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MicroVolt Variations of The Human Brain (Quantitative Electroencephalography) Display Differential Torque Effects During West-East versus North-South Orientation in the Geomagnetic Field

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ABSTRACT

The human brain was assumed to be an elliptical electric dipole. Repeated quantitative electroencephalographic measurements over several weeks were completed for a single subject who sat in either a magnetic eastward or magnetic southward direction. The predicted potential difference equivalence for the torque while facing perpendicular (west-to-east) to the northward component of the geomagnetic field (relative to facing south) was 4 μV. The actual measurement was 10 μV. The oscillation frequency around the central equilibrium based upon the summed units of neuronal processes within the cerebral cortices for the moment of inertia was 1 to 2 ms which are the boundaries for the action potential of axons and the latencies for diffusion of neurotransmitters. The calculated additional energy available to each neuron within the human cerebrum during the torque condition was ~10^{-20} J which is the same order of magnitude as the energy associated with action potentials, resting membrane potentials, and ligand-receptor binding. It is also the basic energy at the level of the neuronal cell membrane that originates from gravitational forces upon a single cell and the local expression of the uniaxial magnetic anisotropic constant for ferritin which occurs in the brain. These results indicate that the more complex electrophysiological functions that are strongly correlated with cognitive and related human properties can be described by basic physics and may respond to specific geomagnetic spatial orientation.

Indexing terms/Keywords

brain magnetic dipole; torque energy; geomagnetic field orientation; electroencephalographic power; brain physics; moment of inertia; magnetization

Academic Discipline And Sub-Disciplines

Physics; Biophysics; Electromagnetism

SUBJECT CLASSIFICATION

Cerebral Magnetic Dipoles; Geomagnetic Field Torque; Quantitative Electroecephalography

TYPE (METHOD/APPROACH)

Experimental Physics; Quantitative Analyses; Convergent Operations

INTRODUCTION

The human brain occupies space and exhibits mass within which billions of polarized neurons generate circulating currents. Along most of the surface area of this oval (ellipsoid) structure the neurons are oriented as electric dipoles which serve as the substrate for steady-state potentials with magnitudes in the range of 10 mV to 30 mV [1]. Superimposed upon these “d.c.” or steady-state fields are time-varying perturbations in the order of 10 μV to 100 μV that reflect interface patterns and correlated inputs from afferent (sensory) pathways and internal, closed circuits that constitute most (~90%) of the system. Considering the approximately 1.27:1 ratio of the major (rostral-caudal) to minor (lateral-medial) axes of this current generating mass and its accompanying electric and magnetic fields, the human brain should display evidence of torque when oriented in an east-west with respect to a north-south direction within the local geomagnetic field. Here we present experimental evidence that quantifiable shifts that are consistent with torque are manifested within measurable shifts in the global power measured by quantitative electroencephalography (QEEG).

THE MODEL

The approximately 25 billion neurons [2] within the 3 to 5 mm shell (cortices) that define the outer boundary of the human cerebrum is considered the primary source of electroencephalographic activity. This activity is strongly coupled to complex subjective experiences and cognitive operations that contribute to overt behaviors. The cerebral cortices can be assumed to be analogous to the billions of circulating atomic currents attributed to the actual sources of the magnetic (B) field in magnetizable materials. The magnetization M is defined as the average dipole moment ($A \cdot m^2$) per unit volume (m^3) or $A \cdot m^{-1}$.

The torque (T) in Joules upon an integrated magnetic dipole such as the human cerebrum when immersed in the static magnetic field of the earth can be described by:

$$T = mB \sin\theta \quad (1)$$

where m is the dipole moment for a current loop ($I\pi r^2$). The integrated loop is generated in a rostral-to-caudal direction every ~20 to 25 ms (or "40 Hz"). When integrated over the length of the magnet, the total torque would be:

$$T=(Ml\pi r^2)\cdot B\ \sin\theta \quad (2)$$

where M is the equivalent of the uniform permanent magnetization and $l\pi r^2$ is the volume of the ellipsoid magnet.

