification of psychic seizures is that they are defined as subjective phenomena and not as objective dysfunctions. Observation of their existence in the patients depends solely on the patients' report, which is often not reliable because of insufficiency of the patients' ability to express the phenomena in his/her words.



From a clinical point of view, current classification of psychic seizures is regarded as the minimum but still usable. On the other hand, from a scientific point of view, replacing the term by “limbic seizures”, which has been done in a standard textbook (Engel & Williamson, 2008) seems immature because the neural substrates of psychic seizures have not been sufficiently determined, although a large part of them seems to be localized to limbic structures. Furthermore, our data has suggested the conflicting possibility, as shown in the following.

2.6 Co-existence of psychic seizures and other simple partial seizures in TLE

Aiming at objectifying psychic seizures, the author performed an investigation on existence and co-existence of psychic seizures and other simple partial seizures in 38 TLE patients. The patients with TLE were investigated on existence and co-existence of autonomic, auditory, olfactory and psychic seizures, which were subclassified into fear/anxiety, déjà vécu, jamais vécu, reminiscence, forced thinking, visual alteration and others.

The sides of the focus of the patients are left in 16, right in 17 and bilateral or not determined in 5 patients.

Fifteen patients had autonomic seizures (5 left, 8 right and 2 undetermined), 23 had psychic seizures (10 left, 10 right and 3 undetermined), 8 had auditory seizures (3 left, 4 right and 1 undetermined), 2 had olfactory seizures (1 left and 1 right) and none had gustatory seizures. Subclassified psychic seizures were déjà vécu in 11 (6 left, 4 right and 1 undetermined), reminiscence in 10 (4 left, 4 right and 2 undetermined), fear/anxiety in 5 (2 left, 3 right), jamais vécu in 2 (0 left and 2 right), forced thinking in 2 (0 left and 2 right) and visual alteration in 2 (1 left and 1 right) (Table 1).

	Left	Right	Bilateral or undetermined
Autonomic seizures	5	8	2
Auditory seizures	3	4	1
Olfactory seizures	1	1	0
Gustatory seizures	0	0	0
Psychic seizures	10	10	3
déjà vécu	6	4	1
reminiscence	4	4	2
fear/anxiety	2	3	0
jamais vécu	0	2	0
forced thinking	0	2	0
visual alteration	1	1	0
Total	16	17	5

Table 1. The type of simple partial seizure and the side of the focus in the subject group.

Co-existence among each of the subcategories of psychic seizure was as follows: fear/anxiety and reminiscence in 2, déjà vécu and reminiscence in 2, fear/anxiety and déjà vécu in 1, etc.

Co-existence between the subcategories of psychic seizure and each type of simple partial seizure was as follows: 3 out of the 5 patients with fear/anxiety, 2 out of the 11 with déjà vécu, 4 out of the 10 with reminiscence and 1 out of the 2 with forced thinking had also autonomic seizures; 4 out of the 11 with déjà vécu, 1 out of the 2 with jamais vécu, 2 out of the 10 with reminiscence and both the 2 patients with visual alteration had also auditory seizures; 1 out of the 11 with déjà vécu, 1 out of the 2 with jamais vécu, 1 out of the 10 with reminiscence had also olfactory seizures.

The results are schematically visualized in Fig. 1 where simple partial seizures are connected each other by the bonds with breadth corresponding to the number of patients. It is noteworthy that the connections between autonomic seizures and the subcategories of psychic seizure are not significantly stronger than those between auditory seizures and them. This result suggests that psychic seizures should not necessarily be based solely on temporolimbic dysfunctions but also on dysfunction of temporal neocortex.

