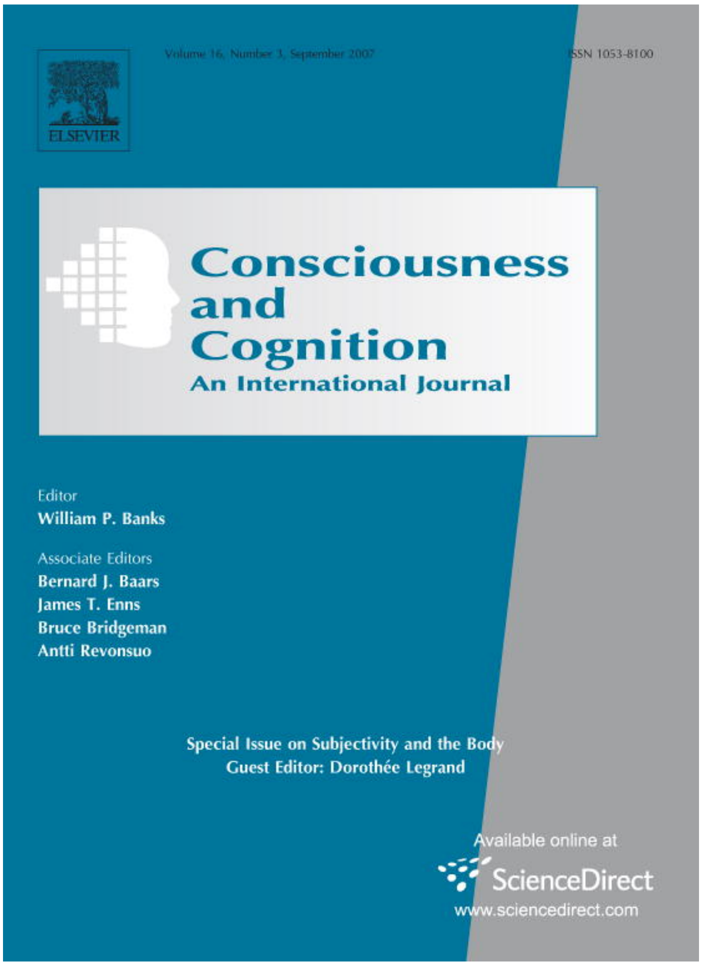
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Anticipating seizure: Pre-reflective experience at the center of neuro-phenomenology

Claire Petitmengin [a,b,*], Vincent Navarro [c,d], Michel Le Van Quyen [d]

[a] *Institut National des Télécommunications (GET/INT), Paris, France*
[b] *Centre de Recherche en Épistémologie Appliquée (CREA), Paris, France*
[c] *Epilepsy Unit, Pitié-Salpêtrière Hospital, Paris, France*
[d] *Neurodynamics Group, Laboratory of Cognitive Neurosciences and Brain Imaging, (LENA), CNRS UPR 640, Pitié-Salpêtrière Hospital, Paris, France*

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This study is dedicated in the memory of Francisco Varela.

Abstract

The purpose of this paper is to show through the concrete example of epileptic seizure anticipation how neuro-dynamic analysis (using new mathematical tools to detect the dynamic structure of the neuro-electric activity of the brain) and ‘‘pheno-dynamic’’ analysis (using new interview techniques to detect the pre-reflective dynamic micro-structure of the corresponding subjective experience) may guide and determine each other. We will show that this dynamic approach to epileptic seizure makes it possible to consolidate the foundations of a cognitive non pharmacological therapy of epilepsy. We will also show through this example how the neuro-phenomenological co-determination could shed new light on the difficult problem of the ‘‘gap’’ which separates subjective experience from neurophysiological activity.

Keywords: Cognitive therapy of epilepsy; Epileptic seizure anticipation; Ictogenesis; Explanatory gap; Lived experience; Micro-genesis; Neuro-phenomenology; Phenomenology; Pre-reflective experience; Subjective experience; Synchrony analysis

1. Introduction

The purpose of this paper is to show through the concrete example of epileptic seizure anticipation how neuro-dynamic analysis and ‘‘pheno-dynamic’’ analysis may guide and determine each other. On the one hand, the neuro-dynamic analysis will use new mathematical tools to detect the dynamical structure of the neuro-electric activity of the brain. On the other hand, the pheno-dynamic analysis will use new interview techniques to detect the pre-reflective dynamic micro-structure of the corresponding subjective experience. We will show that this dynamic approach to epileptic seizure makes it possible to consolidate the foundations of a cognitive non pharmacological therapy of epilepsy. We will also argue through this example that

* Corresponding author. Address: Institut National des Télécommunications, 9 rue Charles Fourier, 91011 Evry, France. Fax: +33 01 60 76 44 93.
E-mail addresses: claire.petitmengin@int-evry.fr, claire.petitmengin@shs.polytechnique.fr (C. Petitmengin).

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neuro-phenomenological co-determination could shed new light on the difficult problem of the ''gap'' which supposedly separates subjective experience from neurophysiological activity.

2. Context of the project

2.1. The neuro-phenomenological program

The founding idea of neuro-phenomenology, a research program initiated by Varela (1996, 1997), is the following: in order to progress in the understanding of the human mind it is indispensable to try ''to marry modern cognitive neuroscience and a disciplined approach to human experience, with respect to the continental tradition of phenomenology'' (Varela, 1996, p. 330). The neuro-phenomenological program is closely linked to the development of a *dynamic* approach to cerebral activity as well as to subjective experience.

On the one hand, and in line with dynamic systems theory (Nicolis & Prigogine, 1977), the brain is considered as a complex system that cannot be understood by studying its different zones separately, but by highlighting its general (spatial and temporal) dynamics. The cerebral activity associated with the realization of a given cognitive act is a global process that unfolds in time (Freeman, 2001; Le Van Quyen, 2003; Thompson & Varela, 2001; Varela, 1995).

On the other hand, according to neurophenomenology, subjective experience, far from being the passive reflection of the properties of the external word, is an active process that also develops in time.[1] A dynamical description of experience supposes a departure from the naive belief that becoming aware of one's lived experience is immediate and easy. Moreover, a large part of our cognitive processes is pre-reflective,[2] i.e., unfolds below the threshold of consciousness. But it is possible to gain access to it thanks to very specific expertise that may be learned and perfected.[3] ''There are numerous instances where we perceive phenomena pre-reflexively without being consciously aware of them, but where a ''gesture'' or method of examination will clarify or even bring these pre-reflexive[4] phenomena to the fore'' (Varela & Shear, 1999b, p. 4).

Neurophenomenology argues that unfolding this twofold dynamic is what allows the articulation of neurological activities and subjective experiences. Therefore the development of this program presupposes the design of suitable methods for:

(1) Analyzing the global dynamics of cerebral activity associated with a given cognitive process.
(2) Collecting rigorous and precise descriptions of the dynamics of the corresponding subjective experience.
(3) Establishing correlations between these two dynamic structures and refining their process of reciprocal determination.

The neuro-phenomenological method is experimented on and tested by a growing fringe of researchers in both the cognitive field (Cosmelli et al., 2002; Lutz, Lachaux, Martinerie, & Varela, 2002) and the clinical field (Price, Barell, & Rainville, 2002; Rainville, 2005). The goal of this article is to evaluate the relevance of this approach, on the basis of the description of an ongoing neuro-phenomenological project, that of the anticipation of epileptic seizures, initiated by Francisco Varela.

3. Methods and results

A double approach, both neurological and phenomenological, led to find that epileptic seizures can be anticipated. We'll first present the neurological aspect of these findings, then its phenomenological aspect, and finally the search for correlations between these two dimensions.

[1] Even a very brief subjective event such as the emergence of a visual perception or a mental image, has a micro-dynamics.

[2] The term ''pre-reflective'' (in French ''pré-réfléchi'', to use the vocabulary of Husserl (1977), later adopted by Sartre (1936, 1938) and Ricœur (1949)) qualifies the part of our lived experience which, although ''lived through'' subjectively, is not immediately accessible to consciousness, introspection, or verbal report.

[3] On the need to develop specific methods for studying lived experience: (Depraz, Varela, & Vermersch, 2003; Varela & Shear, 1999a; Varela, Thompson, & Rosch, 1993). For a synthesis of the difficulties of becoming aware of one's pre-reflective experience: (Petitmengin, 2006b).

[4] In this quotation the term ''pre-reflexive'' is equivalent to ''pre-reflective''.