For comparative precision, the dipole moment (D_m) for a spherical shaped volume would be:

$$D_m=4/3\pi\ r^3\ M \quad (3),$$

such that the total torque would be:

$$T=d_m\ B\ \sin\theta \quad (4).$$

Although the parameters by which predictions might be made for the cerebral volume are not exact, median averages were employed to obtain first order estimates for the solutions for equations 3 and 4. A typical steady state potential difference between the rostral and caudal boundaries of the human cerebrum is ~30 mV ($3\cdot10^{-2}$V). The current within the whole brain which would be mediated primarily through interstitial (extracellular) fluid with a resistivity of 2 $\Omega\cdot$m would be $1.5\cdot10^{-2}$A$\cdot$m^{-1} and when applied across the longitudinal length of the cerebrum (~$1.8\cdot10^{-1}$ m) is $2.7\cdot10^{-3}$ A. Distributed over the total surface area of the cerebral cortices which according to Pakkenburg et al [2] is $8\cdot10^{-2}$ m^2, the magnetic moment would $2.2\cdot10^{-4}$ A$\cdot$m^2 and when divided by the volume of the cerebrum ($1.3\cdot10^{-3}$ m^{-3}), results in a magnetization value (M) of $1.7\cdot10^{-1}$ A$\cdot$m^{-1}.

When this value is inserted into equation 3, where the averaged radius of the cerebrum of $5.5\cdot10^{-2}$ m is assumed, the dipole moment is ~$1.2\cdot10^{-4}$ A$\cdot$m^2. Although the resultant static geomagnetic field in our location of measurement is about 49,400 nT, the N-S component of the local magnetic field was about 10,200 nT. Consequently the torque upon the rostral-caudal dipole of the cerebrum when it is perpendicular (facing east) compared to when it is parallel (facing south) or a sine θ of 90° would be ~$1.2\cdot10^{-9}$ J.

The spatial and temporal properties of the neurons within the cerebral cortices can be extracted from the time constants and space constants of the average cortical neuron. For the time constant (τ),

$$T=R_m\cdot C_m \qquad (5).$$

If the median value for R_m is 10^5 $\Omega\cdot$cm^2 and the capacitance of the membrane is 10^{-6} F$\cdot$cm^2 the time constant is 100 ms or 10 Hz. In fact the latter is peak power output of the human electroencephalogram [3] and the former is the median value for relative refractory periods for major classes of neurons.

The space (or length) constant for the typical axon is classically described by:

$$\lambda=\sqrt{[(d\cdot R_m)\cdot R_i^{-1}]} \qquad (6),$$

where d is the diameter of the axon, R_m is the typical resistance of the membrane, and R_i is the resistance of the axoplasm. Assuming the value 10^5 $\Omega\cdot$cm^2 for R_m, the average axon width of 1 μm and the axoplasm's resistance to be ~50 $\Omega\cdot$cm, the space constant would 0.2 to 0.3 cm or 2 to 3 mm which is the average thickness of the cerebral cortices. Consequently the gross physical and dynamic properties of the cerebral cortices reflect the properties of the individual units that comprise that manifold.

We assumed that the primary source of the electroencephalographic activity from the cerebral cortices whose time constant for the basic unit axon is about 100 ms (10 Hz). The product of the unit charge ($1.6\cdot10^{-19}$ A$\cdot$s), the ~10^6 charges that maintain a resting membrane potential [4], and the ~2 to $2.5\cdot10^{10}$ neurons within the cerebral cortices where about 10% (0.1) are active at any given time because of the time constant, the total Coulombs would be $3.2\cdot10^{-4}$ A$\cdot$s. The division of energy ($1.2\cdot10^{-9}$ J) from the torque at 90° from the north vector by $3.2\cdot10^{-4}$ A$\cdot$s would be ~3 to 4 μV. This is within the range of measurement possibilities for modern QEEG.

METHODS AND MATERIALS

Although the tradition in quantitative electroencephalography has been to assess groups, we reasoned that the repeated measure of the same brain (person) would reduce the large source of variance from individual differences and amplify the experimental differences. A single 30 year old male volunteered for QEEG measurements on 12 separate occasions. For half the number of measurements he sat in a southern direction (parallel to the N-S geomagnetic field component). The other half of the numbers of measurements he sat facing east. The measurements were completed in an alternating direction on separate days.

The data were collected from a 19 channel Mitsar device from sensors distributed and maintained in position by an EEG cap. The data were collected at 500 Hz for duration of 4 min while the subject's eyes were closed. The measurements from the major longitudinal (rostral-caudal) axis (Fp1, O2) were extracted. The spectral power as measured in μV$^2\cdot$Hz^{-1} was obtained for the band between 1 and 40 Hz. The means and standard deviations for the values for the 6 different days in which the person faced south and the 6 different days the person faced east (maximum torque) were calculated by SPSS-PC software.

