International Journal of Psychophysiology xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

International Journal of Psychophysiology

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

Altered alpha brain oscillations during multistable perception in schizophrenia

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ARTICLE INFO

Available online xxxx

Keywords:
Brain oscillations
Spatio-temporal integration
Top-down
Bottom-up
Multistable perception
Object perception

ABSTRACT

Schizophrenia is a complex mental disorder with impairments in integrating sensory and cognitive functions, leading to severe problems in coherent perception. This impairment might be accelerated during multistable perception. Multistable perception is a phenomenon, where a visual pattern gives rise to at least two different perceptual representations.

We addressed this issue by assessing event-related alpha oscillations during continuous viewing of an ambiguous and unambiguous control stimulus. Perceptual reversals were indicated by a manual response, allowing differentiation between phases of reversion and non-reversion (that is perceptual stability) in both tasks.

During the ambiguous task, patients and controls showed a comparable number of perceptual reversals. Alpha amplitudes in patients were larger in non-reversion phases, accompanied by a stronger decrease of alpha activity preceding the perceptual reversal. This group difference was pronounced for lower alpha activity and not apparent during the unambiguous task.

This indicates that ambiguous perception taps into the specific deficits that patients experience in maintaining coherent perception. Given that top-down influences in generating a meaningful percept seems to be low in patients, they appear more dependent on sensory information. Similar, bottom-up mechanisms might be more important in triggering perceptual reversals in patients than in controls.

1. Introduction

1.1. Event-related brain oscillations in schizophrenia

Brain oscillatory activity indicates abnormal temporal integration and interregional connectivity of brain networks as a core disturbance in schizophrenia. Such abnormal oscillatory activity has been shown to be linked with a range of impairments in behavior and perception (Basar, 2013; Basar and Güntekin, 2013; Basar-Eroglu et al., 2013; Ford et al., 2007; Haenschel and Linden, 2011; Lee et al., 2003; Uhlhaas and Singer, 2010).

In the healthy brain, integrative brain functions are obtained through the combined actions of multiple oscillations (Basar, 2008, 2011). Oscillatory activity is reported to be essential for the timing of neuronal discharges (Buzsaki and Draguhn, 2004), and hence it is suggested to provide a potential mechanism for precise temporal resolution in the encoding of information (e.g. Uhlhaas and Singer, 2010).

Although schizophrenia is characterized by multiple impairments, a single frequency band, the gamma-band, has currently captured most attention in schizophrenia. Gamma band oscillations are modified in amplitude, topography or coherence by a broad range of processes, including attention, conscious awareness, multisensory and sensorimotor integration, movement preparation, memory formation, feature integration, and stimulus selection (Basar, 2013; Sun et al., 2011). Several studies report reduced gamma synchrony or amplitude in schizophrenia (e.g. Basar-Eroglu et al., 2009, 2011; Haenschel and Linden, 2011; Haig et al., 2000; Herrmann and Demiralp, 2005; Lee et al., 2003; Spencer et al., 2008).

Since, however, brain functions are realized in the interplay of many frequency bands (Basar, 2008, 2011), it is not surprising that many frequency bands seem to be deficient in schizophrenia (Basar and Güntekin, 2013) under different levels of cognitive load (e.g., Basar-Eroglu et al., 2008; Bates et al., 2009; Fehr et al., 2003). Like gamma activity, alpha oscillations show distinct temporal–spatial brain patterns and are modified in frequency, amplitude, topography or coherence by a broad range of processes, including attention, perceptual requirements, semantic content, memory formation, sensorimotor integration, movement preparation and execution (Basar, 2012; Basar and Güntekin, 2012). Increases in amplitude within the first 200 ms following an attended event have

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http://dx.doi.org/10.1016/j.ijpsycho.2015.02.002
0167-8760/

been suggested to indicate sensory processes, because the increase is mainly observable over primary sensory areas (Basar, 2012). Systematic suppression (i.e., decrease in power) of alpha activity is found in brain regions actively engaged in the attentive processing of sensory information (e.g., Bastiaansen and Brunia, 2001; Pfurtscheller and Lopes da Silva, 1999; Schmiedt-Fehr et al., in press), often in parallel with an increases of alpha activity in task-irrelevant regions (e.g., Foxe and Snyder, 2011; Jensen and Mazaheri, 2010). These specific modulations are thought to enhance the neural responsiveness to attended information and disengage irrelevant neuronal generators, respectively.

Accordingly, recent studies of our research group indicate a more general disturbance affecting the spatial distribution of oscillatory brain activity in gamma as well as in slower frequency ranges, such as delta, theta and alpha oscillations (Basar-Eroglu et al., 2007, 2008, 2009, 2013; Ergen et al., 2008; Schmiedt et al., 2005). For instance, passive listening was found to elicit an altered distribution of event-related alpha activity in patients with schizophrenia compared to controls (Basar-Eroglu et al., 2013). While healthy controls showed the common fronto-central auditory alpha response, patients had lower fronto-central and larger parieto-occipital alpha activity. Ideally, external input amplifies activity of specific neuronal populations, whereas the activities of the other populations are partially suppressed, which provides an effective filtering mechanism (Basar, 2011, 2012; Basar and Güntekin, 2012). Hence, the larger parieto-occipital alpha activity in patients with schizophrenia potentially indicates a disorder of the basic neuronal filtering mechanism.

