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The transliminal brain at rest: Baseline EEG, unusual experiences, and access to unconscious mental activity

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ABSTRACT

Transliminality reflects individual differences in the threshold at which unconscious processes or external stimuli enter into consciousness. Individuals high in transliminality possess characteristics such as magical ideation, belief in the paranormal, and creative personality traits, and also report the occurrence of manic/mystic experiences. The goal of the present research was to determine if resting brain activity differs for individuals high versus low in transliminality. We compared baseline EEG recordings (eyes-closed) between individuals high versus low in transliminality, assessed using *The Revised Transliminality Scale* of Lange et al. (2000). Identifying reliable differences at rest between high- and low-transliminality individuals would support a predisposition for transliminality-related traits. Individuals high in transliminality exhibited lower alpha, beta, and gamma power than individuals low in transliminality over left posterior association cortex and lower high alpha, low beta, and gamma power over the right superior temporal region. In contrast, when compared to individuals low in transliminality, individuals high in transliminality exhibited greater gamma power over the frontal-midline region. These results are consistent with prior research reporting reductions in left temporal/parietal activity, as well as the desynchronization of right temporal activity in schizotypy and related schizophrenia spectrum disorders. Further, differences between high- and low-transliminality groups extend existing theories linking altered hemispheric asymmetries in brain activity to a predisposition toward schizophrenia, paranormal beliefs, and unusual experiences.

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1. Introduction

The flow of information from unconscious to conscious awareness has been of great interest for centuries (e.g.,

Wallas, 1926). James (1890) suggested that thought was ongoing, switching intermittently between internal and external stimuli, relying heavily on processes needed to integrate the past with the present. More recently, researchers

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have examined the interface between unconscious and conscious processing in mental illness (e.g., [Andreasen, 1997](#); [Geyer et al., 2001](#)), the role of the unconscious in the facilitation of problem solving and creativity (e.g., [Bowden, 1997](#); [Bowers et al., 1995](#); [Carson et al., 2003](#); [Jung-Beeman et al., 2004](#)), and the nature of altered consciousness that accompanies paranormal beliefs and experiences (e.g., [Thalbourne, 1994](#); [Thalbourne and Delin, 1994](#)).

Thalbourne and his collaborators have studied the transfer of unconscious thought and external stimulation into conscious awareness and have labeled individual differences in the degree of such transference as *transliminality* ([Thalbourne and Houran, 2000](#)). More specifically, transliminality has been defined as “susceptibility to, and awareness of, large volumes of imagery, ideation, and affect – these phenomena being generated by subliminal, supraliminal, and/or external input” ([Thalbourne et al., 1997, p. 327](#)). Individuals high in transliminality tend to believe in the paranormal, engage in magical ideation, have manic and/or mystical experiences, and possess creative personalities ([Thalbourne and Delin, 1994](#)).

Though the boundary between conscious and unconscious thought has been recognized as a source of individual differences in personality, cognition, and psychopathology, the link between transliminality and these psychological components has gone largely unexplored. A notable exception is the research of [Crawley et al. \(2002\)](#) which examined the relationship between transliminality level and performance on a subliminal card-naming task. When a masked prime of the ‘to-be-identified’ symbol was briefly displayed on the back of the card (<50 msec), participants high in transliminality were more accurate in identifying the target symbol on the reverse.

More is known, however, concerning the unique aspects of cognitive processing associated with transliminality-related traits such as positive schizotypy, out-of-body experiences (OBEs), and belief in the paranormal (e.g., [Bressan, 2002](#); [Claridge, 1997](#); [Tsakanikos and Reed, 2005](#)). Schizotypal personality traits are muted levels of traits present in schizophrenia. These traits have been divided into positive (e.g., perceptual aberrations, hallucinations, and magical thinking), negative (e.g., physical and social anhedonia), and disorganized (e.g., irregular speech and thought) components ([Vollema and Hoijtink, 2000](#); [Vollema and Postma, 2002](#)). Transliminality and positive schizotypy are positively correlated ([Thalbourne, 1994](#); [Thalbourne and French, 1995](#); [Thalbourne et al., 2005](#)), as are transliminality and disorganized cognition ([Thalbourne et al. 2005](#)), though to a lesser degree. Research has also supported a link between positive schizotypy and belief in the paranormal (e.g., [Goulding, 2004, 2005](#)).

Those high in positive schizotypy and related traits exhibit altered cognition in perceptual, spatial, and linguistic domains, among others (e.g., [McCreery and Claridge, 1996, 2002](#); [van de Ven and Merckelbach, 2003](#)). For example, individuals high in positive schizotypal traits were more likely to detect the presence of meaningful patterns (e.g., words) in visual displays where this information was absent ([Tsakanikos and Reed, 2005](#); see also [Fyfe et al., 2008, this issue](#)). This pattern of results was also present in individuals expressing beliefs in the paranormal who were more likely than nonbelievers to detect meaningful patterns in random dot displays ([Bressan, 2002](#); [Brugger et al., 1993](#)).