3.1. Neuro-dynamic analysis of seizure anticipation

3.1.1. History of seizure prediction

Epilepsy is one of the most frequent neurological affections of children and adults: it affects about 1% of the world population. It is the consequence of a neuronal dysfunction that expresses itself by the sudden apparition of seizures. This unpredictability[5] is the main reason for the poor quality of life of epileptic patients and leads to permanent insecurity for them and their families. An epileptic seizure is due to an abnormal and transient hyper-activity of cerebral activity. This hyper-activity starts in an area which is called the epileptic focus, and then expands to the neighbouring areas and sometimes to the whole brain. The electroencephalogram (EEG) locates very precisely the onset of the seizure, especially if it is recorded by means of intracranial electrodes, which are in contact with the epileptic focus. However, before the critical discharge, no signal at the level of the raw EEG permits the anticipation of the emergence of a seizure.

Since 1975, researchers have used EEG analysis techniques such as pattern recognition or analytic procedures of spectral data for the prediction of seizures (Lange, Lien, Engel, & Crandall, 1983; Rogowski, Gath, & Bental, 1981; Viglione & Walsh, 1975). Their findings indicated that EEG changes characteristic for a preictal state may be detectable a few seconds before the actual seizure onset on EEG. Nevertheless, the complexity of EEG activity calls for the use of new mathematical methods in order to understand the underlying processes of ictogenesis. In the course of the last decade, developments in the physical–mathematical framework of the theory of nonlinear dynamics, often called *chaos theory,* have provided new concepts and powerful algorithms to analyze irregular behaviour of complex systems (Kantz & Schreiber, 2003). The fundamental assumption here is that EEG signals reflect the dynamics of coupled nonlinear interactions between neuronal populations. In this way, these methods allow the detection and characterization of hidden dynamical patterns that are not obvious to the human eye (see Faure & Korn, 2001 for an overview). The earliest attempts to use nonlinear time series analysis were made in the 1990s using the ‘‘largest Lyapunov exponent’’ to describe changes in brain dynamics (Iasemedis, Sackellares, Zaveri, & Williams, 1990). The investigators observed transient drops in the temporal evolution of this measure several minutes prior to seizures and claimed that EEG became progressively less chaotic as seizures approached. Similar results were also obtained from a variety of other nonlinear measures (Lehnertz & Elger, 1998; Le Van Quyen, Martinerie, Navarro, Boon et al., 2001; Martinerie et al., 1998) and indicate that seizures are not random events, but rather are related to ongoing dynamic processes that may begin minutes, hours, or days beforehand (see Litt & Echauz, 2002 for an overview). However, a problem with most of these studies is that the measures used to characterize the EEG are difficult to interpret in terms of their physiological correlate. Also, since almost all of these measures are univariate, i.e., related to only a single recording site, they fail to reflect any interaction between different regions of the brain.

Over the last 5–6 years, another method based on newly developed physical–mathematical concepts of synchronization (see Pikovsky, Rosenblum, & Kurths, 2001 for an overview), enabled researchers to focus on bivariate or, more generally, multivariate measures that permit assessment of synchronous activity from multiple sites (Le Van Quyen, Martinerie, Navarro, Baulac, & Varela, 2001; Le Van Quyen, Navarro, Martinerie, Baulac, & Varela, 2003; Mormann, Lehnertz, David, & Elger, 2000). Despite some skepticism about preliminary reports (see Mormann, Andrzejak, Elger, & Lehnertz, 2007 for a critical point of view), this method seems to be a promising approach for the investigation of the spatiotemporal dynamics of ictogenesis. The present research uses this method.

3.1.2. Method

The neuro-dynamic analysis of cerebral activity relies on the following strong hypothesis: the emergence of a cognitive act does not correspond to the activation of a particular area of the brain, but by the activation of a multiplicity of spatially distributed regions, that coordinate their activities through a mechanism of integration. The implied mechanism is temporal resonance: groups of anatomically distant neurons communicate transitorily by synchronizing their oscillating activities in time (Varela, Lachaux, Rodriguez, & Martinerie, 2001). This neuronal dynamic is not organized in a sequential order, as the ‘‘computer’’ metaphor would have it. On the contrary, this hypothesis emphasizes the importance of the properties of networks having reciprocal

[5] In Greek, *epilambanein* means ‘‘to fall suddenly’’.

connections, where the sequential character is replaced by a parallel process of network synchronization. One could take the analogy of an orchestra: suddenly, groups of distant instruments start playing on the same rhythm.

A network of synchronization is identified by an analysis of the electroencephalographic activity of the subject: electrodes are placed at different points either on the surface of the skull, or inside the skull (intracranial electrodes directly implanted in the brain of epileptic patients for presurgical evaluation). Each captor measures the frequency of the different cerebral rhythms emitted by the population of neurons situated in this point of the brain. A synchrony for a given electrode pair occurs when two neural populations oscillate in a precise phase-relationship that remains constant during a given number of oscillation cycles, in a given frequency range. This phenomenon is described as *phase-locking* (Lachaux, Rodriguez, Martinerie, & Varela, 1999).

The phase synchrony analysis method consists of identifying the evolution of neuronal synchronization during a given period (corresponding to the realization of a cognitive process), in order to try to detect a succession of characteristic neuronal configurations (or "signatures").

Our analysis followed several steps (see Le Van Quyen, Martinerie, Navarro, Baulac et al., 2001; Le Van Quyen et al., 2003 for details). First, signals from non-overlapping, consecutive 5-s periods were filtered with a bandpass corresponding to a particular frequency component. Second, the instantaneous phase of each filtered window was extracted by means of the Hilbert transform. Third, the degree of phase-locking between a pair of EEG channels was quantified by the trial-average of the phase differences on the unit circle in the complex plane (Lachaux et al., 1999). These values were computed over consecutive signal segments for all possible combinations of electrode pairs (from 20 to 55 channels) and for 50 frequency bands (2 Hz steps between 0 and 100 Hz). Because we are searching for preictal changes, it is important to determine which electrode pairs and frequency bands carry relevant information and which do not. Therefore, in the final step, we selected a subset of discriminating variables that optimizes the ability to distinguish between interictal and preictal states. For this training purpose, we compute for each variable a deviation distance between a chosen preictal state (30 min before the seizure onset) and a reference state chosen hour before seizures. A synchrony change is considered to be statistically significant when the *t*-index between the synchronization value of a electrode pair in a particular frequency range is above the critical value of $p = .01$.

3.1.3. Results

Twenty-six seizures from eight patients with neocortical focal epilepsy were analyzed. In the majority of the seizures, statistical differences between interictal and preictal states were revealed. Typically, the changes appeared to be concentrated in the middle frequency ranges from 10 to 25 Hz, mostly including the α and β bands. The distributions of these preictal changes varied by individual patient in space and frequency. Nevertheless, in 77% of the seizures, about 5 min before the seizure onset, a decrease in synchronization of the neuronal populations surrounding the epileptic focus is observed (see Le Van Quyen, Martinerie, Navarro, Baulac et al., 2001; Le Van Quyen et al., 2003 for details). This decrease is the exact converse of phase-locking, and is best described as "phase-scattering" (Rodriguez et al., 1999) where the probability of finding synchrony between two electrodes drops well below the interictal level.[6] In accordance with other observations (Mormann et al., 2000), these findings suggest that the participation of epileptic local networks in normal physiological synchronizations appears to be pre-ictally altered, inducing a state of higher susceptibility for seizure activity. Our present observations suggest that two related processes seem to be involved here (Fig. 1): (1) *A state of increased synchronization*. This state may reflect recruitment phenomena within the primary epileptogenic area and its surroundings regions. (2) *A state of decreased synchronization.* This state may isolate pathologically discharging neuronal populations of the epileptic focus from the influence of activity in wider brain areas, thus facilitating the development of local pathological recruitments. On the other hand, a loss of synchrony might also provide an 'idle' population of neurons which may be more easily recruited into the epileptic process. Finally, the preictal loss of synchrony could reflect a depression of synaptic inhibition in areas

[6] Inter-ictal (from Latin *ictus*: crisis) means "between two seizures". Pre-ictal means "before a seizure".

