“SPLIT MIND” AND EEG GAMMA ACTIVITY IN SCHIZOPHRENIA

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Abstract

Synchronous high frequency (Gamma band) activity has been proposed as a candidate mechanism for the integration or 'binding' of distributed brain activities that are closely related to integrative cognitive processing and conscious awareness which is significantly affected in schizophrenia. According to recent evidence schizophrenia is related to temporal disintegration of brain networks which is closely linked to cognitive dysmetria to abnormal integration of sensory input with stored information. These findings indicate that disconnection and disturbed gamma synchrony and neural binding may represent a specific correlate of mental disintegration in schizophrenia. From historical perspectives these findings are in agreement with basic thinking about schizophrenia that was proposed by Bleuler when he introduced the term schizophrenia as “split mind”. These data have important implications for understanding of basic mechanism related to schizophrenia and also its therapy that in the future perspectives might be much focused on specific influences on cognitive functions using psychotherapeutic approaches in close correspondence with pharmacological treatment strategies.

Key words: *Consciousness; EEG; Gamma activity; Mind; Schizophrenia*

1. INTRODUCTION

Consciousness according to basic subjective experience represents the unity of events related to sensory processing of various modalities and memory that enables to integrate and interpret continuous stream of information from the external world. Nevertheless even conscious experience creates this unity recent evidence indicates that the neural correlate of consciousness likely is not represented in a particular brain region that would enable to integrate distributed information during sensory processing (Klemm, Li, & Hernandez, 2000; Von Der Malsburg, 1999; Singer & Gray, 1995). This time and spatial integration of brain functions related to perception, cognition, consciousness and memory is likely related to frequency oscillations (30-90Hz, typically at about 40Hz) in electrical brain activity that occurs synchronously in cycles across various brain regions (Singer & Gray, 1995) and is linked to binding of individual brain functions, the integration of brain activities and composition of neuronal networks (Engel et al., 1997; Von Der Malsburg, 1999).

Schizophrenia is traditionally described as a loss of inner unity and intrapsychic coordination (McCarley et al., 1993; Lee et al., 2003; Bob & Mashour, 2011) and it is related to disturbances of perception as for example illusions and hallucinations, disorganized thoughts,

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and 'blunted' or 'flat' affects (McCarley et al., 1993). These disturbances are frequently related to abnormal integration of sensory input with stored information and accented abnormal temporal integration of brain networks referred to as „cognitive dysmetria“ (Andreasen et al., 1999). These modern concept of consciousness are also in agreement with the traditional view of the split mind there is evidence based that Gamma activity has direct effect on the failure of information integration in schizophrenia (Lee et al, 2002; Bob & Mashour, 2011) and closely linked to GABAergic interneuron activity that enables thalamo-cortical modulation of arousal (Steriade, 1997; Whittington, Traub & Jefferys, 1995).

2. GAMMA ACTIVITY AND BRAIN FUNCTIONS

According to recent data the process of “binding” (also called the “binding problem” , i.e. how the brain codes and represents diverse activities such as perception emotion motor responses cognition and memory) is specifically linked to distributed neurons involved in the processing of a single object that tend to synchronize their firing with each other, while simultaneously desynchronizing their firing from remaining neurons not involved in the processing of that object (Lee et al., 2003; Steriade, 1997; Von Der Malsburg, 1999). Nevertheless other data also show that relevant is also explanation using the “grandmother” (cardinal or Gnostic) cell theory which suggests that the brain contains a raft of single cells that represent clear unitary perceptions, i.e. when a particular cell fires this process triggers a set of synapses relevant to the particular perception (Bauer & Dicke, 1997; Gross & Sergent, 1992). In this context, Gamma activity can be observed at the diverse points of analysis from microscopic to macroscopic, from single neuron to brain hemispheres (Singer, 1993) and it has been suggested that Gamma oscillation may modulate specific integration of information (Koenig, Engel & Singer, 1995).

In addition there is evidence of Gamma activity in arousal and attention, visual perception, motor response and cognitive functions. For example, Steriade (1997) reported that the cat brains after stimulation of Ascending Reticular Activation System (ARAS) changed their high voltage slow waves into low voltage fast wave activity. Similarly Munk et al. (1996) have shown that stimulation of ARAS ease the Gamma activity as well as activity in cat visual cortex.

Other study by Bouyer et al. (1980) reported that Gamma activity (35-45Hz) is related to cat's fixed eyes on the mouse, suggesting that the Gamma activity reflects also the vigilance involved in the hunting strategy. Also Roelfsma et al. (1997) in their research show that the cats waiting for a stimulus related to reward conscientiously showed strong Gamma synchrony. Also other animal studies have shown that Gamma synchrony predominantly is augmented by selective attention that augments the perception and representation of relevant stimuli (Prechtl, 1994).

