Schizophrenia Research 153 (2014) 109–112

Contents lists available at ScienceDirect

Schizophrenia Research

journal homepage: www.elsevier.com/locate/schres

Brain functional connectivity during the experience of thought blocks in schizophrenic patients with persistent auditory verbal hallucinations: An EEG study ☆

Elias Angelopoulos [a,b,*], Elias Koutsoukos [a,b], Antonis Maillis [a,b], George N. Papadimitriou [b], Costas Stefanis [a]

[a] Signal Processing Laboratory, University Mental Health Research Institute, Athens, Greece
[b] Department of Psychiatry, Eginition Hospital, Athens University Medical School, Athens, Greece

ARTICLE INFO

Article history:
Received 29 May 2013
Received in revised form 20 December 2013
Accepted 19 January 2014
Available online 16 February 2014

Keywords:
Thought blocks
Auditory verbal hallucinations
Schizophrenia
EEG
Synchrony
Connectivity

ABSTRACT

Thought blocks (TBs) are characterized by regular interruptions in the stream of thought. Outward signs are abrupt and repeated interruptions in the flow of conversation or actions while subjective experience is that of a total and uncontrollable emptying of the mind. In the very limited bibliography regarding TB, the phenomenon is thought to be conceptualized as a disturbance of consciousness that can be attributed to stoppages of continuous information processing due to an increase in the volume of information to be processed. In an attempt to investigate potential expression of the phenomenon on the functional properties of electroencephalographic (EEG) activity, an EEG study was contacted in schizophrenic patients with persisting auditory verbal hallucinations (AVHs) who additionally exhibited TBs. In this case, we hypothesized that the persistent and dense AVHs could serve the role of an increased information flow that the brain is unable to process, a condition that is perceived by the person as TB. Phase synchronization analyses performed on EEG segments during the experience of TBs showed that synchrony values exhibited a long-range common mode of coupling (grouped behavior) among the left temporal area and the remaining central and frontal brain areas. These common synchrony-fluctuation schemes were observed for 0.5 to 2 s and were detected in a 4-s window following the estimated initiation of the phenomenon. The observation was frequency specific and detected in the broad alpha band region (6–12 Hz). The introduction of synchrony entropy (SE) analysis applied on the cumulative synchrony distribution showed that TB states were characterized by an explicit preference of the system to be functioned at low values of synchrony, while the synchrony values are broadly distributed during the recovery state. Our results indicate that during TB states, the phase locking of several brain areas were converged uniformly in a narrow band of low synchrony values and in a distinct time window, impeding thus the ability of the system to recruit and to process information during this time window.

1. Introduction

Thought blocking is a disorder of thought that is usually a sign of psychotic conditions and is characterized by regular interruptions in the stream of thought. Bleuler (1911) described how the phenomenon develops rapidly and occurs in transitory episodes of varying duration, with blocking not only of the stream of thought but of the entire psyche, involving the processes of attention, perception, memory, speech and motility. Outward signs are abrupt, repeated interruptions in the flow of conversation or actions. Subjective experience is that of a total, uncontrollable emptying of the mind. Blocking may give rise to the delusion that thoughts have been withdrawn from the head (thought withdrawal).

In psychiatric literature, TB phenomena are characterized as abnormalities of thought and, in the case of schizophrenia, are lumped together as formal thought disorder (a disorder in the form of thought, not the content) (McKenna, 1994). True thought blocking phenomena are rare (Andreasen, 1979) and must be distinguished from the occasional, benign loss of topic which occurs in normal individuals. Care must also be taken not to make the diagnosis of thought block when patients are simply distracted by their delusions or hallucinations.