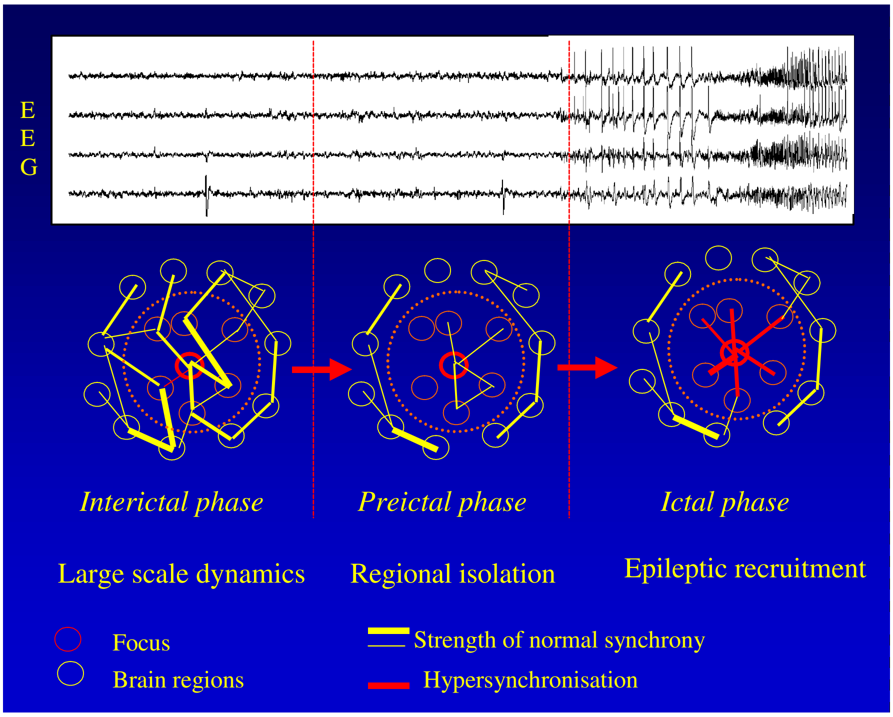

Fig. 1. The dynamics of neuronal synchronizations before and during a seizure.

surrounding the epileptogenic focus, as in certain experimental models of epilepsy (Matsumo & Ajmone Marsan, 1964).

These results show that the seizure does not arise suddenly, but that there is a transition from the interictal state to the ictal state. They also lead to the conclusion that the seizure does not correspond to the deficient functioning of a precise area of the brain, but to the deficient functioning of neural networks, related by abnormally facilitated connections.

But the synchrony analysis does not tell us anything about the way this transition and this deficit are (or are not) felt by the patient. It indicates the *structure* of the cerebral activity, not the *nature* of the subjective experience that could correspond to it. Therefore the following question arises: do the neuro-electric preictal modifications identified among epileptic patients correspond to modifications in their subjective experience, and if that is the case, what are they?

3.2. Pheno-dynamic analysis of anticipation

Concerning the patient's lived experience, the interictal and the preictal periods have not been much explored: the number of publications concerning them is minor (Gastaut, 1954; Marchand & de Ajuriaguerra, 1948; Rajna et al., 1997; Schulze-Bohage, Kurt, Carius, Steinhoff, & Mayer, 2006) compared to the huge amount of work concerning manifestations related to the seizure itself, and to the so-called "aura". The aura (or simple partial seizure) corresponds to the sensations related to the irruption of a seizure, i.e., ictal manifestations, associated with visible electrical modifications on the EEG. Auras are usually brief, lasting a few seconds or minutes (less than 5 min). Auras can be isolated, or can evolve into a complex partial seizure. As they provide crucial information in localizing epileptogenic zones where the seizure starts, neurologists and epileptologists are involved in identifying auras. On the other hand, preictal symptoms, also called prodromes, premonitory sensations, or warning symptoms, are less studied or acknowledged, probably because they seem to have no localization value. Moreover, their investigation has relied almost entirely on the use of questionnaires, which are not sufficient to obtain precise and reliable first person descriptions. These prodromes are the sensations we are intending to investigate, thanks to specific interviewing methods.

3.2.1. Methods

3.2.1.1. Extracting descriptions from the preictal subjective experience. We used specific interview methods which help the patient to become aware of his pre-reflective experience and describe it.[7] This pre-reflective character, which concerns subjective experience in general, is more pronounced in the case of preictal experience for two reasons: (1) the belief, firmly anchored in the environment of the patients and reinforced by the medical discourse on epilepsy, in the suddenness and the unpredictability of seizures, which considerably hampers awareness of their early symptoms; (2) the fact that the perception of warning signals often triggers an emotional reaction of distress and panic, which in turn hampers the perception of these signals. This pre-reflective character explains the paucity of initial verbal self-reports on preictal experience. The process of explicitation unfolds in four stages:

– First, we choose a particular seizure from the past, of which the patient retains a memory. If the patient sometimes feels warning sensations, we choose a seizure in which these sensations were especially vivid; if he does not, we choose a recent seizure, or an earlier one that he remembers particularly. Then we have to identify the right moment to begin the description. In case of warning sensations, we choose a temporal marker shortly before the start of these sensations, and begin the description there. If the patient did not feel anything in particular, we start from the morning preceding the seizure.

– Second, we guide the patient towards a concrete evocation of this particular preictal experience, by helping him to rediscover, in a very precise manner, the images, sensations, and sounds that are associated with his experience, until he feels that he is ''reliving'' it. A set of precise clues, which may be verbal (such as the use of the present tense), para-verbal (such as the slowing of the word flow) or non-verbal (such as co-verbal gestures, or the shifting and unfocusing of the eyes, i.e., the fact that the subject disengages with the interviewer and looks off into empty space, beyond the horizon), enables the interviewer to check that the patient is really going back into a past experience.

– Third, when the evocation is sufficiently stabilized, we use appropriate questions to help the patient turn his attention towards the various registers of his experience: the visual, kinaesthetic, auditory, and olfactory registers, the emotional tone and the internal dialogue—which may have been pre-reflective until then. To detect pre-reflective sensations, we rely on a set of precise verbal and non-verbal clues. For example, noticing non conscious co-verbal gesture of the patient may help us to draw his attention to a warning symptom. It was the case for Christelle, who repeatedly passed her hand over her forehead, which we finally pointed out to her: she then became conscious of a sensation, which until then had been pre-reflective, of a ''slight touch, like a breeze, a veil that lightly touches my forehead'', which marked for her the onset of a seizure. Our prompts also rely on clues of implicit information in the patient's discourse, for example: *At that point I get off my bike/Why do you get off your bike?/(Silence...) I know that I'm about to have a seizure/How do you know that you are about to have a seizure?/(Silence...) Because I feel this sensation of compression in my lungs...* When a specific sensation is identified, our questions help again the patient to direct his attention towards pre-reflected dimensions of this sensation, on which he is not trained to focus his attention. In a first stage, we explore the structural characteristics of the sensation: for example, the size and precise localization of a bodily sensation. In a second stage, we explore the process of emergence of this sensation, its genesis: we help the patient to divert his attention from the sensation once it is stabilized, towards the dynamics of its appearance. For example, the initial description of a ''sensation of panic'' unfolded into the following sequence: ''*There's this headache: a circle in front of me down to the cervix. And which presses in all around the head, then a feeling of heat inside my body which rises from my stomach to my head. At the same time my heart accelerates. Then just after a little dizziness, like when one moves one's head quickly, but in this case without moving one's head. Right after there's a sensation of panic, of nervousness all over the body*''.

– Finally, we enable the patient to put his experience into words, the main difficulty being the paucity of vocabulary for describing these subtle sensations.

[7] For a description of these techniques and more bibliographical references, see (Petitmengin, 2006b; Petitmengin-Peugeot, 1999). For a complete description of one of these methods, the ''explicitation interview'' (Vermersch, 1994).

The average length of an explicitation interview was 1h30. All patients were interviewed at least twice. The subsequent interviews enabled us to collect more precise and/or complementary descriptions, especially when seizures had occurred in the meantime. In fact, it is an iterative process: the interviewer retrospectively draws the patient's attention to his warning symptoms, enabling him to become more and more aware of them at the very moment when a seizure is about to occur.

