Evolution of EEG Functional Connectivity Across Age Groups in Non-Epileptic Children

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Rationale

- EEG functional connectivity reflects statistical dependencies between cortical regions and offers insights into brain network organization. Graph theory applied to EEG data enables visualization of how these networks evolve. However, normative developmental patterns of both functional connectivity and power spectral features remain underexplored, limiting our ability to detect pathological deviations.

Methods

- We retrospectively analyzed de-identified long-term EEGs from 144 children, aged 1 month to 16 years, referred to Saint-Luc University Hospital for paroxysmal events. All participants had normal EEG and a final diagnosis of non-epileptic events or other benign conditions, such as migraine or vasovagal syncope. EEGs were pre-processed (artefact reduction, band-pass filtering, and current source density application), and one hundred 3-second-length epochs were selected in calm wakefulness condition. From these epochs, we computed power spectral analysis (periodic and aperiodic components) using the Fast Fourier Transformation and the Fitting-Oscillations-&-One-Over-F method. Successively, we assessed several connectivity metrics, such as weighted Phase Lag Index (wPLI), corrected imaginary part of Phase Locking Value (cIPLV), and orthogonalized Amplitude Envelope Correlation (ortho-AEC). We finally derived network measures (mean degree and efficiency) from these metrics, both at whole scalp and regional levels.

Results

- Decrease in the absolute band power over age in all bands (Fig. 1)
- Decrease in relative delta band power and increase in relative alpha, beta, and gamma (Fig. 2)
- The offset of the aperiodic component decreases with age (Fig. 3)
- The exponent of the aperiodic component is higher in the age group [0, 4] years (Fig. 4)
- Higher efficiency and degree in the age group [0, 4] years in all bands, particularly in delta band, both with ci-PLV and ortho-AEC (Figs. 5 and 6).
- Most changes in spectral power and connectivity are seen over the complete brain, not regional (but low-density EEG with 19 channels).
- Regional change is seen in spectral peak frequency, more pronounced parieto-occipital (maturation of alpha rhythm ?): data not shown
- No clear sexual difference

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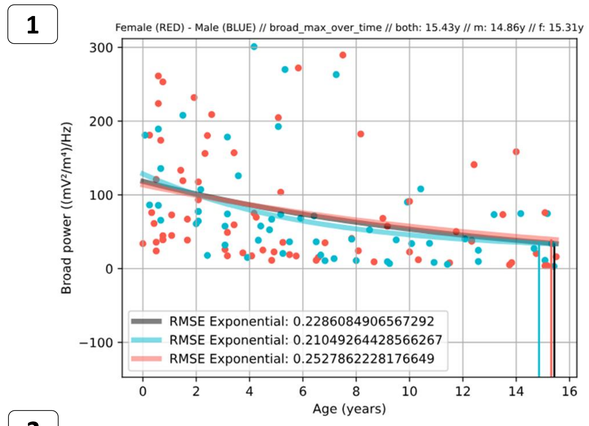

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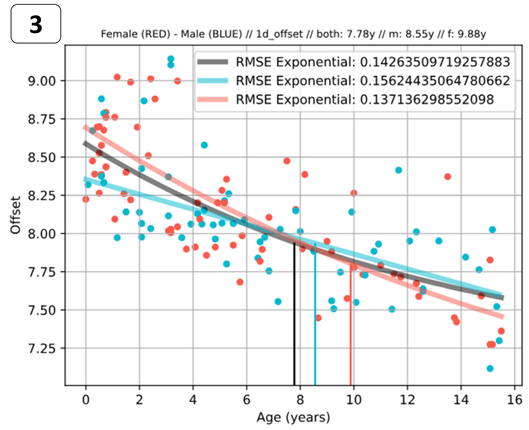

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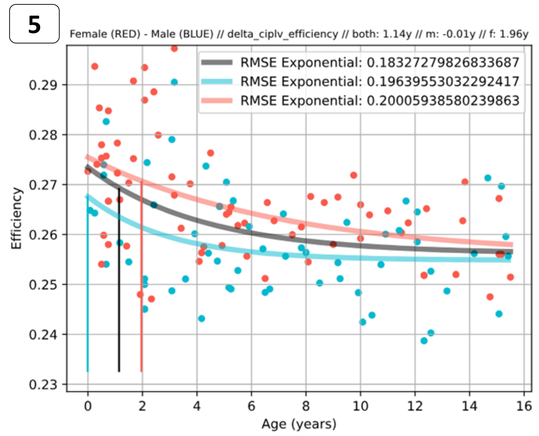

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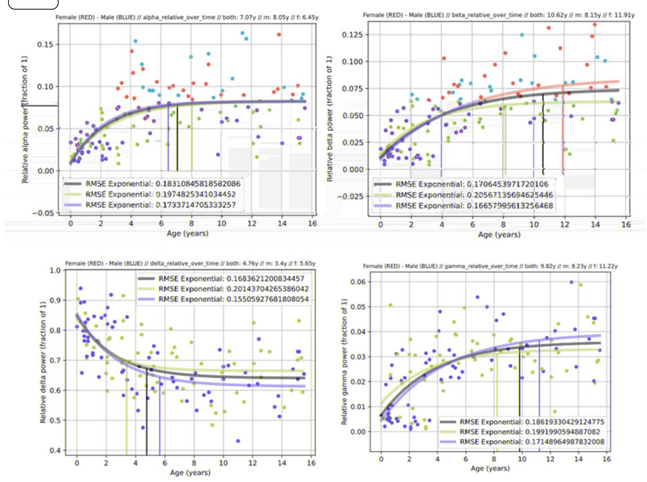

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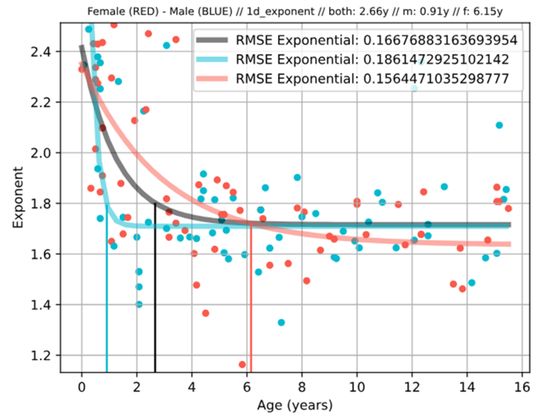

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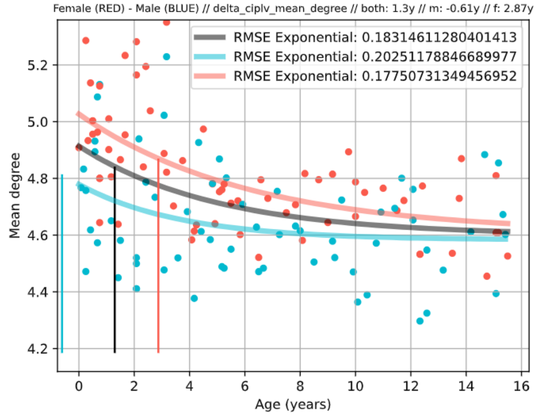

Conclusions

- These findings highlight developmental trends in EEG power and connectivity. Power spectral analysis indicates a developmental shift toward high-frequency activity and a more balanced ratio between excitatory and inhibitory synaptic processes.
- Although connectivity results varied, they suggested age-related changes in network organization, with evolving balance between integration and segregation, consistent with a "small-world" topology.
- A larger longitudinal study is warranted to gain a more robust understanding of these maturational changes over time and to establish normative references to compare brain development trajectories in physiological and various pathological conditions, such as epilepsy.