A statistical perspective regarding the incidence of TBs among other thought disorder symptoms has been described in a study (Andreasen, 1979), where in 45 patients diagnosed with schizophrenia, thought blocking was found to be rare. Bleuler (1911) stated that the Kraepelinian concept of blocking was of fundamental significance in the symptomatology and diagnosis of schizophrenia. Since then, this view has been endorsed in some of the literature on schizophrenia, but the concept appears to have become limited to the sudden occurrence of stoppages

* Corresponding author at: Athens University, Medical School, 1st Psychiatric Dept., Eginition Hospital, 72-74 Vas. Sofias Ave., 115 28 Athens Greece. Tel.: +30 210 7289260.
E-mail address: angelopoulos.ilias@gmail.com (E. Angelopoulos).

0920-9964/$ – see front matter © 2014 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.schres.2014.01.036

in the flow of thinking. The phenomenon, so defined, has been likened to petit-mal epileptic seizures (Mayer-Gross et al., 1960). This peculiar phenomenon, in the case of schizophrenia, is bearing some resemblance to temporal lobe seizures. Both conditions appear to have a common denominator in terms of a paroxysmal impairment in consciousness. Consciousness has been said to depend largely upon the inter-relationship between the neural basis of the body schema and the perceptual organization of the environment, and also upon the capacity for memory storage of sensory data and the availability to recall stored information (Sherwood, 1957). In the same line of evidence, modern cognitive science posits that brain dynamics closely associated with cognitive processes involve synchronous neural oscillations occurring globally throughout the brain (Crick and Coch, 1998). Current views consider that EEG oscillations, with different spectral contents, recorded in various brain sites are assumed to play an important role in the information processes underlying cognition as well as the abnormal brain functioning observed in nosological entities that affect the neuronal connectivity such as schizophrenia and specific psychiatric symptoms such as hallucinations (Friston, 1998; Basar et al., 2000; Phillips and Silverstein, 2003; Uhlhaas et al., 2008; Angelopoulos et al., 2011; Koutsoukos et al., 2013).

In bibliography, the absence of available data regarding the pathophysiology of the phenomenon may reflect the rarity of the symptom itself along with the methodological difficulties to study such a subjective experience. In the present study, we analyzed EEG oscillatory activity during the subjective experience of thought blocks in subjects suffering from persisting auditory verbal hallucinations. In these cases, TBs emerged automatically, in both under eyes open and eyes closed conditions, at distinct periods except for one case where TBs developed at the end of intense burst-like hallucinations. In the latter case, thought blocks marked the end of prolonged and intensive hallucinatory periods.

2. Methods

The present study was motivated from our recent EEG observations on hallucinatory patients where phase overcoupling was observed in the left temporo-frontal cortical areas, indicating the autonomous and disturbed-connectivity profile of AVHs (Angelopoulos et al., 2011; Koutsoukos et al., 2013). More specifically, during the evaluation of patients with persistent AVHs, five of fifteen patients were found to report additionally to AVH experiences, thought blocking phenomena. During the interview with the attending psychiatrist, patients manifested repeated interruptions in the conversation flow for a few seconds. Since TBs may resemble simple moments of distraction due to a defect in the selective attention function (Lake, 2008), patients were asked to describe the subjective experience during these interruptions. Their characterizations were as follows: “spontaneous emptiness of my brain,” “a rock in my head,” “blank page in my mind,” “spontaneous block of my thought” and “a loss of mind.” One patient described that the TBs were developed at the end of intense and burst like hallucinatory states. Moreover, patients confirmed that TBs were elicited automatically under the hallucinatory state.

Thus, our current data are based on recordings from five (3 males, 2 females, mean age: 32 $\pm$ 5, duration of illness: 11 $\pm$ 3 years, mean PANSS score: 72 $\pm$ 4) schizophrenic patients with drug-resistant spontaneous AVHs with criterion the prominent experience of thought blocking during the recording periods. Patients were under medication with three with risperidone (6 to 7 mg/day), one with amisulpride (800 mg/day) and one patient with risperidone (8 mg/day) plus levomepromazine (12.5 mg/day).