3.2.1.2. Analysing and comparing the collected descriptions. Once the descriptions are gathered, reorganization, analysis, and comparison are necessary to delineate and represent the structure of the experiences described.[8] The main stages are the following:

– We analyze each description in order to extract the micro-structure of the experience, i.e., the precise sequence of sensations and possible actions which constitute the experience. This structure is *specific* to a particular experience.
– Comparing these specific structures enables us to detect possible regularities on different levels: synchronic, diachronic or functional. A regularity on the *synchronic* level is a sensation of the same nature, for example a particular visual sensation preceding seizure, described several times by the same patient or by different patients. A regularity on the dynamic or *diachronic* level is a succession of sensations and mental or physical operations of the same nature. A *functional* regularity is a succession of sensations and mental or physical operations of different natures, but which are realized with the same objective, for example for avoiding or stopping a seizure. The detection of a (synchronic, diachronic, or functional) regularity among several specific structures enables the researcher to identify a (synchronic, diachronic, or functional) *generic* structure, which is progressively extracted from the initial descriptions through successive operations of abstraction.[9]

3.2.2. Patients population

Nine patients suffering from pharmacologically resistant partial epilepsy with subjective symptoms preceding their seizures were included (Table 1). They were selected from patients examined at the Epilepsy Unit of La Pitié-Salpêtrière Hospital in Paris. The selection criteria were (1) the ability to recognize a "high-risk" state for a complex partial seizure spontaneously, even without awareness of precise warning symptoms the description of which will be refined in the course of the interviews; (2) a capacity for introspection and self-expression which is sufficient to participate in a phenomenological interview. We excluded the patients whose elocution capacities were too much impaired. But we also noticed that belonging to a high socio-cultural category did not guarantee an easy access to one's lived experience, since the patient is more tempted to move from a description of the particular experience he has lived to a description of his representations and theoretical knowledge about this experience.

3.2.3. Results

All nine patients experienced auras (ictal phenomena), six experienced prodromes (preictal phenomena) (Table 1).

The auras were varied, depending on the suspected epileptogenic focus: vegetative ($n = 7$), dysmnesic ($n = 4$), psychic ($n = 3$), sensory ($n = 1$), or motor ($n = 1$).

The main prodrome (which was often described by the patients with very similar words) was a feeling of "tiredness", "weakness", "lack of energy", or "fragility" ($n = 4$). Other patients described a feeling of distress ($n = 3$), ill-being ($n = 1$), or "loss" ($n = 1$). These feelings may be associated with difficulties in concentrating and speaking ($n = 1$), clumsiness ($n = 2$), hypersensitivity to light ($n = 2$), noise ($n = 1$), or other stimuli ($n = 1$), and with headache ($n = 2$). Ictal symptoms may usually be described as "positive" since they often correspond to motor, sensory, or verbal hyper-activity. In contrast, prodromic symptoms frequently corre-

[8] The method we use for analyzing and comparing descriptions is described more precisely in Petitmengin-Peugeot (1999).

[9] For more details on these operations of abstraction (classification/instantiation, aggregation/disaggregation, and generalization/specialization) see (Petitmengin-Peugeot, 1999).

Table 1
Brain imaging data, prodromes and aura

Patient No.	Sex	Age of epilepsy onset (y)	Age at the time of the phenomenological interview	Epileptic focus	Prodromes	Aura (simple partial seizure)
1	M	16	38	Right frontal and temporal lobe	No (the seizure cancels what happens before)	Feeling of absurdity, tachypsychia, sudden reminiscences, epigastric oppression
2	F	1	38	Left medial temporal lobe	Morale pain, irritation provoked by various stimuli	Dejà vécu, warm feeling, breath difficulty
3	F	4	25	Left frontal operculum	Feeling of head compression since the awakening, buzzing in the ears, lower limb weakness, vertigo and distress	Day time seizures: (infrequent) right hand anaesthesia (or right nasal paresthesia), anxious, right upper limb elevation, then tonic posture of the four limbs and falls without loss of consciousness Nocturnal seizures: (frequent: each night) tonic posture of the four limbs starting by the right upper limb
4	M	12	53	Right medial temporal lobe	Feeling of tiredness, troubled by noise, bad mood (according to his wife). These symptoms sometimes occurred 24 h before the seizure	Dizziness, cold feeling in the lower limb, fear of dying as a ''earthquake''; rarely, thoracic oppression, then complex partial seizure
5	F	15	28	Left insula presumably	Feeling of discomfort, troubled by noise and light, concentration difficulty, clumsiness, headache, aching, elocution difficulty. These symptoms sometimes occurred 24 h before the seizure	Feeling to go out, feeling to lose the control of her body (''all is precipitating in her body), tachycardia, warm feeling, aphasia then loss of consciousness, and frequent secondary generalization
6	M	11	35	Right medial temporal lobe	No	Ascending epigastric warm feeling, dizziness, then complex partial seizure
7	F	16	23	Left parietal or insular lobe	Distress since the awakening	Right hand paresthesia, then modification of hearing perception, then complex partial seizure
8	M	5	31	Right medial temporal lobe presumably	Weakness and tiredness since the awakening	Feeling of flash or explosion in the head, tachycardia, distress, then complex partial seizure
9	M	10	24	Left medial temporal lobe	No	Ascending epigastric feeling, then sometimes déja-vécu, or dreamy state, nauseas, then complex partial seizure

spond to a decrease (of energy, of vitality), a lack (of concentration, of words, of physical balance) and may be described as "negative". They last, often intensifying, until the onset of the seizure.

The delay between prodromes and seizure was usually of several hours (until 24 h), whereas auras occurred a few seconds or minutes before the other ictal symptoms. Prodromes were continuous and progressive, whereas auras were sudden and intermittent.[10]

This is an extract of an interview with a 30-year-old woman (patient 5; Table 1) who identified a prodromic state before most of her seizures:

> "*This can be 24 h in advance. It's in the whole body, I feel ill at ease, inside, it's constant, and it won't leave me until the fit has manifested. What I feel is... a little as if my body was abandoning me, therefore it isn't responding as quickly as usual, taking longer to carry out the orders I give it. I will get a pain in the head, it starts at the forehead, passes to the temples and goes as far as the back of the neck, like a circle around the head, and then down the neck. (...)*
>
> *Then it's speech. I have a tendency to slur words, stammer, lots of little things like that. But not all the time: I might be talking correctly then in suddenly, oops!, the words won't come, I'll start coughing, steady myself and it will pass. Other things also, like slightly feverish but all over the body. It's like I said a while ago, that my body won't respond as quickly as usual. And also a lack of energy. If someone suggested doing something, going out, anything, I'll say no, because I don't want to do anything. Because I don't feel well, because things aren't going well (...) I have no energy, no vitality, no punch*".

All patients were also able to recognize facilitating or provoking factors. They consisted of tiredness ($n = 6$), stress ($n = 4$), sleep deprivation ($n = 3$), alcohol ($n = 3$), intermittent photic stimulation including video games ($n = 3$), or other rhythmic sensory stimulations ($n = 2$), emotion ($n = 1$), and relaxation ($n = 1$).

Finally, we found that patients spontaneously adopted different types of cognitive or behavioral countermeasures: (i) to avoid the seizure either by recognizing precipitating factors, or prodromes, (ii) to interrupt seizures during auras. The countermeasures were of a variable nature. Physical countermeasures consisted of motor (getting up, walking), sensory (rubbing the area where paresthesia occurred), or vegetative (regular breathing) activities. Mental countermeasures were internal (focusing on an object, internal monologue) or external (conversation). These countermeasures were initiated by the patient, or by relatives when they detected a seizure. As the goal of an explicitation interview, unlike that of a questionnaire, is not to collect quantitative estimations, but very precise descriptions of *a few* preictal experiences, we cannot give a precise evaluation of the success of these countermeasures. Nevertheless, we gathered some testimonies which reflect the beliefs of the patients about the effectiveness of their countermeasures, such as: "When a seizure is arriving, my friend tells me funny stories. For little seizures, it always works". Or "Sometimes, I can stop the seizure with this abdominal breathing, that I learnt when I was practicing yoga. But most of the time, it only delays the onset of the seizure".

In conclusion, this pheno-dynamic analysis shows that seizures do not always occur like a bolt from the blue: they are the result of an (often pre-reflected) micro-genesis.

3.3. Search for correlations between neuro-dynamic and pheno-dynamic structures

3.3.1. Method

3.3.1.1. Abstraction levels of the correlations. Fig. 2 represents in a simplified way the different activities of the neuro-phenomenological method: (1) activities of description/recording, analysis, and comparison (boxes), through which the researcher progressively abstracts[11] from cerebral activity and from experience more and more generic structures; (2) activities of correlation (horizontal arrows). This figure also represents the data treated by each of these activities and the results produced, while highlighting their levels of abstraction. It shows that a correlation between a neuro-dynamic structure and a pheno-dynamic structure may be achieved at a specific level (for us, an occurrence of seizure) or at a generic level (a set of seizures). The upper arrow

[10] These findings are confirmed by other studies, for example Rajna et al. (1997), Schulze-Bohage et al. (2006).

