Brain Research 1644 (2016) 267–277

Contents lists available at ScienceDirect

Brain Research

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

Research report

Focal attenuation of specific electroencephalographic power over the right parahippocampal region during transcerebral copper screening in living subjects and hemispheric asymmetric voltages in fixed brain tissue

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ARTICLE INFO

Article history:
Received 10 June 2015
Received in revised form
17 December 2015
Accepted 17 May 2016
Available online 19 May 2016

Keywords:
QEEG
LORETA
Parahippocampal gyrus
Entorhinal cortices
Human brain
Theta activity

ABSTRACT

Covering the heads of human volunteers with a toque lined with copper mesh compared to no mesh resulted in significant diminishments in quantitative electroencephalographic power within theta and beta-gamma bands over the right caudal hemisphere. The effect was most evident in women compared to men. The significant attenuation of power was verified by LORETA (low resolution electromagnetic tomography) within the parahippocampal region of the right hemisphere. Direct measurements of frequency-dependent voltages of coronal section preserved in ethanol-formalin-acetic acid from our human brain collection revealed consistently elevated power ($0.2\ \mu V^2\ Hz^{-1}$) in right hemispheric structures compared to left. The discrepancy was most pronounced in the grey (cortical) matter of the right parahippocampal region. Probing the superficial convexities of the cerebrum in an unsectioned human brain demonstrated rostrocaudal differences in hemispheric spectral power density asymmetries, particularly over caudal and parahippocampal regions, which were altered as a function of the chemical and spatial contexts imposed upon the tissue. These results indicate that the heterogeneous response of the human cerebrum to covering of the head by a thin conductor could reflect an intrinsic structure and unique electrical property of the (entorhinal) cortices of the right caudal hemisphere that persists in fixed tissue.

1. Introduction

One of the basic assumptions for biological systems and of the human brain as a subset of these systems is that structure dictates function and hence microstructure determines microfunction. As quantitative precision and instruments have evolved over the centuries the presumed homogeneity of structure within the cerebral volume has been modified to accommodate this "complex heterogeneity". For example with the development of flat-mapping and the application of non-linear geometries to the sulcal and gyral patterns, the relative absence of geometric similarity between the left and right hemispheres of the human cerebrum was visualized. In 1997 Van Essen and Drury showed that of the ~80 "folding patterns" discernable in both hemispheres only four (pairs): the central sulcus, Sylvian fissure on the lateral side, the calcarine fissure on the medial side and the cingulate sulcus, were in similar locations. The others exhibited asymmetries. For example the posterior inferior temporal sulcus showed a y-shaped pattern in the right hemisphere but a single linearity in the left. With such propensity for structural anisotropy one would expect a geometric-based potential difference (voltage) that is likely to be frequency-dependent.

Quantitative electroencephalograph (qEEG) and the complex algorithms applied to these data have reiterated the heterogeneity of power densities for inferences of potential differences (voltages) measured a few cm over the cerebral surface as well as the time-dependent alterations in those patterns. The slightly larger voltage measures within the alpha frequency (8–13 Hz) range over the caudal right hemisphere compared to other brain regions which were evident in the days of strip-chart recordings (Morgan et al., 1971), has been enhanced and differentiated. The enhancements can occur over larger regions of the cerebral surface. For example the trans-surface microstate analyses described by Lehmann (1990) and developed by Koenig et al. (2002) revealed the remarkable stability of these states, some of which are

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http://dx.doi.org/10.1016/j.brainres.2016.05.034
0006-8993/

hemispherically asymmetric or "diagonally connected", over people"s lifetimes. Inferences of three dimensional dynamic structure, as inferred by LORETA (low resolution electromagnetic tomography), have allowed discernment of intrinsic differences in regional displays of current density coupled to specific frequency bands.

Although there has been substantial documentation concerning the quantitative properties of cerebral structure and function during rest states or those associated with cognitive challenges, the response of cerebral activity to proximal physical boundaries such as conductors has been less frequently pursued. However metallic helmets and other containments for the human head could potentially affect not only measurements but cerebral function. Here we present evidence that when normal people wear a head-covering lined with copper mesh compared to the same covering without copper mesh, a local attenuation of power within specific frequency bands occurred only over the right caudal area. LORETA analyses indicated the region involved was centralized around and within the right parahippocampal region.

This region is very significant because it contains the entorhinal cortices (Pruessner et al., 2002) which is the primary input to the hippocampal formation whose function is important for the initial stages of representation of experiences or memory (Van Strien et al., 2009; Witter, 1993). The area is known structurally for its multimodal integration of information from and to the entire neocortices and for the unusual stellate cells (the stratum stellar of Stephan) that contains pace-maker neurons that continually generate 8 Hz oscillations with peak-to-peak changes of a few mV (Alonso and Klink, 1993). Interestingly, the energy associated with this increment is remarkably congruent with Landauer"s threshold when 1 bit of information is dissipated to entropy or two operations converge (Saroka and Persinger, 2014). This region is also the area that has been directly correlated or inferred to be associated with weak increases in geomagnetic activity as well as simulations of that activity within the laboratory (Saroka et al., 2014).

