LORETA Coherence and Phase Differences

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Example from the Neuroguide Demo from a high functioning business professional prior to right hemisphere brain damage by being struck by a bat to the right parietal/temporal area resulting in a epidural hematoma. Ct-scan of the left hemisphere was normal. Figures 1 to 4 shows LORETA Coherence and Phase differences with respect to the left and right Brodmann Area 13 and the remaining 43 Brodmann areas organized by distance from BA13 on the y-axis and EEG frequency on the x-axis (D = 1-4Hz; T = 4-8Hz; A1 = 8-10Hz;A2 = 10-12Hz;B1 = 12-15Hz;B2 = 15-18Hz;B3=18-25Hz;HiB = 25-30Hz). The colors in figures 1 and 3 are the raw coherence (0 to 1.0) and phase difference values (degrees) that are scaled equally for the left and right hemisphere. In figures 2 and 4 the Z scores are measures of deviation from age matched normal subjects and are also scaled equally for the two hemispheres (±3 st. dev.).

LORETA Coherence - Raw Scores

Figure 1 shows increases and decreases in coherence demonstrating a distinct pattern that is spatially ordered based on the Euclidean distance from Brodmann area 13 which is near the insula and the transverse temporal gyrus. Volume conduction can not explain horizontal alternating yellow-to-red lines except the hypothesized action of 'U' shaped cortico-cortical fibers because the distance between the horizontal bands are approximately those of the cortico-cortical 'U' shaped fiber distances as described by Braitenburg, 1978; Braigtenberg and Schuz, 1991; 1998. Also, this is a similar EEG pattern previously studied showing a linkage between cortico-cortical white matter metrics and LORETA comodulation (Thatcher et al, 2007). In Figure 1, blue colors represent statistically significant coherence but at lower values than the orange and red colored Brodmann couplings. The lowest coherence values were in the theta (4-7 Hz) and low gamma (25-30 Hz) frequency bands. Note that the theta and gamma coherence was independent of distance from Brodmann area 13. Alpha exhibited increased coherence in specific Brodmann areas near to the temporal lobes, for example, the amygdala and hippocampus and the ventral (BA20), medial (BAs 28 & 35) and lateral temporal lobes (BA21). Importantly, the alternating alpha coherence was independent of distance and specific to the temporal lobe and, therefore, this is impossible to account for based on volume conduction. Instead, this is what is expected if the density of cortico-cortical connections varies in a 'U' shaped manner as explained by Braitenberger (1978) and Braitenberg and Schuz, 1991; 1998.

Right hemisphere coherence failed to show strong alpha resonance between temporal lobe, amygdala and hippocampus in comparison to the undamaged left hemisphere. However, the theta (4-7 Hz) and hi-beta (25-30 Hz) exhibited the lowest coherence which is consistent with increased complexity or reduced redundancy that is essentially the same for the control as well as the damaged hemisphere and therefore is likely a structural or stable property of the cortico-cortical fiber system and the human EEG.