A growing body of research has revealed deviations from the normal patterns of hemispheric asymmetry accompanying cognitive processing in individuals high in transliminality and related personality components. For example, the typical left-hemisphere bias in attention present in normal adults is enhanced in individuals high in positive schizotypal traits, exhibited in a further leftward shift in bias when performing the line bisection task ([Mohr et al., 2003](#); [Taylor et al., 2002](#)) and related chimeric faces task ([Luh and Gooding, 1999](#)). This leftward shift in attention has been linked by researchers to hyperactivity in the right-hemisphere ([Mohr et al., 2003](#); for an alternate view see [Schulter and Papousek, 2008, this issue](#)).

[Crow \(2000\)](#) has suggested that the breakdown in typical patterns of hemispheric organization, especially evident in the domain of language, is a key factor in the onset of schizophrenia. Enhanced indirect semantic priming has been demonstrated following the presentation of stimuli to the left visual field (right-hemisphere) in individuals high in positive schizotypal traits (e.g., [Mohr et al., 2006](#)) and in individuals reporting high levels of paranormal experiences and beliefs ([Pizzagalli et al., 2001](#)). Right-hemisphere hyperactivity in these groups may be linked to the dopamine hypothesis of schizophrenia, which suggests that positive schizophrenic traits are associated with hyperdopaminergia in right-hemisphere dopamine systems (e.g., [Goldberg et al., 2000](#); [Mohr et al., 2005](#)).

Finally, unique lateralization patterns have been observed in the spatial characteristics of hallucinations occurring in conjunction with sleep paralysis and during OBEs (e.g., [Brugger et al., 1996](#)). Vestibular-motor hallucinations, such as floating and falling, comprise the types of experiences typical in OBEs (e.g., [Cheyne and Girard, 2004](#); [Girard and Cheyne, 2004](#)). [Girard and Cheyne](#) observed a right-hemisphere hallucination bias in right-handed individuals evident in rightward turning and movement. It has been suggested that vestibular-motor hallucinations are the byproduct of activation in the cortical vestibular system, a theory supported by the occurrence of OBEs and hallucinations following the subdural electrical stimulation in the region around the angular gyrus, the core of the vestibular system ([Blanke et al., 2002](#)).

1.1. The neural correlates of transliminality

Prior research has successfully demonstrated unique patterns of activity in resting electroencephalograms (EEGs) in relation to specific cognitive and affective traits, such as extraversion, schizophrenia, and working memory (e.g., [Knyazev et al., 2003](#); [Kumari et al., 2004](#); [Winterer et al., 2001](#)). For example, [Winterer et al.](#) observed hypoactivation in frontal and temporal regions of the brain stemming from increased slow-wave activity (i.e., delta) in patients with schizophrenia. In contrast, hyperactivation was observed in individuals with schizotypal personality disorder for comparable regions ([Mientus et al., 2002](#); [Wuebben and Winterer, 2001](#)). Research has also suggested that resting brain activity may be predictive of the subsequent onset of psychosis ([Manchanda et al., 2003](#)).

Researchers have begun to examine patterns of brain activity associated with transliminality and related traits. [Pizzagalli et al. \(2000\)](#) examined differences in the resting EEGs

of individuals high versus low in paranormal beliefs, exploring both the location and complexity patterns of cortical activity. Complexity patterns are a reflection of the spatial distribution of total EEG power; lower complexity values reflect either a single distribution of activity with one underlying neural mechanism or the synchronized activity of multiple neural mechanisms (see Wackermann and Allefeld, 2007, for a review). In comparison to the asymmetry in hemispheric complexity present in normal adults (left > right), individuals high in paranormal beliefs exhibited a reduction in asymmetry linked to enhanced right-hemisphere and reduced left-hemisphere complexity patterns. Further, high beta activity (excitatory) was localized to the right-hemisphere in individuals high in paranormal beliefs, but to the left-hemisphere in nonbelievers.

Additional research has proposed the temporal lobes as the primary brain region involved in the determination of individual differences in transliminality level, though this theory has not been explored using neuroimaging or psychophysiological techniques. Thalbourne et al. (2003) have suggested that heightened levels of transliminality stem from increased connectivity in temporal regions. In their research, participants who exhibited high levels of transliminality also demonstrated enhanced temporal lobe lability, as indicated by scores on the Personal Philosophy Inventory (PPI; Persinger, 1984). The PPI assesses characteristics associated with temporal lobe functioning, such as epilepsy, odd sensory experiences, paranormal beliefs, and mania. Thalbourne et al.'s interconnectedness theory suggests that enhanced levels of temporal connectivity should be present with increasing transliminality.

Preliminary support for altered temporal lobe activity has been observed in individuals reporting near-death experiences (Britton and Bootzin, 2004). In their analysis of EEGs recorded during sleep for individuals reporting at least one prior near-death experience, Britton and Bootzin observed patterns of EEG activity associated with epileptic symptoms over the left temporal region. These individuals also scored significantly higher than normal adults on the temporal lobe symptoms of the PPI.

Understanding the brain activity accompanying altered consciousness (e.g., OBEs), as well as the activity influencing transliminality levels is a complex process mediated by a number of factors (e.g., sensory stimulation and baseline arousal levels; see Vaitl et al., 2005, for a review). The goal of the present research was to determine if resting brain activity could differentiate individuals high versus low in transliminality traits. Though one would expect differences between brain activity occurring in conjunction with normal thought and activity accompanying hallucinations and OBEs, reliable differences in resting brain activity when an individual is not engaged in directed cognition would support a predisposition for transliminality-related traits.