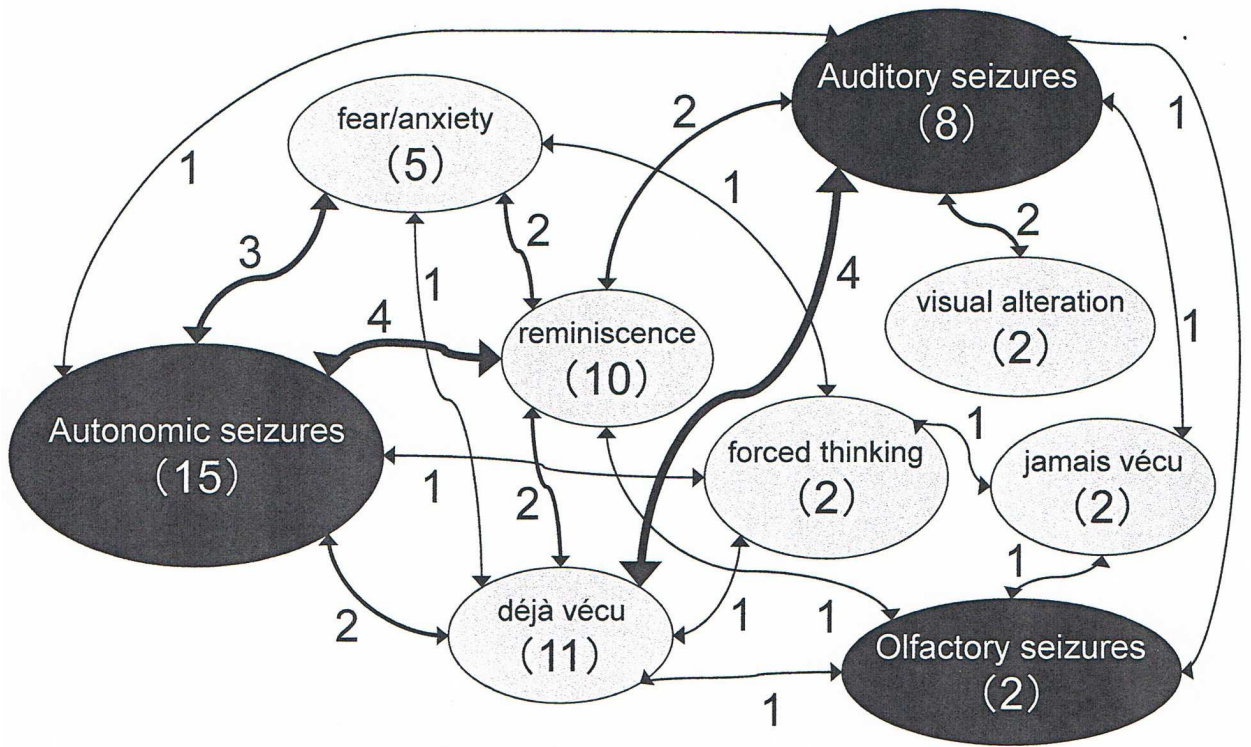


Fig. 1. Co-existence of simple partial seizures and different types of psychic seizure

In summary, co-existence was not conformed between subcategories of psychic seizure and other types of simple partial seizure, and it was fairly rare among subcategories of psychic seizure. Consequently, it seems adequate to assume considerably independent neural networks for the neural basis of different psychic seizures.

3. Various psychiatric disturbances accompanying TLE

TLE patients manifest psychiatric disturbances with significantly higher incidence than normal population. The explanation of this fact is not satisfactory that generally patients with chronic medical problem are inclined to have psychiatric disturbances. It is supposed



that in some proportion of patients epileptic activities by themselves are the cause of the psychiatric symptoms. In this context, amygdalar dysfunction in TLE is the most important.

### **3.1 Depression and dysphoria**

Epilepsy patients show a higher tendency of having depression than normal population (Barry et al., 2007). As it is well-known that depression is frequently seen in the patients with chronic diseases in general, the frequency of depression in epilepsy patients could partly be ascribed to the fact that epilepsy is one of them.

Whereas, it has long been told that epilepsy patients have a special kind of mood disorder, which is not simply depressive or manic, but of periodical character. It is called “interictal dysphoric disorder” (Blumer et al., 2004). The mechanism of this syndrome is not well clarified, but it is thought to have some causal relationship with seizure activities, because it seems that the mood change depends on the appearance of seizures. Namely, there is a tendency that depressive mood is strengthened before the appearance of seizures and manic mood appears after it. Although interictal dysphoric disorder is not confined to TLE, it is most often seen in patients with TLE and its mechanism is supposed to be related to amygdalar dysfunction.

