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An EEG/MRI-dMRI Study: Structural properties of the Thalamus and its Influence on Human Alpha Waves

Authors and Affiliations

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Introduction, Methods, Results, Conclusions - 4000 Total Character Limit (includes spaces)

- *Please include sufficient detail in methods and results to enable readers to have a clear understanding of what data have been collected and what results have been found. For example, where appropriate please include information on data acquisition and analysis, number of subjects tested, quantitative results and statistics*
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Introduction:

Alpha waves are defined as electroencephalography (EEG) oscillations in the 8-13 Hz frequency range, recordable from the occipital lobe when the subject is relaxed, with eyes closed. Despite their discovery by Berger over 80 years ago, the source of their high inter-individual variability is poorly understood. Several studies [1] have suggested that the thalamus, more specifically the pulvinar and the lateral geniculate nucleus (LGN), play an important role in shaping alpha activity. However, such studies are often based on functional magnetic resonance imaging (fMRI) analysis, and few have analyzed the importance of its physical shape. Our goal was to therefore investigate whether alpha variability is related to anatomical features of the thalamus. For this, we used diffusion MRI (dMRI) along with a novel segmentation algorithm to compute the size of the thalamus and its nuclei. These were then correlated to different properties of the alpha rhythm in healthy participants.

Methods : _Subjects._ EEG and magnetic resonance imaging (MRI) was acquired from 19 healthy subjects (10 males, mean age 23, range 18-30). _EEG Acquisition and data processing._ Continuous 64-channel EEG was acquired while alternating 30 seconds eyes closed (EC), 20 seconds eyes opened (EO), 5 times, plus a last 30 seconds EC, for a total of 4m40s. The data were high-passed filtered at 0.1Hz, denoised with independent component analysis (ICA) [2] and re-referenced to a common average. The windows EC and EO were separated, and a Fourier transform was performed in each. Two EEG markers were studied: the alpha peak of each subject was defined as the highest power in the 8-14Hz band of the EC spectrum, and the amplitude of the alpha band was defined as the greatest difference between the EC spectrum and the EO spectrum in the same frequency range. *MRI Acquitision and data processing*. Diffusion MR images (dMRI) were acquired along 64 uniformly distributed directions using a b-value of b=1000 s/mm^2 and a single b=0 s/mm^2 image using the single-shot echo-planar imaging sequence on a 1.5 Tesla SIEMENS Magnetom (128x128 matrix, 2 mm isotropic resolution, TR/TE 11000/98 ms and GRAPPA factor 2). Fiber Orientation Distribution Functions reconstruction was done with dipy (www.dipy.org) with spherical harmonics order 8, and the principal diffusion direction (PDD) was extracted from each voxel. An anatomical T1-weighted 1 mm isotropic MPRAGE (TR/TE 6.57/2.52 ms) image was also acquired. It was denoised with non-local means [3], skull-stripped and registered to diffusion space. The thalamus was segmented using FIRST [4] and all voxels with a fractional anisotropy between 0.1-0.5 were removed. The thalamus was then sub-segmented in its nuclei using an algorithm that groups voxels with similar PDD within an N degree angle. Correlations were calculated between the sizes of the most posterior clusters and the EEG markers.

Results : Across subjects, the inferior-posterior part of the thalamus, that should correspond to the LGN, was segmented into one or two clusters (see fig.1). We did not find a statistically significant correlation with either marker of EEG, as showed in fig.2. However, the cluster situated in the superior-posterior part of the thalamus (likely related to the pulvinar) showed a better correlation ($R=0.61$, $p<0.005$).

Conclusions : The size of the LGN was not correlated to subject-to-subject variations in EEG alpha activity. However, the superior part of the posterior thalamus, corresponding to the pulvinar, seemed to correlate better. These results suggest that anatomical variations in specific thalamic nuclei may explain a portion of alpha variability in healthy subjects. We are currently refining our segmentation algorithm by using state-of-the-art tractography to better separate thalamic clusters.

Figures (optional)

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References

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Annas, G.J. (1997a), 'New drugs for acute respiratory distress syndrome', New England Journal of Medicine, vol. 337, no. 6, pp. 435-439.

1 Omata, K., Hanakawa, T., Morimoto, M. and Honda, M. (2013), 'Spontaneous Slow Fluctuation of EEG Alpha Rhythm Reflects Activity in Deep Brain Structures : A Simultaneous EEG-fMRI Study', Plos

One, vol. 8, no. 6, pp. E66869.

2. Comon, P. (1994), 'Independent component analysis, a new concept?', Signal processing, vol. 36, no. 3, pp. 287-314.

3. Buades, A., Coll, B. and Morel, J.-M. (2005), 'A non-local algorithm for image denoising', Computer Vision and Pattern Recognition, 2005. CVPR 2005. IEEE Computer Society Conference on, vol. 2, pp. 60-65.

4. Patenaude, B., Smith, S.M., Kennedy, D., and Jenkinson M. A Bayesian Model of Shape and Appearance for Subcortical Brain NeuroImage, 56(3):907-922, 2011.

Possiblement: Mang, S.C., Busza, A., Reiterer, S., Grodd, W. et al. (2011), 'Thalamus Segmentation Based on the Local Diffusion Direction: A Group Study', Magnetic Resonance in Medicine, vol.67, no. 1, pp. 118-126.

using (WHAT) amplifier and a cap (actiCAP) using the international 10–20 system, at a sampling rate of 500 Hz. The reference electrode was positioned at the FCz. The subject sat, relaxed. The paradigm was a block design, with

An EC frequency spectrum was obtained by taking the mean of the frequency spectrum of each EC window, and an EO frequency spectrum was obtained in the same way.

All subjects provided written, informed consent and all protocols were approved by the Centre Hospitalier Universitaire de Sherbrooke.