Prior research using self-report measures has linked transliminality components such as paranormal beliefs and unusual experiences with positive schizotypal traits (e.g., hallucinations and perceptual aberrations; Goulding, 2005). In line with prior research that observed differences in baseline brain activity between individuals high in paranormal beliefs and nonbelievers (Pizzagalli et al., 2000), we predicted that

hemispheric differences in resting brain activity would exist between individuals high versus low in transliminality. Further, due to the link between transliminality and positive schizotypal traits, we expected that regions connected to processing differences in individuals high in schizotypal traits, such as the temporal lobes, would be regions where differences would exist between high- and low-translinality participants.

2. Method

2.1. Participants

Thirty-four adults (18 female; mean age = 22.38 years, SD = 4.66 years) from Drexel University and the surrounding community participated in the present research (94% of participants were students). Participants were involved in the present study as part of a larger project on concept processing. All participants were right-handed (nine reported at least one left-handed first-degree relative), native speakers of English, and reported no history of chemical dependency, psychological disorder, or closed head injury. Participants were recruited using the following flyer:

Would you like to participate as a subject in an electroencephalogram (EEG) study examining how the brain processes concepts? This study is open only to people who are 18–35 years of age, are right-handed, have no neurological or psychiatric problems, no learning disabilities, and are not using drugs which affect mental function. In addition, the study is open only to fluent speakers of English who learned this language in childhood (i.e., not as a later, second language).

2.2. Translinality measure

The Revised Translinality Scale (RTS) of Lange et al. (2000) was used to measure translinality. The scale is a 29-item assessment that examines factors linked to the construct of translinality such as fantasy-proneness, mystical experience, magical ideation, hyperesthesia, positive attitude toward dream interpretation, and manic experience. The scale was scored using the Rasch theme presented in Lange et al. generating a range of possible scores of 13.7–37.3. Rasch scaling transforms ordinal-level data generated by many self-report measures to interval-level data, allowing for improved data analysis. Sample items from the assessment include “Often I have a day when indoor lights seem so bright they bother my eyes” and “I have experienced an altered state of consciousness in which I felt that I became cosmically enlightened” (Houran et al., 2003, p. 142). Thalbourne and Houran (2000) observed that performance on the RTS correlated with measures of paranormal beliefs and experiences, introspection, altered consciousness, daydreaming, mental potency, and the feeling of being high, leading the researchers to suggest that the RTS was indeed a valid measure of the translinality construct. Further research conducted by Lange et al. confirmed both the reliability and validity of the measure.

Mean performance on the RTS was 22.95 (SD = 4.28; normally distributed), comparable to scores on the measure obtained from large samples of similar make-up (e.g., Thalbourne et al., 2003). To examine differences in resting EEG in relation to transliminality, participants were divided by thirds into high ($n = 11$), medium ($n = 12$), and low ($n = 11$) groups, with the decision a priori to use only the data from participants in the top and bottom thirds for analysis. The high- and low-transliminality groups did not differ in the number of male or female participants (five male and six female participants each) and did not differ in age ($t(20) = .746, p = .464$). The two groups did differ as expected in mean scores on the transliminality measure ($t(20) = 8.769, p < .001$) with the high group ($M = 27.76, SD = 2.53$) exhibiting higher levels of transliminality than the low group ($M = 18.54, SD = 2.41$).

2.3. EEG recording

As part of a larger experimental design, we measured EEG from participants for 3.5 min during eyes-closed rest and then for 3.5 min for eyes-open rest before they were told the nature of the subsequent experimental task. Subjects were given the following instructions prior to baseline recording:

We're interested in measuring your brain activity at rest. First, we'll take a 3.5-min recording with your eyes-closed. Then we'll do the same with your eyes-open. Because muscle tension and movement can wash out the brain signals we are most interested in, we would like you to remain as still and relaxed as you can, especially the muscles in your face and scalp. During the eyes-open recording, there will be a plus-sign on the screen for you to keep your eyes fixated on. It is important to keep your eyes focused on the cross because eye movements will adversely affect the data. It is okay to blink, but please try to limit them during the recording. And when you do blink, please try to keep the movement light and quick, because slow or hard blinks may leave residual muscle tension that can affect the data.

Only the eyes-closed data are reported here. Prior to data collection, all participants gave informed consent in compliance with the protocol approved by Drexel University's Office of Research.

Detailed information about EEG recording is available in the Ref. Jung-Beeman et al. (2004). Continuous high-density EEGs were recorded at 250 Hz (bandpass: .2–100 Hz) from 128 tin electrodes embedded in an elastic cap (digitally-linked mastoid reference with forehead ground) placed according to the extended International 10–20 System. Prior to data analysis, EEG channels with excessive noise were replaced with interpolated data from neighboring channels (number of channels interpolated: $M = 4.18, SD = 3.01$). Eyeblink artifacts were removed from the EEG with an adaptive filter constructed separately for each subject using the EMSE 5.1 Software Toolkit (www.sourcesignal.com). EEG segments containing other artifacts were detected by visual inspection and excised. The remainder of each 3.5 min EEG segment was used for analysis; on average, 193.36 sec (SD = 14.77) of data were available per subject.