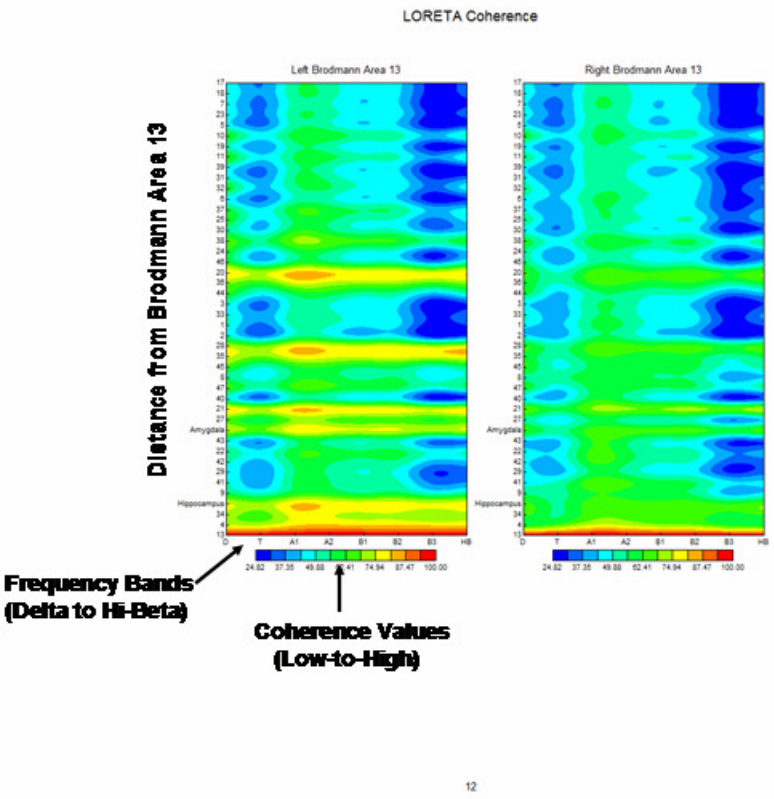

Fig. 1 - Left and right hemisphere LORETA coherence with respect to Brodmann area 13 in right hemisphere damaged patient. Y-axis is the Euclidean distance with respect to Brodmann area 13. The x-axis are frequency bands (D = 1-4Hz; T = 4-8Hz; A1 = 8-10Hz;A2 = 10-12Hz;B1 = 12-15Hz;B2 = 15-18Hz;B3=18-25Hz;HiB = 25-30Hz). The colors represent the magnitude of coherence with blue = lowest values and red = highest values. This shows that theta (4-7 Hz) and Hi-Beta or Gamma (25-30 Hz) exhibit the lowest coherence values which means that these two frequency bands are the most differentiated frequencies. Theta is limbic in origin and Gamma is neocortical in origin and the Alpha1 to Beta3 (8 - 25 Hz) is hypothesized as representing the competitive regime involved in the moment to moment integration of emotion and reason. The alternating horizontal bands of high and low coherence reflect the 'U' shaped cortico-cortical axons that connect different Brodmann areas.

LORETA Coherence - Z Scores

LORETA Z scores show that the right hemisphere is deviant from the age matched normative database primarily in delta, theta and alpha-1 frequency bands and is normal in the beta and hi-beta (Gamma) frequency bands. This is consistent with the surface EEG coherences but provides much greater anatomical detail. For example, deviation from normal is between Brodmann area 13 & right temporal lobe Brodmann areas 20, 21, 24, 28, 36 and the amygdala and hippocampus. Brodmann area 13 is the transverse temporal gyrus and insular cortex and thus the functional connectivity of area 13 with respect to other temporal lobe gyri and the amygdala and hippocampus are deviant from normal.