There are also studies that prove the role of Gamma activity in contiguous sensation of visual and auditory stimuli in humans. For example, Lutzenberger et al. (1995) reported that Gamma activity was enhanced over the occipital electrodes for bars that were moving with a regular rather than irregular frequency and that Gamma activity is greater at occipitotemporal electrode sites when subjects are exposed to a single bar that moves across the sites compared to two incoherently moving bars (Muller et al., 1999). Similarly, Klemm et al. (2000) proved coherent Gamma activity in a study of riddling figure task in which subjects were asked to push the button when they perceived a hidden alternative image in the stimulus. Greater Gamma coherence was observed in the midst of frontal, parietal, central and occipital regions of both hemispheres. Specifically, Gamma activity was evaluated when subjects looked at emotional (angry, fearful, happy, and sad faces) or neutral faces in two different conditions: supraliminal (10 ms) vs subliminal (150 ms) stimulation. The results showed that both consciousness and significance of the stimulus in terms of arousal can modulate the power synchronization. Gamma activity was enhanced by supraliminal more than subliminal elaboration, as well as more by high arousal (anger and fear) than low arousal (happiness and

sadness) emotions. In this context other data show that heightened Gamma activity is related to emotional stimuli (Muller et al., 1999; Rodriguez et al., 1999; Schneider et al., 2008)

In summary these findings show that the Gamma synchrony is achieved when visual and an auditory perceptual binding occurs. This synchrony is modulated by arousal and attention specific for different states of awareness and it is related to relevant perceptual and motor responses essential for any information processing in the brain that enables integrated subjective experience (Basar-Eroglu et al., 1996; Roelfsema et al., 1997; Martinovic et al., 2009; Balconi & Lucchiari, 2008).

3. NEURAL BINDING, GAMMA ACTIVITY AND SCHIZOPHRENIA

According to recent findings schizophrenia is related to abnormal integration of sensory input with stored information and temporal disintegration of brain networks described as cognitive dysmetria (Andreasen et al., 1999). These findings indicate that disconnection and disturbed binding as a correlate of mental disintegration in schizophrenia likely are related to decreased or increased synchrony (Le Van Quyen et al., 2001; Ford et al., 2005; Ford et al., 2007; Feinberg & Guazzelli, 1999). These deficits related to disturbed (decreased or increased) synchrony could produce mental disintegration, i.e. positive symptoms presented as hallucinations, delusions, thought disorder or odd behavior and also negative symptoms such as lack of content of speech, blunted affect, social withdrawal, lack of motivation and goal-directed behavior (Le Van Quyen et al., 2001; Lee et al., 2003). These specific patterns of cognitive and neuropsychological dysfunctions in schizophrenia also suggest that psychomotor poverty reflects a slowing of mental activity and global cognitive deficits, whereas disorganization might reflect language processing and an impaired ability to inhibit disintegrated and irrelevant mental activity (Le Van Quyen et al., 2001; Sporns, Tononi & Edelman, 2000).

Decreased or increased synchrony associated with schizophrenia symptoms likely reflects process of functional segregation of sets of neurons that occurs in different cortical areas and causes disturbances in information flow across specialized brain areas of the brain (Ito, Nikolaev & Van Leeuwen, 2005; Zhan et al., 2006). As recent data show positive symptoms of schizophrenia have been associated with extremely high Gamma activity, whereas psychomotor activity is related to reduced Gamma activity (Lee et al., 2003; Gordon et al., 2001; Kissler et al., 2000). Altogether these data suggest that the core abnormality of schizophrenia is functional disconnection and mental disintegration related to dysregulation of the oscillatory Gamma activity linked to neural binding in distributed and local networks.

4. CONCLUSION

This review of Gamma activity in schizophrenia suggests that the core disturbance in schizophrenia is abnormal temporal integration of brain networks that are widely distributed and according to recent findings these disturbances in Gamma activity can explain a broad range of schizophrenia symptoms (Lee et al., 2003; Gordon et al., 2001; Kissler et al., 2000). These underlying functional disconnections may produce two opposing processes represented by Psychomotor poverty on the one hand, and Disorganization and Reality distortion on the other, i.e. Psychomotor poverty is associated with decreased Gamma synchrony, whereas Reality distortion and Disorganization show increased Gamma synchrony.

From historical perspectives these findings are in agreement with basic thinking about schizophrenia that was proposed by Bleuler when he introduced the term schizophrenia as "split mind" (Lee et al., 2003; Bob & Mashour, 2011). These data have important implications for understanding of basic mechanism related to schizophrenia and also its therapy that in the future perspectives might be more focused to specific influences on cognitive functions using

psychotherapeutic approaches in close correspondence with pharmacological treatment strategies.

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