2.4. EEG analysis

All EEG analyses were performed with EMSE 5.1. Power spectra were computed and mean EEG power was computed at each electrode for individual subjects at the following frequency bands: delta (1–4 Hz), theta (4.5–7.5 Hz), low alpha (8–10 Hz), high alpha (10.25–13 Hz), low beta (13.25–18 Hz), high beta (18.25–21 Hz), and three gamma bands (35–45 Hz, 46–58 Hz, and 62–85 Hz). Mean EEG power values for each subject were log-transformed and then converted to z-scores (across electrodes, separately for each frequency band; Kounios and Holcomb, 1994). Normalization was performed for each subject to reduce global differences among participants (due to differences in arousal or skull thickness) and allows our analyses to focus on regional differences in brain activation.

Four-way Analysis of Variances (ANOVAs) were performed on spectral data of participants using hemisphere (left, right), lateralization (dorsal, ventral), and location (frontal, central, parietal, and occipital) as within-subjects factors, and transliminality (high, low) as a between-subjects factor. ANOVAs were conducted on normalized, log-transformed EEG power values for each frequency band for the following electrode sites: AF1/2, F3/4, C1/2, T7/8, P1/2, P7/8, O1/2, and PO7/8. In addition, two-way ANOVAs using midline location (frontal, central, parietal, and occipital) as a within-subjects factor, and transliminality (high, low) as a between-subjects factor were conducted using AFZ, CZ, PZ, and OZ electrode sites in an attempt to more directly explore anterior versus posterior differences in EEG power between transliminality groups. The results of all analyses were corrected using the Huynh-Feldt procedure to adjust for multiple repeated measurements. This manuscript focuses on the interactions of topographic factors with the transliminality factor because such interactions indicate a differential pattern of neural activity at rest for participants who are high versus low in transliminality.

3. Results

Four-way ANOVAs on spectral data recorded during eyes-closed rest revealed no significant differences between high- and low-transliminality groups in the delta or theta frequency bands. However, significant results were obtained for the low alpha ($F_{(3, 60)} = 4.322, p = .033$), high alpha ($F_{(3, 60)} = 4.615, p = .019$), low beta ($F_{(3, 60)} = 4.084, p = .023$), high beta ($F_{(3, 60)} = 5.611, p = .005$), and gamma frequency bands (35–45 Hz, $F_{(3, 60)} = 4.972, p = .006$; 46–58 Hz, $F_{(3, 60)} = 4.669, p = .012$; 62–85 Hz, $F_{(3, 60)} = 4.229, p = .021$). Two-way ANOVAs conducted on midline electrode sites revealed significant differences for all gamma bands (35–45 Hz, $F_{(3, 20)} = 6.158, p = .008$; 46–58 Hz, $F_{(3, 20)} = 5.415, p = .031$; 62–85 Hz, $F_{(3, 20)} = 5.375, p = .013$), but no significant differences were found in the other frequency bands.

As follow-up tests to significant ANOVAs for alpha, beta, and gamma frequency bands, post-hoc independent-samples t-tests were conducted for each electrode and then plotted on topographic maps showing the distribution of the statistically significant t-scores. The resulting t-score maps for alpha and beta frequency bands are presented for review

(see Figs. 1 and 2). Differences between high- and low-transliminality groups were evident in the same general posterior region for alpha and beta bands, with the high-transliminality group showing less alpha and beta power than the low-transliminality group over left posterior association cortex. In addition, less high alpha and low beta power were observed in the high-transliminality group over right superior temporal cortex.

T-score maps for the three gamma bands are also presented in Fig. 3. In comparison to the low-transliminality group, low gamma (35–45 Hz) activity was greater over the frontal-midline region in the high-transliminality group. The high-transliminality group also exhibited more low gamma activity over right anterior and left anterior prefrontal cortex. In contrast, less gamma activity was observed in the high-transliminality group over left temporal/occipital cortex, as well as a region of the right temporal cortex. It should be noted, however, that gamma results have historically been interpreted with caution due to concerns over possible contamination by electromyogram (EMG) (see Goncharova et al., 2003, for a review). We will discuss these concerns further below.

4. Discussion

The present study examined differences in baseline (i.e., resting) EEG in normal adults exhibiting high versus low levels of transliminality, an index of the degree of transference from

unconscious or external sources to conscious thought (Thalbourne and Houran, 2000). Ongoing EEGs were recorded during a period of unconstrained mental activity prior to participants' knowledge of the experimental task, thus eliminating the possibility of mental preparation for the following task. It is still possible, however, that differences between transliminality groups might be related in some way to the types of thoughts experienced by the two groups when cognition is not directed toward the performance of a specific task. EEG recordings from the eyes-closed baseline condition were subjected to analysis for differences between transliminality groups for delta, theta, alpha, beta, and gamma frequency bands. During this resting state, individuals who scored high in transliminality manifested lower EEG power in alpha and beta frequency bands over the left parietal/occipital region, as well as lower high alpha and low beta power over right superior temporal cortex compared to individuals low in transliminality. Less power in the gamma frequency bands was also observed for high-transliminality participants over the left temporal/occipital region, as well as a region of the right temporal lobe. Finally, gamma power over medial-frontal cortex was stronger for high-transliminality subjects than for low-transliminality subjects. We discuss these results in relation to general patterns of resting brain activity, the personality components underlying transliminality and schizotypy, and the hypothesis of hemispheric asymmetry as a predisposition for the unique forms of thought associated with altered consciousness, creativity, and schizophrenia-related disorders.