[11] From the Latin *abs-trah-o*: I ex-tract, I pull out of. For example, the researcher abstracts a description from an experience, and then a specific structure from this description, and then a generic structure from a set of specific structures.

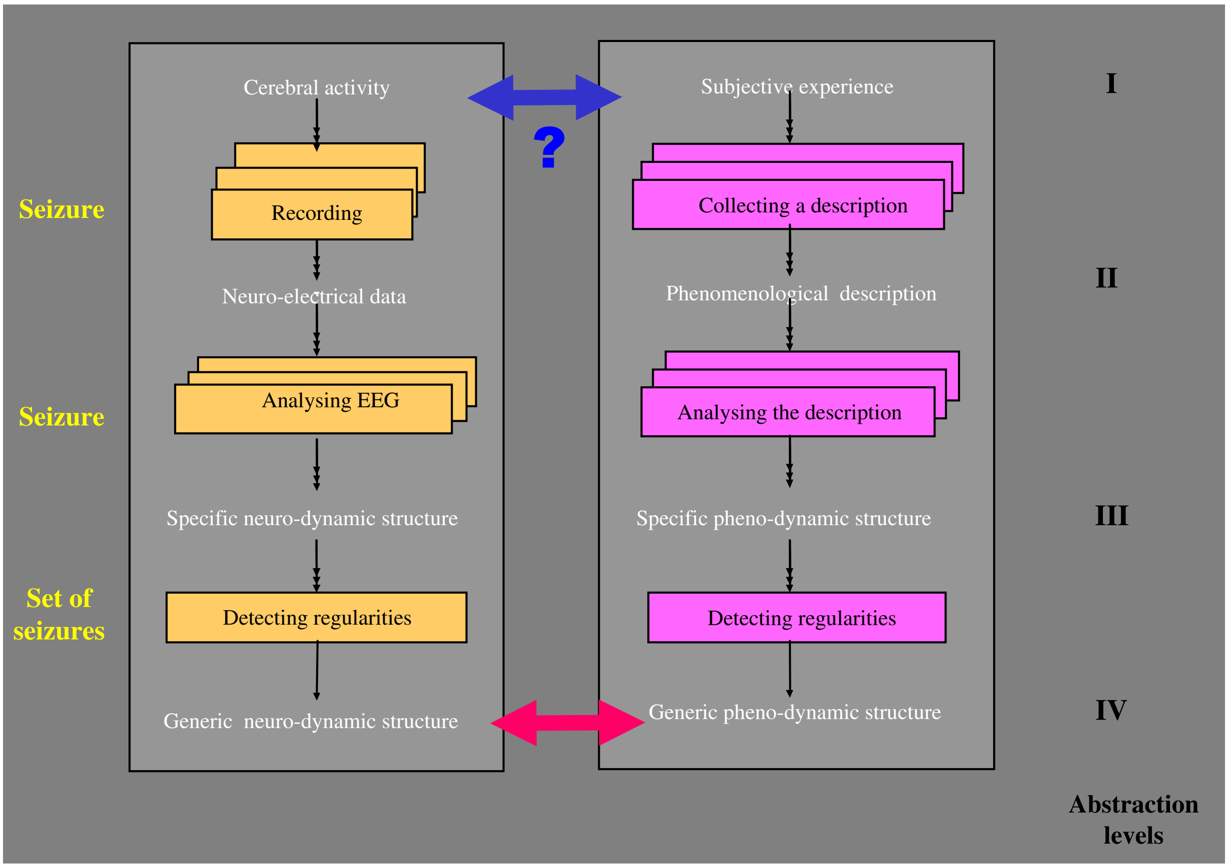

Fig. 2. Neuro-phenomenological activities.

symbolizes the question of the "gap" between cerebral activity and subjective experience, which will be dealt with in the next section.

The symmetry of these abstraction levels from the phenomenological and neuronal point of view, shown here in order to clarify the presentation of our results and further discussion, does not mean that the investigations in these two domains are executed in a parallel and independent way: as we shall see, the added value of the neuro-phenomenological method resides, on the contrary, in the interweaving of the operations of these two aspects, the discovery of a regularity at the neuro-physiological level triggering and determining the discovery of a regularity at the phenomenological level, and reciprocally.

A correlation between a neuro-dynamic structure and a pheno-dynamic structure consists of establishing:

(1) A temporal coincidence between the cerebral activity which is recorded and the subjective experience which is described.
(2) A possible correspondence between the neuro-dynamic structure (a succession of neuronal configurations) and the pheno-dynamic structure (a succession of subjective events) that corresponds to the former in time; this correspondence may take the form of an homeomorphism.[12]

3.3.2. Results

We tried to correlate the generic structure of the preictal subjective experience with the corresponding generic neuro-dynamic structure (Fig. 2, abstraction level IV) (Petitmengin, Navarro, & Baulac, 2006).

[12] In mathematics, a homeomorphism (from the Greek *homoios*: similar and *morphe*: shape) is "a correspondence between two figures or surfaces or other geometrical objects, defined by a one-to-one mapping that is continuous in both directions" (Encyclopedia Britannica).

3.3.2.1. Search for a temporal coincidence. First, we showed a time-lag: the decrease of neuronal synchronization occurs a few minutes before the seizure, whereas the state of fragility that seems to characterize the preictal period for the patients that we have interviewed, is felt several hours before the seizure.

The detection of this state suggested that electro-encephalogram should be analyzed in the long term. An analysis of the evolution of cerebral synchronization has thus been achieved from the intracranial recordings of a group of five patients suffering from epilepsies of the medial side of the temporal lobe, and having been monitored continuous EEG-video recording 24 h on 24 (about 50 seizures and 305 h of recording were studied). This analysis enabled the discovery of a ''preictal state'' characterized by a desynchronization of the neuronal populations related to the epileptogenic focus, up to 5 h before the seizure onset (Le Van Quyen et al., 2005). These observations have been confirmed by other studies (Mormann, Andrzejak et al., 2003; Mormann, Kreuz et al., 2003).

The neuro-dynamical analysis, here guided by the phenomenological analysis, seems to show that the seizure is just the ''tip of the iceberg'', the climax of a process that starts long before.

3.3.2.2. Search for a structural correspondence and working hypothesis. We noticed that, interestingly, prodromi were frequently referred to as ''negative'' symptoms (''weakness'', ''lack'', ''loss''), which subsist while intensifying until the onset of the seizure, whereas auras were frequently referred to as ''positive'' symptoms, appear brutally and last a short time. We hypothesized that the subjectively negative character of prodromi and the progressive increase in their intensity, observed among five patients in this study, could be correlated with the progressive loss of phase synchrony observed during the preictal period, and therefore be the clinical expression of the phenomenon. On the other hand, the ''positive'' and sudden character of the symptoms related to the aura seemed to correspond to the hyper-synchronization observed as soon as the onset of the seizure (Fig. 3). This concomitant evolution led us to hypothesize a homeomorphism between the preictal neurodynamic and pheno-dynamic structures.

4. Consequences and lines of research

> ''Exploring the pre-reflexive represents a rich and largely unexplored source of information and data with dramatic consequences''[13]

4.1. Therapeutic consequence: a cognitive therapy of epilepsy

The discovery that an epileptic seizure may be anticipated opens an unexpected research line towards a non-pharmacological, cognitive therapy of epilepsy. The key to this therapy is the awareness of usually pre-reflective warning symptoms, that opens a temporal interval during which the patient can take some countermeasures to avoid the seizure, to stop it, or at least to protect himself from it. Five of the nine patients we interviewed developed countermeasures of a physical or mental nature spontaneously. The type of countermeasure chosen is different depending on whether the premonitory sensation belongs to the aura or not. The earlier the awareness of the warning symptom is, the more efficient the countermeasure seems to be.

Several research groups, interested in cognitive control of seizures, showed promising results (Wolf, 1997). Dahl (1992) proposed adapting countermeasures to the preserved brain functions at the beginning of seizure, by activating healthy neuronal networks surrounding the presumed epileptogenic focus. For example, if the patient has speech problem, because the focus is close to the area of language, he would be encouraged to talk.