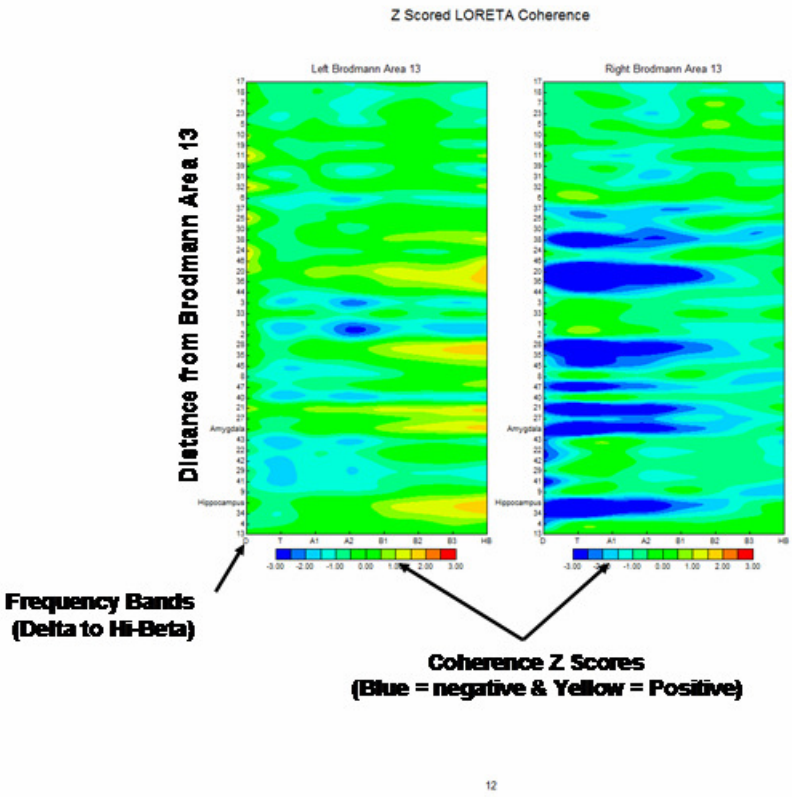

Fig. 2 - Z scores of left and right hemisphere LORETA coherence with respect to Brodmann area 13 in a right hemisphere damaged patient. Y-axis is the Euclidean distance with respect to Brodmann area 13. The x-axis are frequency bands (D = 1-4Hz; T = 4-8Hz; A1 = 8-10Hz;A2 = 10-12Hz;B1 = 12-15Hz;B2 = 15-18Hz;B3=18-25Hz;HiB = 25-30Hz). The colors represent the magnitude of Z scores with blue = negative Z scores and green to red the positive Z scores (± 3 st. dev). This shows reduced connectivity in the right temporal lobe, amygdala and hippocampus in the lower frequency bands. The alternating horizontal bands of high and low coherence reflect the 'U' shaped cortico-cortical axons that connect different Brodmann areas.

LORETA Phase Differences (deg) Raw Scores

Phase differences with respect to Brodmann area 13 show an alternating pattern that can not be explained by volume conduction and is consistent with the existence of the 'U' shaped fiber system of the cortico-cortical white matter axons (Braitenberg, 1978; Braitenberg and Schutz, 1991, 1998; Nunez, 1981). Zero phase difference is present with respect to Brodmann area 4 with the smallest Euclidean distance. This may or may not be due to volume conduction but certainly phase differences increase as a function of distance which cannot be explained by volume conduction. Spatial heterogeneity of phase differences cannot be explained by volume conduction and, instead, LORETA phase differences are best explained by physiology and anatomy. The pattern of alternating high and low phase differences horizontal stripes is characteristic of LORETA phase differences and is present in all combinations of Brodmann areas.

The alternating long horizontal bands of phase differences tend to be independent of frequency. This is what is expected if conduction velocity is constant for all frequencies. For example, for 'cable' connecting locations like Cable TV where telephone, internet, TV, etc. are mixed together and all carried at the same velocity.

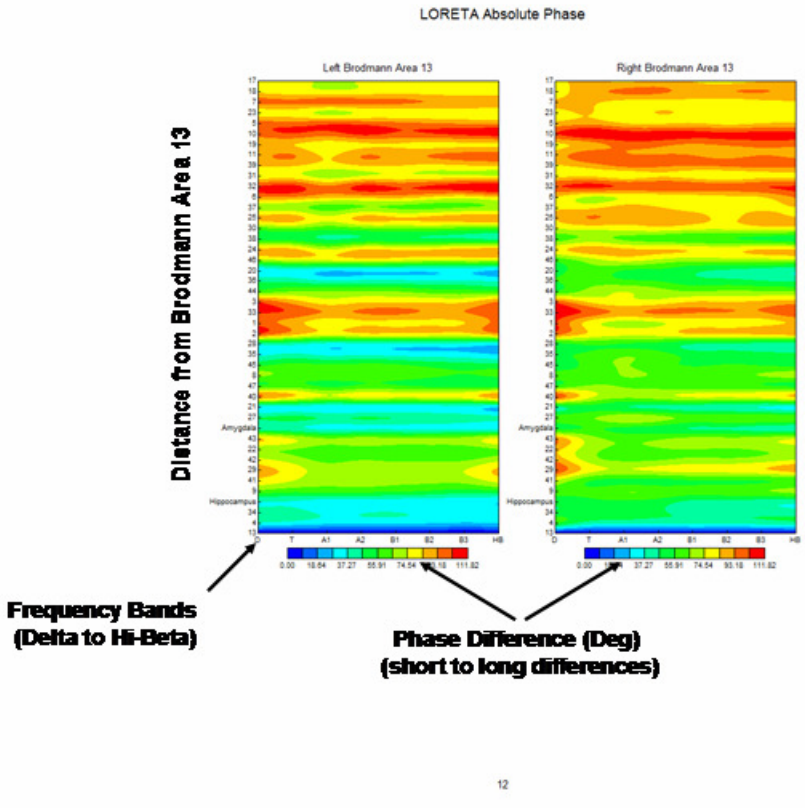

Fig. 3 - Left and right hemisphere LORETA absolute phase differences with respect to Brodmann area 13 in right hemisphere damaged patient. Y-axis is the Euclidean distance with respect to Brodmann area 13. The x-axis are frequency bands (D = 1-4Hz; T = 4-8Hz; A1 = 8-10Hz; A2 = 10-12Hz; B1 = 12-15Hz;B2 = 15-18Hz; B3=18-25Hz; HiB = 25-30Hz). The colors represent the phase difference values with blue = lowest values and red = highest values. The alternating horizontal bands of high and low phase difference reflect the 'U' shaped cortico-cortical axons that connect different Brodmann areas.