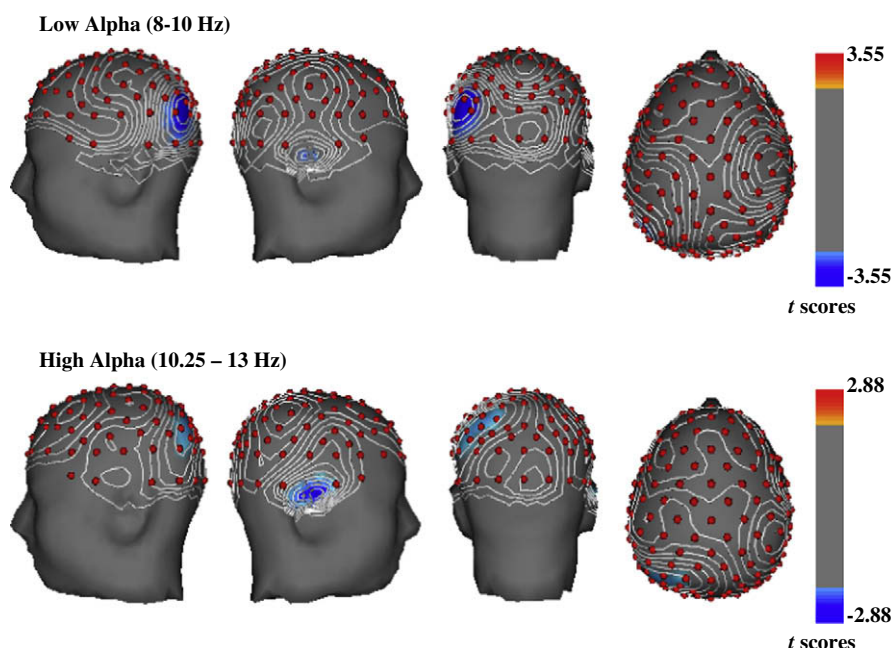


Fig. 1 – T-score maps indicate significant differences in power between transliminality groups ($p < .05$) in alpha, beta, and gamma frequency bands. Because all t-scores were calculated as the difference between high- and low-transliminality groups (high-transliminality minus low-transliminality) positive t-scores (in red) indicate greater power in the high-transliminality group, whereas negative t-scores (in blue) indicate greater power in the low-transliminality group. Significant t-values for the low alpha frequency band were observed over left parietal/occipital electrodes P7, PO5, and PO7. Significant t-values for the high alpha frequency band were observed for a similar region over P1, P3, P7, PO355, and PO755. An interpolated region of high alpha power was also observed over the right temporal lobe, but was not focused at any electrode site.

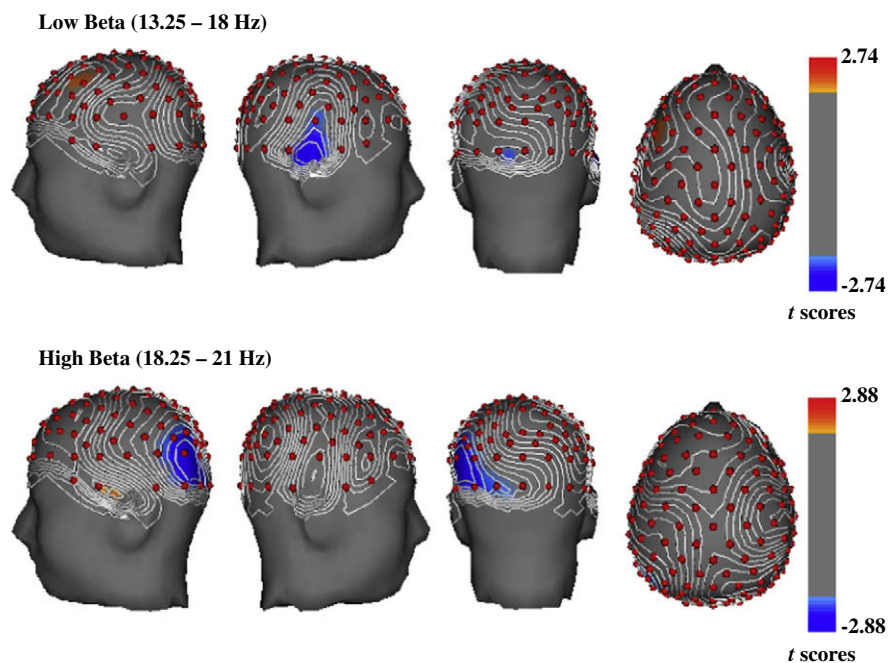


Fig. 2 – Significant electrodes in the low beta frequency band were observed over the left parietal/occipital region and included electrodes PO7, PO755, and O9. In addition, significant low beta activity was observed over the right superior temporal lobe at electrodes T855 and TP10. Electrode sites exhibiting significant activity in the high beta frequency band covered a more extensive left parietal/occipital region and included electrodes P7, P755, P9, PO7, PO755, PO9, and O9.