### **3.2 Anxiety disorders**

Epilepsy patients are inclined to develop anxiety disorders. One reason is purely psychological, namely, they are naturally anxious about presenting seizures in public and this anxiety can become pathologically strong. Especially those who have auras perceived only by themselves can get psychologically conditioned and present panic attacks triggered by perceiving auras. Furthermore, there is possible enhancement of conditioning in TLE patients based on amygdalar dysfunction. Ictal fear can by itself condition panic attack, because panic attack and ictal fear are in common supposed to be the results of paroxysmal dysfunction of amygdala. Moreover, amygdalar dysfunction may cause anxiety symptoms also in a persistent form, represented as generalized anxiety disorder.

### **3.3 Psychosomatic inclination**

As amygdala contains also the center of autonomic system, its dysfunction may cause various autonomic disorders. For example, epilepsy patients are often sensitive to the moisture and have seizures at the time of the passing of a rain front. Another example is the sensitivity to the lights which are not flashing or flickering lights inducing photosensitivity, but glimmering lights from the cloudy sky. Psychosomatic inclination among epilepsy patients may be ascribed not only to the pure psychological complication but also to the amygdalar dysfunction directly linked to the epileptic activities.

### **3.4 Aggressiveness or “explosiveness”**

Historically epilepsy patients have been believed to have aggressive tendency in general, and aggressiveness or “explosiveness” has been regarded as a component of so-called epileptic personality change, which is most remarkable in TLE patients. In reality, it is not so often to find extraordinary aggressiveness in epilepsy patients at present, probably due to

the propagation of anticonvulsant medication from early stages of the disease. Aggressiveness observed in some TLE patients may be understood by amygdalar dysfunction, because stimulation of amygdala is known to cause not only fear and anxiety but also aggression.

### 3.5 Obsessive-compulsive disorder

It has long been known that obsessive-compulsive disorder (OCD) is frequently seen in TLE patients. The mechanism of the comorbidity of OCD and TLE is supposed to be plural, one of which being comorbidity of autism spectrum disorder and TLE. However, it seems certain that there are some cases in which confined epileptic activities cause obsessive-compulsive behavior. To date, laterality and subdivision within the temporal lobe of the focus causing OCD is not determined.

### 3.6 Epileptic personality change

“Epileptic personality change” or a special kind of personality disorder caused by suffering epilepsy has long been discussed and remains under dispute. Several elements such as viscosity, circumstantiality, explosiveness, and religiosity have been believed to characterize this type of personality change. Although believed to be caused by epilepsy, because it becomes increasingly manifest as the duration of the illness increases, it is regarded as non-specific “organic personality change” by some researchers (Slater et al., 1963). According to Bear and Fedio (1977), the elements included in epileptic personality change are: 1. humorlessness or sobriety, 2. sadness or depression, 3. emotionality, 4. circumstantiality, 5. philosophical interest, 6. sense of personal destiny, 7. viscosity or interpersonal stickiness, 8. dependence, 9. aggression, 10. obsessionality, 11. paranoia or suspiciousness, 12. sense of guilt, 13. hypergraphia or excessive writing, 14. changes to or diminution of sexual drive, 15. hypermorality, 16. religiosity, 17. elation or mood change, and 18. anger or irritability.

Gastaut and Waxman and Geschwind attempted to treat these features in neuropsychological style (Gastaut, 1956; Waxman & Geschwind, 1975). In particular, the personality change characteristic of TLE (limbic epilepsy personality syndrome; LEPS) was interpreted as the opposite of Klüver-Bucy syndrome, which is a group of symptoms seen in monkeys and humans with bilateral anterior temporal lesions. Whereas Klüver-Bucy syndrome comprises (1) oral tendency or cognitive deficit, (2) indifference or diminution of emotionality, (3) hypermetamorphosis or difficulty in attention fixation and (4) increase in sexual activity, LEPS comprises (1) strengthened cognition, (2) increased emotionality, (3) viscosity or difficulty in attention shift and (4) diminution or alteration of sexual activity. This apparent opposition has been explained by interictal epileptic activities within the temporolimbic structures (Gastaut, 1956), or “sensory-limbic hyperconnection” established by a kindling effect (Bear, 1979). In any case, the explanation is based on the positive or excessive function of the temporolimbic structures.