RESULTS AND VERIFICATIONS

The means and standard deviations for spectral power ($\mu V^2 \cdot Hz^{-1}$) for the 6 days in which the subject faced east (maximum torque) were 365±115 $\mu V^2 \cdot Hz^{-1}$. These values for the average of the 6 days the subject faced south were 257±83 $\mu V^2 \cdot Hz^{-1}$. This inference of cerebral voltage during the maximum torque orientation was 108 μV^2 higher than during the minimum torque (θ=0) and was statistically significant. The square root of that value 10 μV and is within the same order of magnitude as that predicted from the model and physical approach to the cerebrum as a magnetic dipole that is prone to torque from the geomagnetic field in which it is immersed.

The torque equivalence of $1.2 \cdot 10^{-9}$ J becomes relevant if it is distributed within every neuron within the cerebral volume. If the numbers of neurons in addition to the 20 to 25 billion within the cerebral cortices are considered, that is about 3 times that value (60 billion), the average energy per neuron would be $2 \cdot 10^{-20}$ J. This is within the increment associated with effect of a voltage shift ($1.2 \cdot 10^{-1}$ V) for each action potential with a duration of ~1 ms on a unit charge ($1.6 \cdot 10^{-19}$ A s). It is also the energy associated with the electric force between two adjacent potassium ions, the sum of which is one of the candidates for the plasma membrane resting potential and the typical sequestering energy for many ligands to receptors. This resulting biophysical potential would be within the range of magnitudes to accommodate the differential orientation effects within the geomagnetic field upon the onset of dream (Rapid Eye Movement) sleep as measured by Ruhenstroh-Bauer et al [5].

This quantity of energy per cell that would be associated with a frequent torque within the cerebrum as it orients within the degrees between parallel and orthogonal confluence with the north-south geomagnetic directional field is not trivial. Wien's law of λ=0.29 $cm \cdot deg \cdot K^{-1}$ where K is temperature in Kelvin, indicates that at 37° C, the wavelength is 10 μm. The equivalent frequency when the velocity of light in a vacuum is assumed results in 10^{-20} J. In addition when the product of the mass of the earth ($5.98 \cdot 10^{24}$ kg) and the mass of a 10 μm diameter cell ($5.2 \cdot 10^{-13}$ kg) is divided by the square of the earth's radius ($6.38 \cdot 10^{6}$ m) and multiplied by G ($6.67 \cdot 10^{-11}$ $m^3 \cdot kg^{-1} \cdot s^{-2}$) the force is $5.1 \cdot 10^{-12}$ N. When applied across the width of a plasma cell membrane (~10^{-8} m) the energy is ~10^{-20} J. The convergence of the magnitudes of energies from the steady-state gravitational source and the dynamic (transient) magnetic field torque-initiated source suggests a potentially recondite synergism.

The human brain also contains iron as measured by electron microscopy, Mossbauer spectrometry and SQUID magnetometry [6]. Approximately 61% to 88% of the iron is ferritin-like in nature. The total concentration within the brain has been estimated to be 1.5 (3) mg. The average core diameter of the particles was about 3 to 5 nm. This was similar to original work of Kirschvink et al [7] indicating ~4 ng of magnetite per gm of brain tissue. However the magnitude within the meninges which covers the cerebral cortices was 70 ng per g. They found that brain tissue contained about 5 million crystals of magnetic per gm distributed in 50,000 to 100,000 discrete clusters. Grain sizes were bimodal in distribution: between 10 to 70 nm or 90 to 200 nm. The particles' magnetic orientation energies in the geomagnetic field were 20 to 150 times higher than the background kT values. The value of $4 \cdot 10^{4}$ $J \cdot m^{-3}$ for the uniaxial magnetic anisotropy constant for ferritin in the brain measured by Dubiel et al [6] is particularly relevant. This is within the upper limit of the energy associated with glucose utilization per s (~20 to 30 W). The effective volume within the cerebrum to obtain the value $2 \cdot 10^{-20}$ J would be $0.5 \cdot 10^{-24}$ m^3 or a functional linear distance of 8 nm, which is within the range of the width of a plasma cell membrane.