Schmid-Schönbein (1998) suggested that young patients may generate a cognitive state similar to that of the postictal inhibitory period, where the probability of seizure reoccurrence is weak, using biofeedback strategies. The biofeedback device, since it gives the patient a real time picture of his cerebral working, enables him (1) to become more conscious of the variations of his interior state, (2) to learn to reproduce them voluntarily. One of the programs of seizure control achieved by Schmid-Schönbein (1998) has been carried out with 16 children: the treatment lasted between 3 and 30 months according to the children. 68% of the children had a reduction

[13] Varela and Shear (1999b, p. 4).

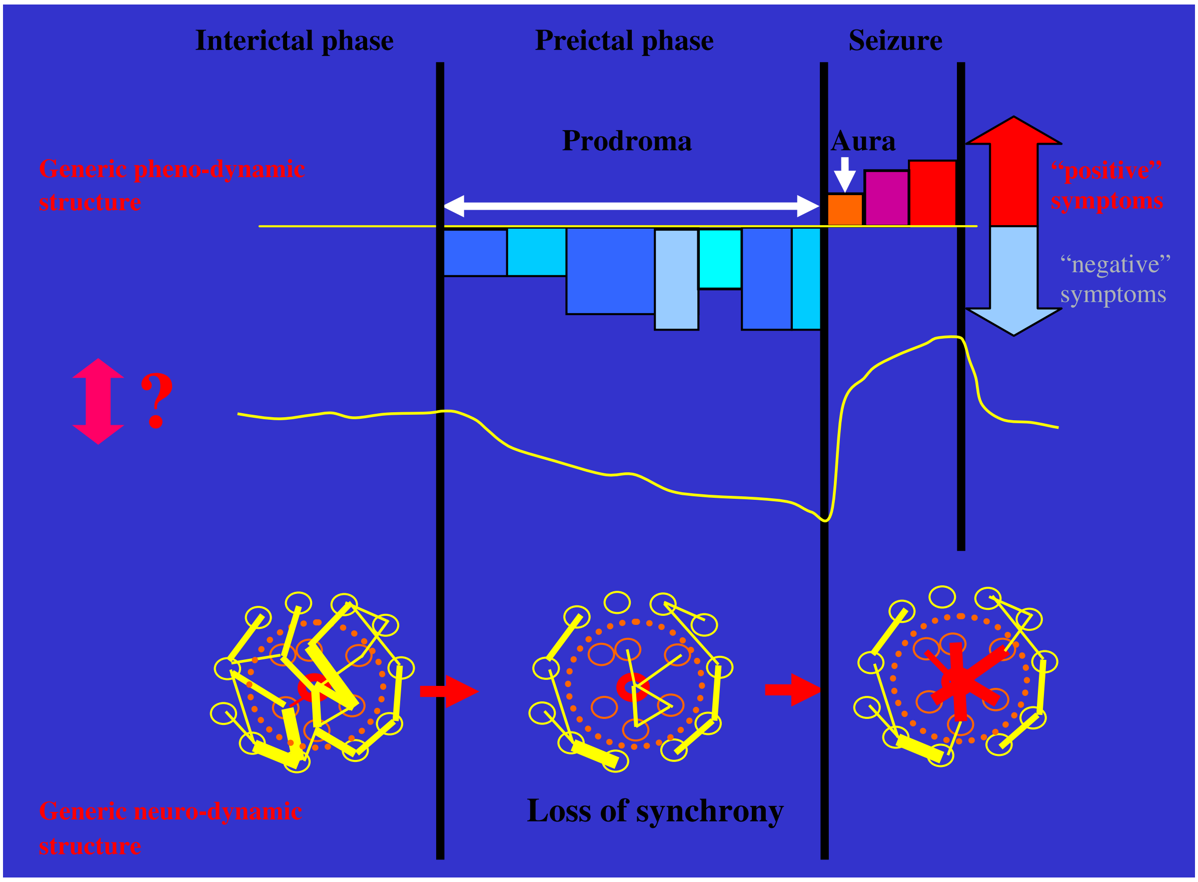

Fig. 3. Correlating pheno-dynamic and neuro-dynamic structures.

of 80–100% of the number of their seizures, 12% a reduction of 60–70%. In the program described by Reiter and Andrews (2000), 79% of the 45 patients succeeded in controlling their seizures completely.

The setting up of countermeasures, like the detection of preictal symptoms and provoking or facilitating factors, is not immediate, it requires long-term training. Moreover, epilepsy often seems to fulfil a function in the life of the patient and his whole family[14]: the cognitive treatment must then be accompanied with a deep reorganization of his life and his familial and social relations. But this treatment gives him the possibility to take control of his life, until now under the sword of Damocles of the seizure. The patient learns to enter a relationship with his seizures in a different manner: to observe them instead of only dreading them, to familiarize himself with them; and in a way to become reconciled with them. He learns to become an actor in his relationships with others, starting with his physician: indeed the patient plays an extremely active role in the specification of the treatment, and at the end of the treatment, he will control his seizures alone. This therapy initiates for the patient a deep transformation of himself, that is a key to his recovery.[15]

The neuro-phenomenological approach to seizure anticipation contributes to the development of these cognitive therapies, for several reasons. First, the identification of a particular neuronal configuration before the onset of a seizure reinforces the hypothesis of the existence of preictal sensations, which until now were not taken seriously and little studied, and therefore to the possibility of cognitive therapies. Moreover, this approach helps to enrich and refine these therapies:

– Through the development of suitable interview techniques, which enable the therapist to guide the patient towards becoming aware of his preictal symptoms and describing them, and then specifying countermeasures.

[14] See for example Soulayrol (1999) and Diebold (1999).
[15] On this topic the reader may refer to the very interesting testimony of Benak (2001).

– Through the setting up (in progress) of biofeedback devices based on cerebral synchrony analysis, which facilitates the awareness of premonitory sensations and the setting up of countermeasures.

Looking beyond epilepsy, becoming aware of the pre-reflective micro-genesis of a given cognitive process develops the possibility of transforming it. The neuro-phenomenological approach thus opens up promising paths in both the medical and pedagogical field.

4.2. Lines of research

The rough homeomorphism that we have identified could be made more precise, thanks to finer comparisons of the neuro-dynamic and pheno-dynamic structures. This may be done in several ways:

– Realising correlations at the specific level of *one* crisis (Fig. 2, abstraction level III), before establishing possible specific and generic homeomorphisms. We plan to perform simultaneous analyses of EEG synchronization and subjective correlates, among patients in presurgical evaluation of their intractable partial epilepsy justifying intracranial EEG electrodes.

– On the neurophysiological side, taking functional neuroanatomy into account by identifying more precisely the regions of the brain where the preictal synchronization or desynchronization occurs. Several studies have analyzed the brain location of preictal changes. Some of them, using linear or non-linear methods, have found that preictal changes were more pronounced in the epileptogenic focus than in remote areas (Litt, Esteller, & Echauz, 2001). According to these findings, the preictal state may result from a progressive build-up into the focus. Observations of our research group using non linear analysis suggest on the contrary that preictal changes are not only related to the epileptogenic focus, but can also be detected in remote brain areas (Le Van Quyen, Martinerie, Navarro, Boon et al., 2001; Navarro, Martinerie, & Le Van Quyen, 2002; Navarro et al., 2005). Thus, the preictal state may result from a widespread change of the brain activity. Our phenomenological results further suggest that prodromes (difficulties in concentrating, speaking, together with headaches, or distress) are not specific to a brain area, but related to a widespread dysfunction of the brain activity (whereas auras are always specific to the epileptogenic focus). We did not observe the preictal deficit of a (cognitive or sensory-motor) function related to a specific brain area, followed by an ictal hyperactivation of this function, which could be the respective subjective correlates of the preictal desynchronization and ictal synchronization. Nevertheless, additional studies, simultaneously combining phenomenological and neuro-electric analyses, are needed to explore this possibility in more detail.