Reductions in alpha and beta power over the left posterior association cortex observed in the high-transliminality group coincide with results of prior research exploring this region in patients with schizophrenia and those with related personality traits (e.g., Dickey et al., 1999; Sumich et al., 2005). More specifically, the junction of the temporal, parietal, and occipital lobes (TPO junction) has been characterized as a polymodal association region, and has been associated with unusual experiences such as synesthesia (Ramachandran and Hubbard, 2003a, 2003b). Synesthesia is characterized as the blending of two or more senses (e.g., presentation of the number 3 also results in the perception of the color red). The blending of colors and numbers, for example, has been associated with the fusiform and angular gyri of the left TPO junction, and may result from cross-talk among these regions. Research of Thalbourne et al. (2001) observed a strong positive correlation between high levels of transliminality and high scores on a synesthesia measure, leading the researchers to conclude that altered cortical connectivity generally could be a factor underlying both transliminality and synesthesia.

In addition, structures in the temporal–parietal region, most notably the angular gyrus, Heschl’s gyrus, and the planum temporale, exhibit volumetric reductions in patients with schizophrenia (e.g., Dickey et al., 1999; Flaum et al., 1995; Hirayasu et al., 2000; Sumich et al., 2005) and schizotypes (e.g., Dickey et al., 2002), especially in the left-hemisphere. Research has linked volumetric reductions in this region to auditory hallucinations (e.g., Barta et al., 1990; Flaum et al., 1995; Levitan et al., 1999) and thought disorder in schizophrenia (Rajarethinam et al., 2000). It is possible that reduced alpha and beta power in high-transliminality participants

could be tied to volumetric reductions in the region. Scalp EEG is the end result of neurons’ summed synchronous post-synaptic activity. Therefore, if there is less brain tissue (i.e., fewer neurons), it then follows that there will be less post-synaptic activity in the region resulting in reduced EEG power (see Nunez, 1990, for a review of this relationship). Although volumetric reductions could explain the effect observed in high-transliminality subjects over the left posterior region, such a reduction is not necessary to explain our effect. Instead, a decrease in activity over the region could be related solely to the unusual experiences present in transliminality and positive schizotypal traits.

The topography of power differences in alpha and beta frequency bands between high- and low-transliminality groups is consistent with prior research reporting variants in hemispheric organization in conjunction with positive schizotypy and paranormal beliefs, such as OBEs (e.g., Mohr et al., 2003; Pizzagalli et al., 2000). We observed a reduction in beta power over the left posterior association cortex in high-transliminality participants. This was coupled with a decrease in high alpha and low beta power in high-transliminality participants over a region of the right temporal lobe. Differences between transliminality groups for this right temporal region coincide with the results of prior research supporting differences in right-hemisphere processing in schizotypy and related traits (e.g., Jung-Beeman et al., 2004; Pizzagalli et al., 2001).

Prior research reporting atypical patterns of hemispheric organization in positive schizotypy has consistently reported a pattern of hyperactivity in the right-hemisphere. Individuals high in positive schizotypy exhibit a left-hemisphere bias in

