Age-Related Trends in Transient Beta Bursts: Observations from Big Data

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Human neurophysiological signals recorded by MEG consist of a series of transient bursts of neural activity with variable underlying sources and temporal characteristics. The characteristics of these bursts (e.g., burst rate, power, timing, etc.) change during task performance and throughout the normal ageing process in ways that can inform about underlying neural dynamics. In this work, we are interested in investigating the temporal and spatial characteristics of transient beta (15-30 Hz) bursts in the sensorimotor brain regions. Our objective is to identify age-related changes in these characteristics that may provide insight into functional changes in neurophysiology across the lifespan. Here, we present a novel method for source localization of transient bursts, along with a novel convolutional dictionary learning (CDL) method for transient burst detection that minimizes bias in the burst detection procedure.

We applied these methods to a large, open-access MEG dataset of over 500 healthy participants between the ages of 18-88 collected by the Cambridge Center for Ageing and Neuroscience (CamCAN). Our source localization method was used to identify the cortical sources that were most active during high-power beta bursts recorded during movement and rest. Regression analyses were then used to relate the peak source locations and regional distributions to participant age to identify age-related changes in the cortical sources of beta bursts. The analysis revealed that transient beta bursts localized to the primary sensorimotor cortices and exhibited a significant anterior shift in peak source location with age (see Figure A). These findings suggest that there is a shift in the cortical generators of beta bursts with age and that older adults may recruit additional anterior mechanisms during sensorimotor activation.

In the second part of our work, CDL was used to detect transient bursts by decomposing the signal into a convolution between a few repeating spatiotemporal patterns, called atoms, and their associated sparse activation vectors. Each atom consisted of a temporal component (i.e., a 500 ms waveform) and a spatial component (i.e., an array of weights representing the contribution of each MEG sensor to the pattern). We used CDL to extract 20 atoms for each participant and then applied an unsupervised clustering algorithm to cluster atoms across participants based on spatiotemporal similarity. This procedure allowed us to identify common signals at the group level and assess inter-subject variability and age-related trends in the characteristics of the detected atoms. The application of CDL to this dataset resulted in the detection of two distinct types of sensorimotor beta bursts with different spatial patterns (see Figure B). Age-related analyses revealed that both burst types increased in activity with age and that the increase in activity was dependent on the burst rate (i.e., number of non-zero instances of activity) rather than the burst power (i.e., magnitude of the activity). This finding provides insight to the neural mechanisms underlying age-related changes in MEG signals, suggesting that increases in beta activity with age are dependent on increases in the rate of neuronal firing rather than the size of the neuronal population.

The complimentary methods presented in this work provide a novel set of tools that can be used to probe neural transients to provide insight into functional changes in the brain. These methods together revealed the presence of multiple cortical generators of beta bursts that are dynamically related to healthy ageing.