– On the phenomenological side, identifying more precisely the dimension of subjective experience which could conceal the echo of the cerebral synchronies. Indeed synchrony analysis permits the discovery of some very subtle variations of rhythm, and modifications of the cerebral synchronization at very short intervals (a few hundreds of milliseconds). Which dimension of subjective experience could be correlated with such subtle and rapid variations? Exploring the micro-temporality of lived experience, thanks to the refinement of first and second person methods, has permitted us to discover a deeply pre-reflective dimensions of subjective experience, whose structure is quite different from its more superficial structure. First, the frontier between the different sensory modes is far more permeable than in our more conscious experience. This transmodality is associated with a transformation of the separation usually perceived between the interior world and the outside world, which is described as far less rigid or even absent. In a concomitant manner, the feeling of individual identity changes: it becomes ‘‘lighter’’ or even disappears. It is in the micro-dynamisms animating this primitive dimension that moment after moment our feeling of identity and our relationship to the world seem to be played out. The epileptic seizure, often described as the dramatic loss of all points of reference, the downfall of the world and the loss of identity, could originate in this very deep dimension of our experience, from a disruption of this original rhythmic process. More generally, it is in this felt dimension, close to our body but made of a more subtle texture, which seems to be situated at the hinge between the physical and the psychic, that we could discover the subtle rhythms which could be correlated to the cerebral rhythms. We try to collect a very precise description of this dimension, which until now has been little explored because it is deeply pre-reflective and thus particularly difficult to become aware of, and to identify its dynamic micro-structure (Petitmengin, 2007).

– Finding a unique, intermediate and neutral formalism (symbolic or analogical), that would allow the representation of both neuro-dynamic and pheno-dynamic structures (this being especially difficult for the latter) (Varela, 1997). One of our lines of research consists of constructing neuronal and phenomenal dynamical landscapes or ''state spaces'' (Le Van Quyen, 2007) and researching homeomorphisms between them.

– Identifying the neuronal correlate of therapeutic countermeasures. A few marginal studies have highlighted the modulation of an epileptic activity by a cognitive act. Penfield and Jasper (1954) have described a parietal seizure blocked during a complex mathematical calculation. Fenwick (1981) has reported a biofeedback experiment where a patient was able to watch online the count of epileptic spikes arising from the temporal structures. She was asked to try by an act of will to reduce the number of spikes. She gradually learned to reduce the number of spikes compared with the control period, with a subsequent reduction of her seizure frequency. Le Van Quyen et al. (1997) analyzed the sequence of intervals between spike discharges in a particular patient with an unusually focal and stable occcipito-temporal discharge. This analysis showed that the spikes display a distinct periodic activity for a short time before they progress to a different temporal pattern. This periodic activity was modulated by perceptual tasks engaged by the patient in the gamma frequency range (30–70 Hz) (see also Le Van Quyen & Petitmengin, 2002). Fenwick (1994) had suggested that the correlate of the countermeasures for stopping seizures could be the inhibition of the neurons surrounding the epileptogenic focus. The countermeasures proposed by Dahl (1992) in her therapeutic programs consisted on the contrary in activating healthy neuronal networks surrounding the presumed epileptogenic zone: for example, if the focus is related to the centre of language, the patient is incited to talk. In view of our results from phase synchrony analysis, we now hypothesize that such countermeasures are effective because they prevent the isolation of neurons in the epileptogenic focus using recruitment of surrounding neurons or a more global re-synchronization of distant areas of the brain. Further testing of this hypothesis would require a systematic search for the neuronal correlates of therapeutic countermeasures, a future line of research for the neuro-phenomenological analysis of anticipation.

4.3. *Epistemological implications*

As soon as its first formulation by Varela (1996), the neuro-phenomenological program claimed to shed new light on the explanatory gap (Levine, 1983)[16] which separates objective biophysical processes from lived experience. What sort of light do our attempts to articulate pheno-dynamic and neuro-dynamic preictal structures shed on this question?

4.3.1. *Questions of correlation*[17]

Comparing phenomenal and neuronal structures enabled us to hypothesize a homeomorphism. Although this homeomorphism is still rough, it permits us to suppose a certain correspondence between the cerebral activity and the subjective experience analyzed, and therefore to make a hypothesis about the *nature* of the subjective experience corresponding to the neuro-dynamic modifications we discovered. More precisely, the existence of a homeomorphism between the progressive decrease of preictal synchronization and the intensification of the ''negative'' state felt before the seizure, permits us to suppose a link between the particular quality of this experience—loss of consistency, of energy, of meaning—and the observed desynchronization. As

[16] The ''explanatory gap'' is the core of the ''hard problem'' formulated by Chalmers (1996): *why* does conscious experience emerge from some neuro-physiological processes. The reader will find a presentation of this problem in Roy, Petitot, Pachoud, and Varela (2002). The recent article of Bitbol (2006) contains a summary of the theories—Behaviorism, Theory of identity, Eliminativism, Functionalism, Idealism—that tried to solve the problem, without providing any satisfactory solution.

[17] This paragraph is inspired by Petitmengin (2005, pp. 86–87).

Fig. 2 shows it, *through the intermediary of a homeomorphism of their dynamic structures* (lower arrow, abstraction level IV), which are themselves the products of a succession of complex transformations (i.e., the progressive extraction of generic structures from cerebral activity and subjective experience), we may have established a footbridge between cerebral activity and subjective experience (upper arrow, abstraction level I).

But while achieving these transformations, we have not reduced one level of abstraction to the other. The quality of lived experience cannot be reduced to its dynamic structure, neither to its description: it is not sufficient to read or to hear the description of an experience to access the corresponding experience (in our example, to know "what it is like" (Nagel, 1970) to feel the imminence of an epileptic seizure). From an experience to its description (i.e., between level I and level II), a dimension is irremediably lost. At the very most, a description can trigger the described experience, or enable me to recognize it, if I have already lived it. In the same way, cerebral activity cannot be reduced to its dynamic structure, nor to its neuro-electric activity. Moreover, cerebral activity itself is only one element of a much more complex system, of which some dimensions are probably still unsuspected, implying not only our body but our whole environment. In other words, "the mind is not in the head" (Thompson & Varela, 2001; Varela, 1999).

Therefore the footbridges that we are establishing between the neurobiological and the phenomenal sides of the gap only enable us to begin to detect from one side the echo of the rhythms of the other. They enable us to anticipate the seizures better, and to understand[18] the preictal dynamics better. But they still do not enable us to explain how the peculiar quality of "this sensation of the absurd, with a very characteristic texture, that marks for me the perimeter of the seizures" can emerge from a neuronal desynchronization. Bringing the pheno-dynamic and neuro-dynamic structures (Fig. 2, level IV) closer does not permit us to eliminate the distance that separates them from lived experience and from cerebral activity (Fig. 2, level I). This attempt only highlights another gap, the gap that separates the formal structure of a domain from its nature[19]

If in future the designing of suitable protocols enables us to identify the neurological correlate of the cognitive countermeasures for controlling seizures, and the dynamical structure of the process of interruption of an emergent seizure, correlating the neuro-dynamic and pheno-dynamic structures would enable us to build another type of footbridge. We could hypothesize, through the intermediary of the corresponding pheno-dynamic and neuro-dynamic structures, that a conscious cognitive act is one element in *constraining* cerebral activity. Thompson and Varela (2001) called this constraint *global-to-local determination* or *downward causation*. Such investigations are interesting to develop since most research in cognitive sciences relies upon the presupposition, and seeks to prove, that cerebral activity determines subjective experience, but not the inverse. However, highlighting this link would still not permit us to close the gap, i.e., to explain the phenomenal character of a cognitive act by the corresponding neuro-dynamic structure.

4.3.2. Questions of co-constitution

Another track of exploration of the "gap" (complementary to the first) opens up at another level. It does not consist in trying to bring closer the neurological and phenomenological structures, but in observing, at a meta-level, the way these structures construct themselves, i.e., the *neuro-phenomenological circulation process* itself. In other words, it does not consist of detecting and comparing specific preictal states at the neurological and phenomenological levels, but of observing this very process of detection and comparison. It is not a matter of analyzing the ictogenesis, but the genesis of this analysis itself.

First, this meta-observation shows that the neurological analysis and the phenomenological analysis guide and enrich each other. Indeed, the discovery of a new neuro-dynamic structure (the preictal neuro-electric desynchronization) permitted a refinement of the consciousness of the corresponding experiential dynamics (preictal symptoms and therapeutic countermeasures) (Fig. 4, arrow no. 1). Reciprocally, a refined consciousness of the experiential dynamics enabled the detection of an original structure in the neuronal dynamics (neuronal desynchronization at a distance of the seizures) (Fig. 4, arrow no. 2): in this second case, it is the

[18] Indeed, a homeomorphism between A and B brings elements of *explanation*, in the sense that "A is linked to B by a law". This does not mean at all that A is reducible to B, or B to A. And this link is symmetrical (if A is linked to B, B is linked to A).