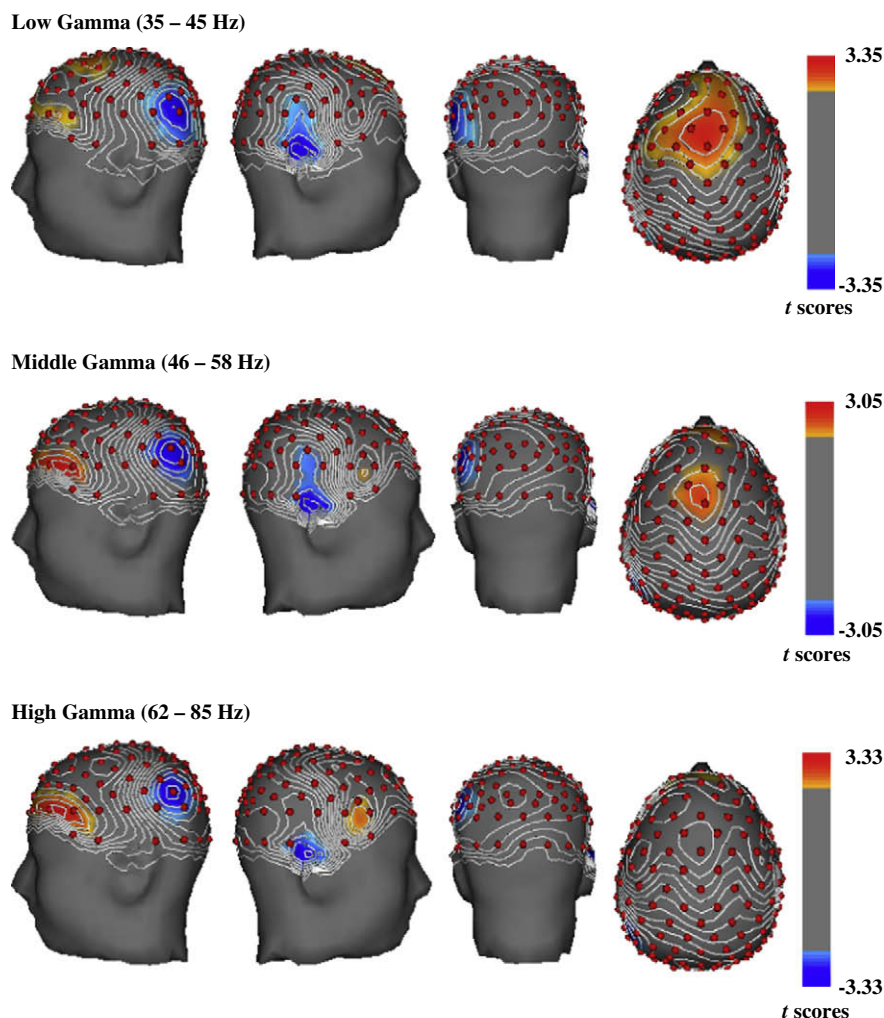


Fig. 3 – Significant positive t-scores were observed in the low gamma frequency band over the frontal-midline region and included electrodes AFZ, AF1, AF2, FZ, F455, FCZ, FC1, FC155, FC355, FC255, FC455, and CZ. T-scores in this region decreased in value with increasing gamma frequency. Significant negative t-scores were observed over the left temporal/occipital region and included electrodes TP7, PO9, P0755, PO7, P9, P755, and P7, and over a region of the right temporal lobe, including electrodes TP8 and TP10. T-scores in these regions decreased with increasing gamma frequency. Finally, significant positive t-scores were observed over a region of the left anterior prefrontal cortex and a less extensive region in the right anterior prefrontal cortex. T-scores at these electrode sites which included AF7, F7, F9, and F8, increased with increasing gamma frequency suggesting that these prefrontal differences are likely the result of EMG.

attention (Taylor et al., 2002), as well as enhanced semantic priming for indirectly-related words presented to the left visual field, right-hemisphere (e.g., Mohr et al., 2006). Hemispheric differences have also been observed in the regions associated with the occurrence of OBEs (Blanke and Mohr, 2005) and the location of sleep-induced hallucinations (Girard and Cheyne, 2004). Prior research reporting volumetric reductions over left temporal and parietal regions in schizophrenia has associated these reductions with a loss of the typical left-hemisphere lateralization of language processing present in normal adults (Crow, 1997; Weisbrod et al., 1998).

Research comparing brain activity between problem solving via insight and problem solving via noninsight observed the unique involvement of the right superior temporal gyrus when participants solved problems using

insight but not during the solution of the same problem types when participants generated solutions using noninsight strategies (Jung-Beeman et al., 2004). Insight experiences, most notably associated with the Aha! Experience, are considered a form of creative problem solving. The present research identified power differences between high- and low-transliminality groups in high alpha and low beta frequency bands over a similar region of the right superior temporal lobe. Additional research conducted by Weinstein and Graves (2002, 2001) observed a bias toward right-hemisphere processing, measured by dichotic-listening-task performance, for participants high in positive schizotypy and creativity.

Researchers examining OBEs in patients with neurological disorders who experience full or partial seizures have linked these OBE experiences to lesions at the temporal parietal

junction (TPJ; Blanke et al., 2004). Subsequent research examining the cortical regions linked to OBEs in normal adults observed evoked potentials localized to the TPJ when subjects were asked to complete a mental own-body-transformation task in which they imagined themselves in positions typically described by individuals experiencing OBEs (Blanke et al., 2005). In a recent review of the neural mechanisms underlying OBEs, Blanke and Mohr (2005) observed that OBEs were more often the result of right-hemisphere than left-hemisphere lesions, and that these lesions were localized primarily to the right TPJ.

Finally, prior research of Pizzagalli et al. (2000) observed an increase in right-hemisphere and a decrease in left-hemisphere complexity patterns for participants high in paranormal beliefs when compared to the left > right complexity patterns present in normal adults. These results suggest a decrease in synchronization over the right-hemisphere for participants high in paranormal beliefs. Reduced coherence throughout the brain has also been observed in highly creative adults during baseline recording, and was more pronounced in the right-hemisphere (Jaušovec and Jaušovec, 2000). Because EEG is an index of synchronized brain activity, less high alpha and low beta activity over the right temporal region in high-transliminality participants is consistent with desynchronization of activity in the region corresponding to the results of Pizzagalli et al. The similarity between the region of the STG involved in creative problem solving and the general pattern of reduced baseline activation over this region for individuals high in transliminality may reflect a general pattern of differences in hemispheric processing common across schizophrenia and related populations.