1.2. The potential functional significance of event-related alpha oscillations in multistable perception

Multistable visual perception is a phenomenon in which a visual pattern gives rise to at least two different perceptual representations (e.g., the Necker cube). In order to maintain perceptual coherence only one perceptual alternative at a time is perceived. During continuous observation, perception switches between all possible alternatives although the physical properties of the stimulus remain unchanged (Long and Toppino, 2004). It is generally acknowledged that this phenomenon is driven by sensory information (bottom-up) as well expectations and prior experiences (top-down, Gregory, 1997; Long and Toppino, 2004). Neurophysiological processes underlying perceptual reversions have been investigated to disentangle bottom-up from top-down influences in multistable perception (Mathes et al., in press; Strüber et al., 2014). For instance, several studies reported a continuous alpha decrease preceding perceptual reversals during multistable visual perception (Isoglu-Alkac et al., 2000; Isoglu-Alkac and Strüber, 2006; Strüber and Herrmann, 2002). Isoglu-Alkac and Strüber (2006) suggest that lower alpha suppression (i.e., amplitude decrease) reflects an automatic arousal reaction, which triggers attentional processing during perceptual switching in a bottom-up manner. Desynchronization of higher alpha activity might be more closely related to top-down processes during multistable perception (see also Klimesch, 1999).

1.3. Present study

Pathological changes of alpha activity during visual multistable perception in schizophrenia may provide an appropriate model to investigate integrative processes of the brain and the potential impact of failures in object perception due to psychiatric illness. Several behavioral studies indicate that patients with schizophrenia show altered processing of visual ambiguous stimuli (e.g., McBain et al., 2011; Tschacher et al., 2008).

The aim of this study was to assess event-related alpha oscillations during perception of an ambiguous visual stimulus, termed stroboscopic alternative motion (SAM, see Fig. 1). EEG data were recorded in patients with schizophrenia and healthy controls while they viewed the SAM in two tasks that differed in terms of stimulus ambiguity (*ambiguous* stimulus and an *unambiguous* control stimulus). We compared alpha activity in both groups and both tasks during phases of perceptual stability (*non-reversion*), on the one hand, and during perceptual reversals (*reversion*) on the other hand.

We assumed that the ambiguous (i.e., multistable) version of the visual pattern (i.e., SAM) would require considerably more cognitive control mediation, in contrast to an unambiguous visual pattern (see also Mathes et al., in press). Since top-down control of ambiguous perception seems to be specifically impaired in schizophrenia (e.g., McBain et al., 2011), we expected that disturbances in object perception would be more apparent during ambiguous than unambiguous perception. The continuous alpha decrease should ideally reflect upon that, because it occurs specifically during ambiguous perception (Strüber and Herrmann, 2002) and seems to reflect the interplay of bottom-up and top-down mechanisms (Isoglu-Alkac and Strüber, 2006). Based on previous studies, we expected that the alpha-band would reflect abnormal visual multistable perception in schizophrenia with a brain activation pattern indicating failures in spatial-temporal integration (see e.g. Basar-Eroglu et al., 2008; Basar-Eroglu et al., 2009).

2. Methods

2.1. Participants

All patients were recruited as in-patients after clinical stabilization of an acute psychotic episode. Fourteen patients were diagnosed with

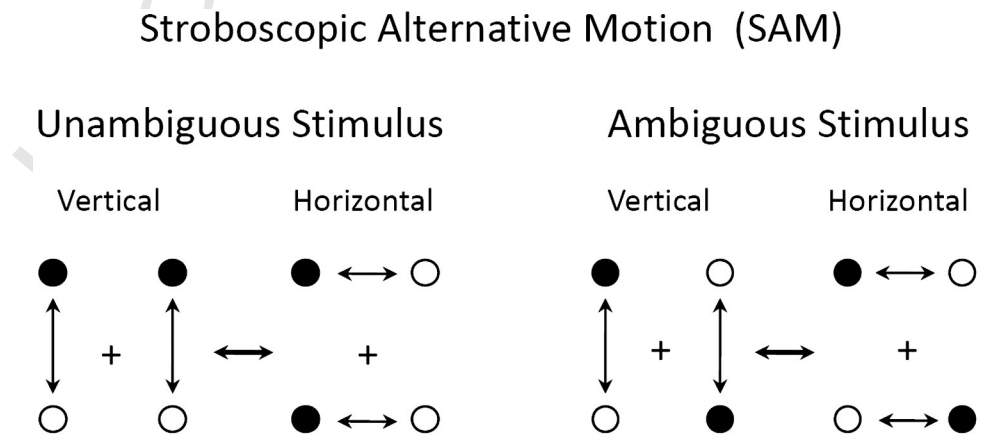

Fig. 1. Schematic representation of the stroboscopic alternative motion (SAM). During viewing of the SAM vertical apparent motion alternates with horizontal apparent motion (*ambiguous* stimulus, left) even though the physical properties of the stimulus remain unchanged. The *unambiguous* stimulus pattern (right) elicits apparent vertical and horizontal motion by externally controlled alternation of the presented stimulus displays. (+) = Fixation point.

Please cite this article as: Basar-Eroglu, C., et al., Altered alpha brain oscillations during multistable perception in schizophrenia, Int. J. Psychophysiol. (2015), http://dx.doi.org/10.1016/j.ijpsycho.2015.02.002