[19] On this topic, we fully agree with Baynes (2004): "Formal models can only capture the structure of a domain; they cannot capture its intrinsic nature. Those who think that the hard problem is hard do so because they think that the phenomenal character—the "what it is like" of experience—cannot be fully captured by structural descriptions" (Baynes, 2004, p. 13).

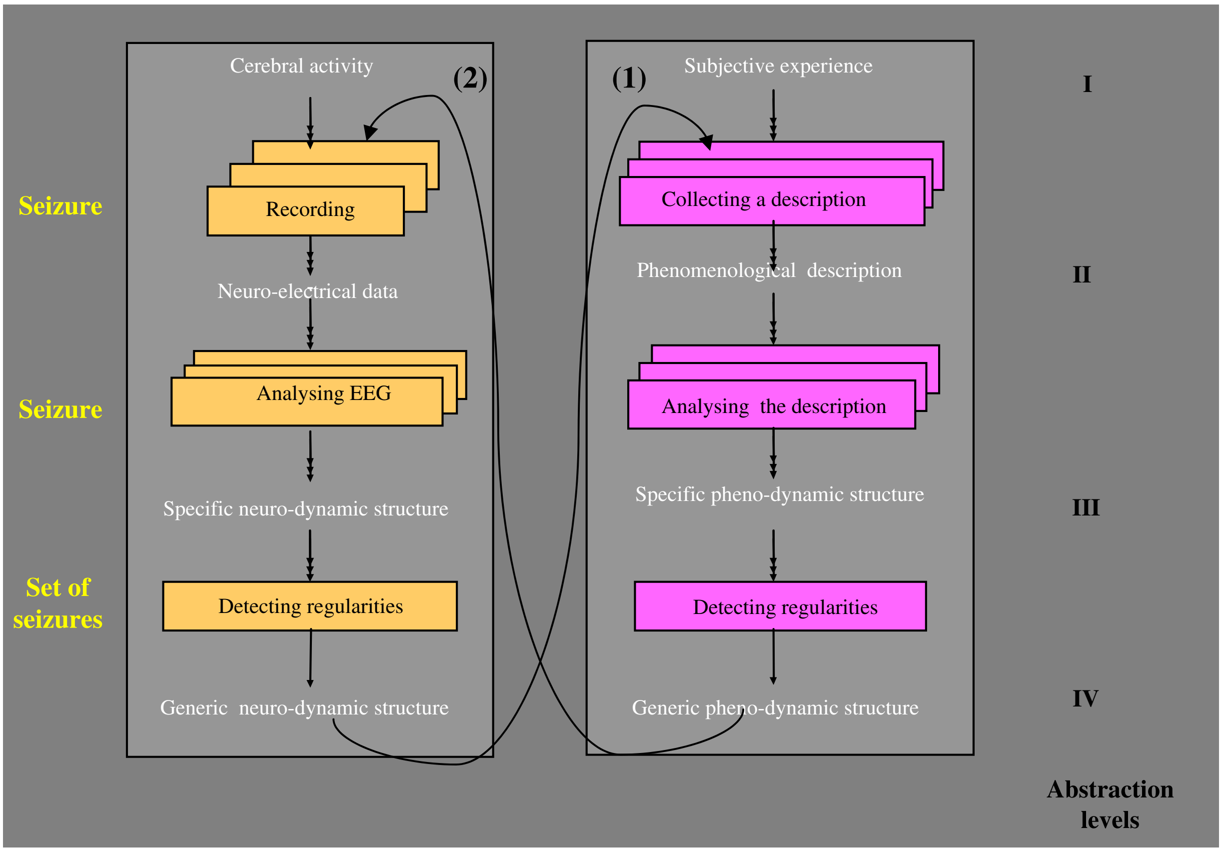

Fig. 4. Co-constituting the pheno-dynamic and neuro-dynamic structures.

phenomenological analysis that guided the neuro-dynamic analysis. In a different research context, this result confirms the heuristic character of the research strategy inaugurated by Antoine Lutz,[20] which consists of detecting an unobserved structure in the neuronal data by using phenomenological categories (Lutz, 2002; Lutz et al., 2002; Lutz & Thompson, 2003). We notice that in both cases, it is the temporal unfolding of the phenomenological description—becoming aware of the pre-reflective *genesis* (of a 3D perception, or of an epileptic seizure)—that enables the refinement of the neuro-dynamic analysis.

The neuro-phenomenological method therefore does not consist here of a simple "static" comparison of results that would be achieved independently. But it does not limit itself either to a heuristic process, the discovery of a regularity on one side triggering investigation on the other. We observe a real interweaving of the construction processes (that Varela (1997) called "mutual generative constraints"): the results achieved on one side do not only trigger, but *structure* the process of analysis and the results achieved on the other side. This intertwining of the pheno-dynamic and neuro-dynamic analyses is especially well highlighted in the protocol of Lutz, where it is the use of an experiential category as a criterion for neuro-dynamic analysis that enables the detection of an original structure on this level (which confirms in turn the relevance of that category). Far from being constructed independently, the phenomenological and neuro-dynamic structures result from a complex process of mutual stabilization, selection, adjustment and validation, of a real "dynamics of reciprocal elaboration of the phenomenological and physico-physiological sides" (Bitbol, 2006).

Does this co-constitution of the two sides of the gap concern only the description and analysis levels (levels II to IV)? Or does this co-constitution originate in an even more fundamental process, at the experiential and neuronal levels (level I)? For example, the dynamic refinement of neuronal analysis contributes to making the patients conscious of the pre-reflective premises of their seizures. The effect of this analysis is therefore to transform not only our *knowledge* of the preictal experience (which from nothing, gains the status of object of personal and scientific investigation), but the experience itself. The neurological analysis contributes to

[20] This neuro-phenomenological research of Lutz deals with 3D vision.

enriching not only the description, but the lived experience of the patient himself: it gives him access to a pre-reflective part of his experience that until now was inaccessible to him, and while enabling him to control his seizures, this consciousness will deeply transform his existence.

Conversely, the dynamic refinement of phenomenological analysis permits the discovery of a succession of characteristic neuronal configurations or ''signatures'' where until now only noise was perceived. Can one consider that these structures existed in the neuronal dynamics before the researcher detected them? On the contrary it seems to us that the neuro-electric activity is not ''given'', but that it is the result of a very complex construction process, of which every stage is determined (in a pre-reflective and implicit manner) by the degree of consciousness that we have of our subjective experience,[21] and limited and constrained by the previous stages of the process.

In this perspective, the question of the gap is being transformed: it is no longer enough to explain the lived experience by its hypothetical neuro-physiological substratum, but to understand the process of co-determination of the objective and subjective poles, a process of which neuro-phenomenological circulation seems to be only a late instance (Petitmengin, 2006a, 2007). The question is no longer exhausting ourselves bringing closer the two sides of the gap—reducing one to the other, eliminating one for the other, or explaining one by the other—but to adopt quite a different point of view: to observe how the gap constitutes itself, and the different stages of this constitution. In this perspective, the question is not to try to eliminate all trace of subjectivity, but to observe how lived experience intervenes at the different stages of the co-construction of the two sides. The neuro-phenomenological correlations do not aim at trying to suppress or to overshadow the gap, but at revealing the synergy of the two sides, specifying and amplifying it.

5. Conclusion

In this article we wanted to show, on the basis of the results of the research on the anticipation of epileptic seizures:

– That a refined analysis of the preictal neuronal dynamics permitted the refinement of the consciousness of the pre-reflected micro-genesis of a seizure, an awareness that permitted in return the specification of the neuro-dynamic analysis.
– That this awareness is the key of the cognitive therapies of epilepsy.
– That this neuro-phenomenological circulation casts a new light on the question of the ''gap'', by highlighting the co-constitution of its subjective and objective poles.

In this approach, the awareness of the pre-reflective dynamics of lived experience is central. But what seems the most interesting is not the refinement of the correlations that this awareness permits; it is the fact that this refinement makes visible the neuro-phenomenological circulation, and through it the co-constitution of the subjective and objective sides of the gap. Taking lived experience into account enables mutual enrichment and the increased convergence of neurological and phenomenological analyses. But an even more important result seems to be the half-opened perspective on this process of co-constitution, which may deeply renew our vision of ourselves and of our relationship to the world.

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[21] Is there even one experimentation that makes absolutely no reference to subjective experience? For example, a cerebral area is called ''auditory'' because a correlation is made between its activation and a first person report of an auditory experience. The first person point of view is always present, but in an implicit, naive manner.

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