After a detailed description of the experimental protocol, all subjects gave written informed consent, and the University Mental Health Research Institute ethics committee approval was obtained. Recruitment and inclusion in the study details have been reported elsewhere (Angelopoulos et al., 2011). All participants were selected from a larger sample of subjects suffering from schizophrenia with the ability to cooperate in the experimental procedure as the basic concern. Subjects were seated in a light and sound attenuated double-skin Faraday cage. Electrodes (Fp1, Fp2, F7, F3, Fz, F4, F8, FT7, FC3, FCz, FC4, FT8, T7, C3, Cz, C4, T8, TP7, CP3, CPz, CP4, TP8, P7, P3, Pz, P4, P8, O1, Oz and O2) were placed on the scalp using a standard cap. Recordings of the horizontal plane eye-movement potentials were made by two electrodes fixed 1 cm bilateral to the outer canthus of each eye. The skin resistance of each electrode was kept $\leq$5 kΩ for the entire session. The participants were instructed to report any TB experience by pressing a miniature optical switch with the middle finger of their dominant hand to indicate the experience of TB, immediately after the recovery from the thought blocking state. The EEG signals were acquired using a Synamps (Neuroscan Labs) amplifier module sampled at 500 Hz. In the present study, we examined the phase alterations during the experience of TBs. The frequency-specific coupling index (FCI), shown in Eq. (1), allowed us to identify synchrony patterns between two brain sites in association with the marked thought blocking events.

$$\mathrm{FCI}_{a,b}(f,t) = \left| \frac{1}{w} \sum_{t-w/2}^{t+w/2} \exp(j(\varphi_a(f,t) - \varphi_b(f,t)))d\tau \right| \quad (1)$$

where FCI is the value of the temporal coupling of two preselected brain sites α and b for a specific frequency component f and a given time point t and w is the duration of the time window that varied from 50 to 200 ms. In this case, phases $\varphi\alpha$ and φb were computed by convolution with Morlet complex wavelet, considering the argument of the complex wavelet coefficients. In the practice, the above formula was computed in a number of overlapped phase segments that corresponded to a period of 4 s, which preceded the mark that denoted the recovery from TBs. The results gave the amount of coupling as a function of time, with a value of 1 indicating the higher coupling and 0 the lower coupling. The comparison of phase synchrony data set obtained from original EEG signals, with those obtained from surrogate data sets, evaluated the statistical significance of our findings against the background fluctuations of phase differences. For this purpose, 200 phase difference vectors obtained from surrogate data sets were examined in the same manner as in the original EEG data. The proportion that the distribution of the maximum $\mathrm{FCI}_{\mathrm{surrogate}}(f,t)$ values were intersected by the instantaneous $\mathrm{FCI}_{\mathrm{EEG}}(f,t)$ value defined the significance of the difference found for the given time window and frequency. This analytical technique is sensitive in the detection of frequency-related changes of synchrony in frequency steps defined by the wavelet parameters and capable enough to study phasic synchronous activity in single trials (Lachaux et al., 2000). Additionally, entropy computations were applied to the synchrony proportions as illustrated in Fig. 1b and c, introducing, in this way, a new descriptor of the synchrony variability the synchrony entropy (SE).

$$\mathrm{SE} = \sum_{k=1}^{n} s_k \log s_k / \log(n) \quad (2)$$

where n is the number of synchrony bins and s is the synchrony values of each bin. The SE equation defined in Eq. (2) is the Shannon entropy formula (Shannon, 1948) applied to the normalized data obtained from the distribution shown in Fig. 1b and c. Since SE represents the relative peakedness or flatness of the synchrony distribution, SE could reflect the functional status of a neuronal circuitry in a time window.

3. Results

A total number of 69 TBs were reported by five patients during the EEG recording procedure. The rate of TBs (thought blocks/min) was 2.4 $\pm$ 0.7 under eyes closed and 1.8 $\pm$ 1.6 under eyes open condition. The synchrony index between electrode T7 and the rest of the electrode