In turning to the results in the gamma frequency bands we observed greater gamma power for the high-transliminality group over medial-frontal cortex. This effect is noteworthy because it is an instance in which power is greater for high-transliminality subjects, in contrast to significant power differences in other bands which were the result of high-transliminality < low-transliminality power differences. This finding argues against the possibility of less overall activity across frequency bands for high-transliminality subjects. We suggest the unlikelihood that this effect is the result of EMG. First, it is not localized over regions typically associated with EMG activity. Second, EMG artifact is typically strongest in the 70–90 Hz range (Goncharova et al.). Therefore, finding an effect that is stronger at lower gamma frequencies, as in the present research, is unlikely to be a reflection of EMG contamination (see Goncharova et al., 2003; see also Lutz et al., 2004). We suggest that greater gamma power over the medial-frontal cortex in high-transliminality participants could be associated with conflict signaling that accompanies the need for cognitive control (e.g., Ridderinkhof et al., 2004). High-transliminality participants report an increase in perceptual aberrations and unusual experiences (e.g., sensitivity to environmental stimuli and hallucinations; Dubal and Viaud-Delmon, 2008, this issue) that would increase their need to utilize higher-level cognitive control to organize incoming stimuli that would otherwise result in sensory confusion. This possibility is supported by prior research in which greater gamma activity was observed over the anterior cingulate cortex in tasks with increasing selective attention demands (Mulert et al., 2007).

Gamma power over the left temporal/occipital region, as well as a region of the right temporal lobe, was lower in the high-transliminality group. Differences over these regions decreased with increasing gamma frequency, arguing against contamination from EMG. It should be noted that in both regions significant power differences (high-transliminality < low-transliminality) were also present in alpha frequency bands. The similarity in regions of interest in alpha and gamma frequency bands could suggest center-activation/surround-inhibition in the regions. This will be discussed further below. Finally, we find it likely that the significant differences observed over the left anterior prefrontal cortex and to a lesser degree over the right anterior prefrontal cortex are linked to EMG. Power differences over these regions increased with increasing gamma frequency and the differences were localized over regions typically associated with EMG activity.

In both hemispheres we observed positively related activity rather than inversely related activity in the alpha and beta, as well as alpha and gamma frequency bands. Traditionally it has been suggested that an inverse relationship exists between alpha and cortical activity in the brain (see Shaw, 2003, for a review). The view of an inverse relationship between alpha and beta has been challenged by the possibility that decreases in alpha can co-occur with decreases in beta power (e.g., Kaufman et al., 1990; Ray and Cole, 1985). Further, it has been suggested that the parallel alpha and beta changes observed in prior research which might appear linked to the same underlying source are instead the result of different underlying sources.

Others have suggested a center-increase/surround-decrease in cortical activity (e.g., Pfurtscheller, 2003; Pfurtscheller and Lopes da Silva, 1999) linked to thalamic gating. Pfurtscheller and colleagues proposed that selective visual attention on the cortical level functions in a pattern comparable to lateral inhibition. An increase in activity at the center (beta) could be coupled with an inhibition of activity in surrounding regions as a result of alpha synchronization. Prior research has indicated an increase in thalamic and visual cortical beta in tasks requiring visual but not auditory attention (Bekisz and Wróbel, 2003; Wróbel, 2000). Further, Bekisz and Wróbel have proposed that coupled activity in these regions is mediated by the cortico-thalamic loop. We suggest that the parallel alpha and beta changes, and perhaps the parallel low alpha and gamma changes over the left poster and right temporal regions are indeed reflections of center-activation/surround-inhibition activity.

4.1. Conclusions

The above results indicate differences in baseline EEGs for individuals high versus low in transliminality. Though differences in brain activity during unusual experiences would be expected, differences would not necessarily be expected in the same individuals at rest during periods of presumably normal affect and consciousness. We believe that the differences observed between transliminality groups in the present research can be linked to transliminality characteristics such as hallucinations and unusual experiences, characteristics also present in positive schizotypy. These

findings strengthen the results of existing research linking schizotypy and transliminality. We further interpret these data as supporting prior research indicating alterations in traditional patterns of hemispheric organization in normal adults. Our results coincide with those of prior research indicating a reduction in the typical left-hemisphere lateralization of language processing in schizophrenia and related disorders, as well as normal adults exhibiting above-average creativity levels.

Results of the present research highlight several key needs for future research. In spite of the differences emerging between transliminality groups in baseline brain activity, it is less clear how these variants at rest are related to brain activity during highly transliminal experiences such as hallucinations and paranormal experiences. In addition, if our predictions are correct and baseline differences are linked to changes in cognitive-task performance, then differences should also be present between high- and low-transliminality groups during the performance of typical cognitive tasks. We did not explore this possibility in the present research.

Research examining transliminality and positive schizotypy suggests an association between these traits but has not explored directly the specific mechanisms linking the two. Similar patterns of cognitive-task performance and hemispheric organization have been identified in prior research suggesting that baseline EEGs between high- and low-schizotypy individuals, especially those differing in positive schizotypy, should parallel the types of differences observed between high- and low-transliminality individuals. Thus, further research is needed that explores specifically the link between resting brain activity and particular characteristics of transliminality, as well as commonalities linking transliminality to schizotypy and creativity.

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