The author has shown a case which suggests presumed persistent seizure activities confined around the right amygdala had caused acute psychosis and rapid development of epileptic personality change (Fukao, 2010).

### 3.7 Psychosis in TLE

Psychosis in TLE patients is a rather independent problem, which has a long history of research and dispute. The question whether psychosis in epilepsy patients or epileptic psychosis is peculiar and different from schizophrenia and other psychoses is still unresolved (Gibbs, 1951; Slater et al., 1963). Although some studies suggested that epileptic psychosis is nothing but enhanced occurrence of schizophrenia in people with epilepsy and that there is no significant difference in the symptomatology between them (Adachi et al., 2011). However, it is frequently seen that symptoms of psychic seizures appear in the episodes of acute psychosis in TLE patients.

Importance has been attached to the distinction between acute and chronic forms of psychosis in epilepsy patients, because the acute form is clinically hard to discriminate from postictal confusional state that is not genuinely psychotic. However, since the recognition of postictal psychosis differentiated from postictal confusional state (Logsdail & Toone, 1988), different mechanism is supposed for acute psychosis in TLE patients from confusion or impairment of consciousness, for example, “hyperarousal” after the cluster of seizures (Wolf, 1991). On the other hand, progression from postictal acute psychosis into chronic psychosis was confirmed in substantial part of TLE patients (Tarulli et al., 2001). It is, therefore, uncertain whether the distinction between acute and chronic forms of psychosis in TLE patients is really important or not.

Furthermore, some part of psychosis occurring among TLE patients are apparently induced by anticonvulsant drugs. Some anticonvulsant drugs like topiramate and zonisamide are evidently more prone to induce psychiatric disturbances than others, while there has been a general concept of “forced normalization” that means the reciprocal appearance of psychotic disorders when the patient’s seizures were inhibited by any drugs (Krishnamoorthy & Trimble, 1999).

One point to be clarified in the problem of psychosis in TLE is the relationship between psychic seizures and psychosis, which has not been confirmed by clinical evidence. The author addressed this point by magnetoencephalographic study on TLE patients as described below (Fukao et al., 2009; Fukao et al., 2010).

## 4. Magnetoencephalographic localization of psychic seizures and psychosis in TLE

In this section the author’s data obtained from magnetoencephalographic (MEG)

localization of epileptic activities in TLE patients is described briefly and its implication on the relationship between psychic seizures and psychosis is discussed.

### 4.1 Methods

#### 4.1.1 Patients

The subject of this study comprises 57 patients who had been diagnosed as having TLE based on EEG findings and clinical symptoms. Out of the 57 patients, all having complex partial seizures, those who had autonomic seizures were 25 in numbers, those with

auditory seizures were 10 and those with psychic seizures were 16. Six patients had both autonomic and psychic seizures, and 5 patients had both auditory and psychic seizures. One patient had all of the three types of aura. One patient had psychic, olfactory and gustatory seizures, and another patient had only olfactory seizures. Those who had no aura were 16.

Sixteen out of the 57 patients had history of psychosis, whether chronic or episodic. Age of the patients with psychosis ranged from 20 to 46 (mean = 29) years old and the mean duration of the illness was 19 years. Eight out of the 16 patients had chronic psychosis and the remaining 8 had episodic psychosis.

#### 4.1.2 Magnetoencephalographic measurements and spike-dipole typing

MEG measurements were performed using Magnetic Source Imager (a dual sensor system containing 37 channels of first order gradiometer in each sensor; Biomagnetic Technologies Inc., San Diego, CA, USA), whose sensors were positioned symmetrically on both temporal regions of the patients, with simultaneous recordings of scalp EEG which helped the examiner find epileptiform discharges. MEG was recorded as epochs each of which consisted of a 6 seconds segment including 5 seconds before and 1 second after the trigger by manual button press. The sampling rate was 200 Hz. The duration of the recording session was 1.5-2 hours including the time needed to place EEG electrodes on the scalp. After filtering the all MEG epochs by 3-30 Hz digital band-pass filter, equivalent current dipoles of magnetic spikes collected (spike-dipoles) were calculated off-line by the attached software, and overlaid on MR images.