FURTHER EXTRAPOLATIONS

In a dynamic system where the displacements would be minute, the energies would be extremely small such as 10^{-20} J and the functional distances would be with the range of delocalized electrons. Newton's third law should be quantifiable as an oscillatory return to the initial baseline condition. It would be related to the angular displacement. Consequently the electrical processes within the cerebrum that respond with torque to the east-west relative to north-south orientations should oscillate around the central (equilibrium) condition with a frequency (*f*), such that,

$$f=(2\pi)^{-1} \sqrt{[(vMB) \cdot I_m^{-1}]} \quad (7)$$

where v is the volume of the cerebrum, M is magnetization equivalent, B is the magnetic field strength and I_m is the moment of inertia of the "magnet" (the brain) around its center of oscillation. Technically, moment of inertia is the sum of the products of the mass of each unit or particle of a body multiplied by the square of its perpendicular distance from the axis of central tendency.

The moment of inertia for the cerebrum as a whole mass would be the product of its mass (~1.5 kg) and square of the radius ($5.5 \cdot 10^{-2}$ m) or $4.6 \cdot 10^{-3}$ $kg \cdot m^2$. The square root of the quotient for $2.2 \cdot 10^{-9}$ J and the moment of inertia is $0.7 \cdot 10^{-3}$ Hz and after accounting for $2\pi^{-1}$ the frequency would be $1.1 \cdot 10^{-4}$ Hz, or, $9 \cdot 10^{3}$ s. This is 1.5 to 2 hrs. Such a period would be expected to be negligible considering the frequency of shifting orientation of the typical person.

However if the moment of inertia of the whole cerebrum (cortices) was considered the averaged values for each cell that constitutes the mass, then a more rational value emerges. Although most approaches employ the features of only the neuronal soma, the dipole component arises from the processes (axon and dendrites). The soma constitutes only about 10% of the total volume of the neuron. Consequently the mass of the entire neuron with processes would be $4.7 \cdot 10^{-11}$ kg. Assuming the average depth of the cerebral cortices, 3 mm ($3 \cdot 10^{-3}$ m), the resulting moment of inertia would be

$1.1 \cdot 10^{-16}$ kg·m^2. The square root of the ratio of $2.2 \cdot 10^{-9}$ J and this estimate of frequency is $4.5 \cdot 10^3$ Hz. When divided by 2π, the oscillation frequency would be ~$0.7 \cdot 10^3$ Hz. The equivalent duration is between ~1 ms and 2 ms.

This calculated "oscillation" around the reference center is within the precise range of multiple fundamental electrophysiological and chemical properties of neurons upon which the QEEG is based. It is within the range of the absolute refractory period for action potentials. As shown by Clements [8] the slower phase of the biphasic time constant for transmitters to traverse the synaptic cleft requires 2 ms. According to Benke et al [9] the range of the "opening time" for single conductance ion channels ranges between 0.5 and 4 ms. The convergence of the frequency for these components suggests that the temporal frame of cerebral function upon which higher functions strongly depend may reflect the cumulative history of the oscillations around the central equilibrium of the frequently moving dipole cerebral volumes within the earth's magnetic field.

DISCUSSION

The results of this study indicate that the total spectral power over the major axis of the human cerebrum displays evidence of energy accumulation or torque when the person is facing east (perpendicular to the north directional component of the geomagnetic field) relative to facing south. The difference in the total amount of this energy and associated voltage was consistent with predictions from the basic equations of physics. In addition the oscillation of the "cerebral dipole" around its central equilibrium involved a frequency that was consistent with the contribution from the averaged sum of each neuron and its processes rather than the brain as single mass unit. The specific frequency reflected a duration (about 1 ms) that defines the basic temporal unit of the physical brain. This is the duration of the absolute refractory period of axons, as well as the matched time for neurotransmitters to diffuse across the synaptic cleft.

Although traditions in many cultures refer to the orientation of the experient with respect to beneficial influences of the local static geomagnetic field, precise measurements employing the perspectives of modern physics have been published only recently. Ruhenstroh-Bauer et al [5] found that compared to subjects sleeping in the N-S position those sleeping in the E-W direction display a shortened latency to display REM (Rapid Eye Movement) sleep that is significantly correlated with dreaming. If there is an additional 10^{-20} J per neuron available from simply this orientation then an acceleration of the neural processes that initiate the pontine-geniculo-occipital processes that precede normal dreaming might be expected.