In this article we present the results that show electrophysiological activity within the right caudal hemisphere differentially responds to trans-cerebral "shielding". In addition, we found that direct measurements of coronal sections of human brains which had been maintained in ethanol-formalin-acetic acid for decades exhibited visible integrity of general cytological structure within the cerebral cortex revealed a consistent hemispheric anisotropy in potential difference with specific EEG related frequency bands. These increments included potential within the theta (4–7 Hz) band, sufficient to reflect resonance "circuits", within the grey matter (cortices) of the right parahippocampal region. Finally, and in consideration of the intra-cranial environment, we identified rostrocaudal asymmetries in frequency-dependent hemispheric spectral power density as well as spatial-chemical discriminant factors in a whole, unsectioned fixed brain.

2. Results

2.1. qEEG while wearing copper screen-line toque

The presence of plates or surgical metals in some of our patients over the years produced conspicuous changes in strip-chart amplitudes and some frequency modulation over the sites of implant. However the effects of covering the entire scalp with a conductor and then placing more modern sensor caps over the copper lining has not been employed routinely. A priori, one would expect some difference over the right caudal hemisphere in light of the well known enhancement of alpha power over this region.

To test this hypothesis we custom-constructed two cloth coverings shaped like toques. One was lined with 28 gauge copper mesh such that when it was placed on the head the entire brain would be covered. The second identical toque contained no mesh. Following approval by the university's human ethics committee and signed consent a total of twelve men and women from university classes were recruited. Each subject sat within a comfortable arm chair that was housed within an acoustic chamber that was also a Faraday cage (13 m^3). The resultant geomagnetic field within the space was reduced from 45,000 nT to 20,000 nT (Persinger et al., 2015). For the first or second half of the measurements each subject wore the wire lined toque or the control toque. The order was counterbalanced.

A Mitsar 19-channel Quantitative Electroencephalography (qEEG) system connected to a Lenovo ThinkPad laptop running Windows 7 logged electric potential difference from the surface of the scalp referenced to an average of sensors placed on the ears. The qEEG cap contained sensors positioned according to the 10–20 International System of Electrode Placement. A sodium-based electrogel was applied in order to establish a cap-scalp interface. Data were collected for 1 min when the subject"s eyes were closed and for 1 min while the eyes were opened. Data were extracted as spectral power densities and uploaded to SPSS v20. All recording equipment was outside the closed chamber and the only contact with the subject during the recording was through a lapel microphone.

The results were quantitatively evident. Aggregated potentials from the right caudal sensors (T6, P4, and O2) displayed a decrease in global power spectral density ($\mu V^2\,Hz^{-1}$) during the copper-lined condition (M=5.16, SE=1.85) relative to the control condition (M=5.98, SE=2.08) when the participants' eyes closed, $t(11)=2.18$, $p=0.05$. This was not measured for other cerebral regions and was not apparent in the right caudal sensors when the participants' eyes were open ($p>0.05$).

To discern a specific frequency-band source for this effect, global power was separated into low frequency (1.5–14 Hz) and high-frequency (14–40 Hz) band ranges. The right caudal sensor cluster displayed a decrease in high-frequency $\mu V^2\,Hz^{-1}$ during the copper-lined condition (M=1.59, SE=0.73) relative to the control condition (M=1.91, SE=0.81) when the participants' eyes were closed, $t(11)=2.89$, $p<0.05$. The contralateral sensor cluster (T5, P3, and O1) also demonstrated a comparable decrease of $\sim 0.33\,\mu V^2\,Hz^{-1}$ during the copper-lined condition relative to the control condition when for this band of high-frequencies, $t(11)=2.37$, $p<0.05$.

Inspection of the data revealed a conspicuous gender effect. When the females were removed from the analyses the significant decreases in power spectral densities observed during the copper-lined condition were effectively eliminated. Male subjects did not demonstrate decreases in power as a function of cap type within any sensor or band ($p>0.05$). Average decreases of 0.60 $\mu V^2\,Hz^{-1}$ within the high-frequency bands were observed for females during the copper-lined condition relative to control condition, $t(5)=4.41$, $p<0.01$, $r^2=0.80$. In other words for the female subjects wearing or not wearing the copper toque accommodated 80% of the variance in the power variation within the high frequency band.

In addition a specific decrease in theta power over O2 was noted for females only during the copper-lined condition relative to control condition, $t(5)=2.58$, $p=0.05$. This decrease was equivalent to $\sim 0.80\,\mu V^2\,Hz^{-1}$. To discern if there was a finer increment of frequency, spectral frequencies within the theta band (4–7.5 Hz) for the O2 sensor were split into 0.5 Hz increments. A significant decrease in spectral densities within the 5.5 Hz increment were noted during the copper-lined condition, $t(6)=5.41$, $p<0.005$. The same 5.5 Hz increment was associated with a decrease in spectral densities over T6 during the copper-lined