“Clustering” of spike-dipoles was approved only when more than 10 dipoles show concentration within a cube with edges of 3 cm. Then spike-dipole clusters found in the patients were classified according to anatomical localization and orientation of the dipoles.

As a preparation of the study, we classified the patients according to the type of “clustering” of magnetic spike-dipoles. We found two major types of the pattern of “clustering” of spike-dipoles in the patients. One of which is positioned on the lower part of the temporal lobe and oriented from anterior toward posterior as shown in Fig. 2, and we name this “inferotemporal-horizontal (IH) type”. The other is positioned on the upper part of the temporal lobe and oriented from superior toward inferior as shown in Fig. 3, and we name this “superotemporal-vertical (SV) type”. Of the 57 patients showing spike-dipole clusters, 33 patients showed IH type of spike-dipole and 27 showed SV type. Among them 10 patients showed both types, ipsilaterally in 8 and contralaterally in 2. Three patients had bilateral SV type, and one had bilateral IH type. None had more than two spike-dipole clusters. Thus 88% of the patients had either IH type or SV type of spike-dipole, and the presence of the two types were statistically exclusive (Fisher’s exact test:  $p = 0.027$ ). In the following studies, we investigated only these two, or four, when each divided into two according to the side, types of spike-dipole.

#### 4.1.3 Correlation analyses

Correlation analyses were performed using Fisher’s exact test between these four types and the presence of autonomic, auditory and psychic seizures and history of psychosis.

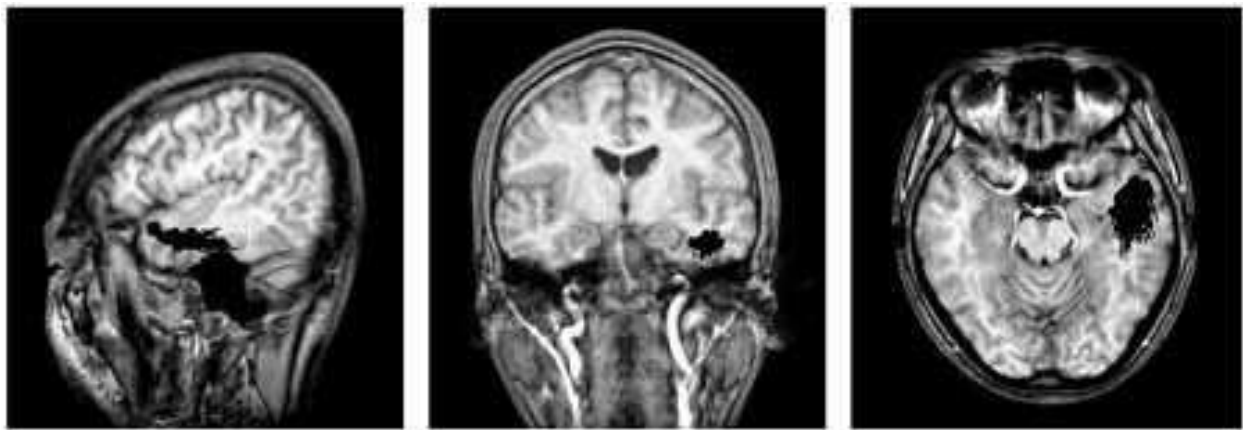


Fig. 2. An example of IH (inferotemporal-horizontal) type of spike-dipole distribution.



Fig. 3. An example of SV (superotemporal-vertical) type of spike-dipole distribution.

4.2 Results

The results of the correlation analyses are summarized in Table 2. Left IH type positively correlated to autonomic seizures. Right SV type positively correlated to both auditory and psychic seizures. Left SV type positively correlated to history of psychosis.

	Left	Right
IH type	Autonomic seizures	
SV type	Psychosis	Auditory seizures Psychic seizures

Table 2. The positive correlations between left and right IH and SV types of spike-dipoles and autonomic, auditory and psychic seizures and psychosis.



### 4.3 Interpretation

As IH type correlated not only to autonomic seizures on the left side but also correlated to hippocampal sclerosis on both sides, it seems very certain that IH type of spike-dipole should represent hippocampal or temporolimbic discharges. On the other hand, the correlation of SV type to auditory seizures suggests that SV type should represent temporal neocortical discharges.