LORETA Phase Differences Z Scores

LORETA phase difference Z scores show that the right hemisphere deviates from the age matched normative database in the right hemisphere primarily in delta, theta and alpha-1 frequency bands and is normal in the beta and hi-beta (Gamma) frequency bands. Deviation from normal is in the direction of greater phase delays in the right temporal-parietal lobe. This is consistent with the LORETA EEG coherences and the surface EEG phase but provides much greater anatomical detail. For example, deviation from normal is between Brodmann area 13 & right temporal lobe Brodmann areas 20, 21, 24, 28, 36 and the amygdala and hippocampus. Brodmann area 13 is the transverse temporal gyrus and insular cortex and thus the functional connectivity of area 13 with respect to other temporal lobe gyri and the amygdala and hippocampus are deviant from normal.

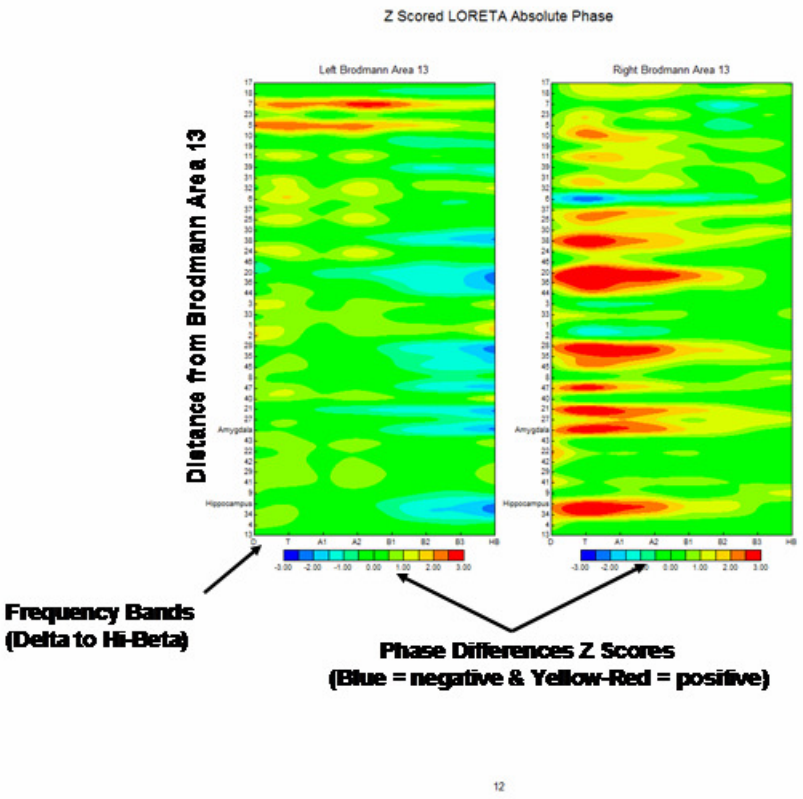

Fig. 4 - Z scores of left and right hemisphere LORETA absolute phase differences with respect to Brodmann area 13 in a right hemisphere damaged patient. Y-axis is the Euclidean distance with respect to Brodmann area 13. The x-axis are frequency bands (D = 1-4Hz; T = 4-8Hz; A1 = 8-10Hz;A2 = 10-12Hz;B1 = 12-15Hz;B2 = 15-18Hz;B3=18-25Hz;HiB = 25-30Hz). The colors represent the magnitude of Z scores with blue = negative Z scores and green to red the positive Z scores (± 3 st. dev). This shows increased delays in the right temporal lobe, amygdala and hippocampus in the lower frequency bands. The alternating horizontal bands of high and low coherence reflect the 'U' shaped cortico-cortical axons that connect different Brodmann areas.

References

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