Later Ruhenstroh-Bauer et al [5] found that even with strip-chart recording the EEGs of normal subjects differed depending if they were sitting in a N-S or E-W direction. They employed a 16 channel system with a band pass filter of 0.5 to 30 Hz. Mean power spectra of 6 s periods were obtained for classic bands that included delta, theta, alpha, beta1 and beta2. The measurements were taken while the subjects opened and close their fists. They found the overall power across all frequency bands was decreased to 78.1% (by about 21%) for those who were sitting in the magnetic E-W vs the magnetic N-S position. One possible explanation might be that the additional energy from effects of the torque was utilized to augment the power associated with this gross motor movement.

The convergent values of 10^{-20} J for the differential between parallel and perpendicular (torque) orientations to the specific north-south (X) component of the magnetometer field with those associated with the effects of gravitational energy across the membrane and the uniaxial magnetic anisotropy at the level of the membrane may suggest a site of synergism within the cerebral volume. Specific orientation, such as the W-E direction, might allow for the information associated with these energies to be manifested, transiently at least, within the human brain. In general however these effects would not likely be discerned subjectively.

CONCLUSIONS

The slightly longitudinal human cerebrum which displays a steady state potential behaves as a dipole within the geomagnetic field. The differential torque predicted by traditional equations was within the same order of magnitude as that measured by precise quantitative electroencephalography. The oscillation of the constituent moments of inertia match the temporal boundaries for the electrophysiological (action potential duration) and chemical (neurotransmitter diffusion) parameters that create the transcererbral processes measured by quantitative electroencephalography. The net increase in energy associated with the E-W torque relative to the N-S direction was 10^{-20} Joules per neuron and is the same order of magnitude as that associated with ferritin molecules and terrestrial gravity effects upon a unit cell. Considering the pervasive occurrence of this quantity of energy within the single action potential, the resting membrane potential and "binding" energies for neurotransmitters at receptors, the potential significance of sitting east vs south might be explored in more detail.

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Author's Biography

David A. E. Vares, is a Ph.D. student of the Interdisciplinary Human Studies Program and a Member of the Biophoton and Quantum Molecular Biology Laboratories. He demonstrated the relationship between the paucity of 3.6 to 3.7 M quakes globally and their potential connection to Planck Length energies. He has applied basic physics to interpersonal distances as factors in cancer prevalence and the potential contributions of energies from small magnitude global seismicity to human group conflicts. Recently he and his colleagues demonstrated a strong (0.99) inverse correlation between global warming in the atmosphere and oceans, carbon dioxide increases, and the diminishing strength of the earth's magnetic dipole. The quantitative change in intermolecular magnetic energies converged with bulk changes in global temperature and CO_2.

Paula L. Corradini, completed her H.B.Sc. in Behavioural (Physical) Neuroscience and her M.A. in Psychology, specializing in the physics and physiology of the human brain. Her expertise involved Quantitative Electroencephalography (QEEG) and s_LORETA (Low Resolution Electromagnetic Tomography). She was the first to demonstrate that even the most complex neuropsychological tests employed in clinical settings could be differentially indentified by viewing the current density profiles of incremental frequencies from the subjects' brains while they were engaging in the tasks. She has applied microstate analyses of brain functions to reveal recondite patterns of injury within patients who sustained closed head injuries but without loss of consciousness.

Michael A. Persinger, Ph.D. is a Full Professor at Laurentian University in Sudbury, Ontario, Canada. He is affiliated with a number of different programs including Biomolecular Sciences, Behavioural Neuroscience and Human Studies as well as the Quantum Molecular Biology Laboratory where he is examining the relationship between 10^{-20} J events within the brain and complex functions. Dr. Persinger and his colleagues have experimentally demonstrated the validity of Cosic's Molecular Resonance Recognition Model, Bokkon's Cerebral Photon Field Hypothesis and the efficacy of proton driving patterned magnetic fields that inhibit the growth of cancer cells but not normal cells. He is an interdisciplinary scientist whose primary goal is to integrate the physical sciences, social sciences and humanities according to their fundamental operations. Within the last 50 years he has published more than 500 technical articles in variety of areas that range from Astronomy to Zoology. His present experiments are focused upon understanding the relationship between the structure of space and distribution of energy, the shared dimensional equivalence of quantized gravitational and electromagnetic fields, and the empirical demonstration of an intrinsic entanglement velocity.