In view of the discussion in section 2, the neural substrates of psychic seizures are supposed to be interconnected networks within and around the temporal lobes. Therefore, the correlation of SV type to psychic seizures suggests that SV type should represent also interconnected networks. The correlation of SV type to psychosis should be interpreted in the same way as psychic seizures, not as simple as auditory seizures.

It is, nevertheless, suggested by our results that temporolimbic discharges should not be essential to psychic seizures and psychosis, compared to temporal neocortical discharges. This is a remarkable finding in view of the other researches' suggestion that temporolimbic dysfunction should be essential to psychic seizures and psychosis.

The results described above imply that psychosis in TLE should be causally related to epileptic activities occurring in the superior portion of the left temporal lobe. From the neuropsychological viewpoint, the superior portion of the left temporal lobe is related to the function of awareness. Therefore, while seizures occurring on the right side are perceived by the patient as various psychic phenomena, those occurring on the left side might not be perceived as such phenomena due to the disturbance of awareness. Furthermore, prolonged seizure activities on the area might bring about the disturbance of self-consciousness resulting in psychosis characterized as an ego disorder. Thus psychosis in TLE patients might be caused by epileptic activities on the superior portion of the left temporal lobe.

### 4.4 Magnetoencephalography's advantage in this study

More than a half century ago, Penfield wrote, "The relationship of epileptic discharge, in temporal cortex and in the gray matter that is hidden deep in the Sylvian fissure, to psychotic states deserves exhaustive study" (Penfield & Jasper, 1954). Our findings seem to confirm his prediction. However, as neural activities detected by EEG and MEG are same in origin, the reason why these findings became available only by MEG has to be explained.

The key point is thought the orientation of the current of the epileptic discharges. As magnetic field is produced around the electric current on the plane tangential to the current, MEG can detect magnetic fields tangential to the corresponding neural currents. This condition makes possibility that MEG could detect spike activities that are not detectable by EEG. To be concrete, if spike generators existed deep within the Sylvian fissure, whether frontal, parietal or temporal operculum, and those spikes would elude detection by scalp EEG. In contrast, MEG can detect spike activities in considerably deep part of the cortex within the fissure, as far as the originating current is tangential to the scalp, accordingly, vertical to the fissure (Iwasaki et al., 2003). As can be seen, our SV type of spike-dipoles

represents such deep current generators. Moreover, the elusiveness of deep Sylvian discharges is also the case with intracranial recording using subdural electrodes, because usually the electrodes are not inserted into the Sylvian fissure but laid striding over it. In those cases with deep spike foci, therefore, MEG would be more powerful in spike detection than subdural electrodes.

## 5. Conclusion

There are various kinds of psychic seizures, or psychic phenomena induced by seizure activities in the brain and the classification is fundamentally difficult because of their subjective nature. Although the neural substrates of psychic seizures are supposed to reside mostly in temporal lobes, they are not necessarily localized and possibly some of them are extensive networks. Various psychiatric disturbances observed in TLE patients should be understood in relation to psychic seizures. Furthermore, because seizure activities may inhibit psychic functions or induce negative phenomena, the concept of psychic seizures could theoretically be extended to cognitive impairments induced by seizure activities, which are clinically elusive. Our results from MEG studies suggest that cognitive impairments induced by seizure activities on the left temporal lobe should lead to the generation of psychosis in TLE patients. This is a novel finding and interpretation that MEG made possible.

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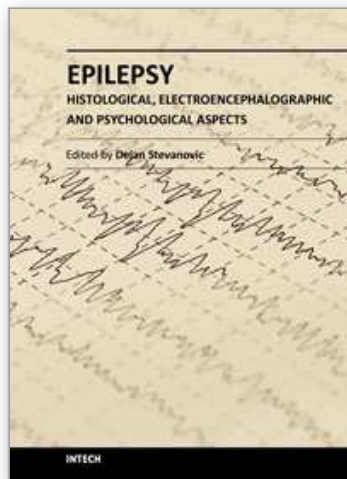
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