Time-frequency analysis of brain connectivity with fMRI: A new method based on Wavelet Transform Coherence

Miguel Almeida[1,2], Luís Filipe Botelho[3], Adriana Martins da Silva[1,4], Matthew Brett[5], Jean-Baptiste Poline[6], Jean-Luc Anton[7], Alexandre Andrade[1]

[1]Instituto de Biofísica e Engenharia Biomédica, Faculdade de Ciências da Universidade de Lisboa, Portugal; [2]Instituto Superior Técnico, Universidade Técnica de Lisboa, Portugal; [3]Hospital Geral de Santo António, Porto, Portugal; [4]Faculdade de Medicina de Lisboa, Portugal; [5]Medical Research Council – Cogniton and Brain Sciences Unit, Cambridge, UK; [6]Commissariat à l'Énergie Atomique/Service Hospitalier Frédéric Joliot, Orsay, France; [7]fMRI Center, CHU La Timône, Marseille, France.

miguelbalmeida@gmail.com, aandrade@fc.ul.pt

Introduction

Connectivity

•Several groups have studied low-frequency fMRI connectivity over the last years [1,2].

•Coherence-based approaches are a suitable way to study low-frequency fMRI connectivity [3,4].

•Time-frequency methods have the ability to capture temporal fluctuations of connectivity.

•The Cross-Wavelet Transform (CWT) measures common time-frequency power between two signals and their phase difference:

$$W^{XY}(n,s) = W^X(n,s)W^{Y*}(n,s)$$

where $W^X(n,s)$ is the (Morlet) wavelet transform of the signal X [5].

•Wavelet-Transform Coherence (WTC) is a coherence measure in time-frequency. It can measure the temporal evolution of connectivity in each frequency band:

$$R(n,s) = \sqrt{\frac{|\langle s^{-1}W^{XY}(n,s)\rangle|^2}{\left\langle s^{-1}|W^X(n,s)|^2\right\rangle \left\langle s^{-1}|W^Y(n,s)|^2\right\rangle}}$$

with < . > an appropriate smoothing operator [6].

•Our goal was to develop and implement an automatic method to compute and analyze CWT and WTC in fMRI data, and to test it to probe fMRI functional connectivity.

Rest State Networks

•There is a network of brain areas that oscillate coherently during rest. This Rest-State Network (RSN) is detectable with fMRI. Some studies suggest that up to 5 concurrent RSNs exist [7].

•It has been proposed that these RSNs are not affected by simple cognitive tasks, and that demanding tasks such as Working Memory (WM) tasks inhibit or modulate their connectivity [8].

•Recent studies have challenged this hypothesis, suggesting that WM-related modulation of connectivity is mild or non-existent. [9,10,11].

Our Work

•We acquired rest-state data and WM-task data and analyzed its WTC to study connectivity in the time-frequency domain.

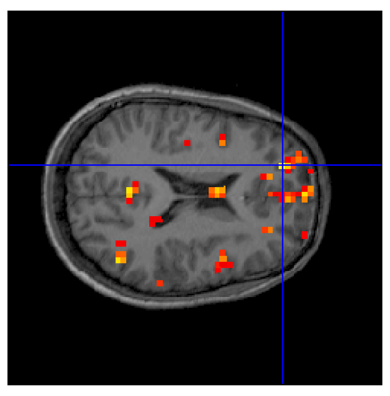
•We used very short TRs to avoid aliasing of physiological signal into the frequency bands of interest.

Data

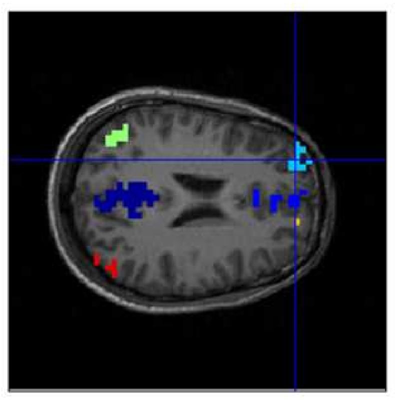
•1.5 Tesla Philips Intera MR scanner.
•Two subjects.
•TR = 333 msec, TE = 50 msec, flip angle = 30º.
•4 slices, thickness = 7 mm, gap = 4 mm.
•Block paradigm acquisitions and block paradigm with working-memory task (2-back task with 0-back control).
•Pre-processing and parametric analysis done with SPM2 [12].

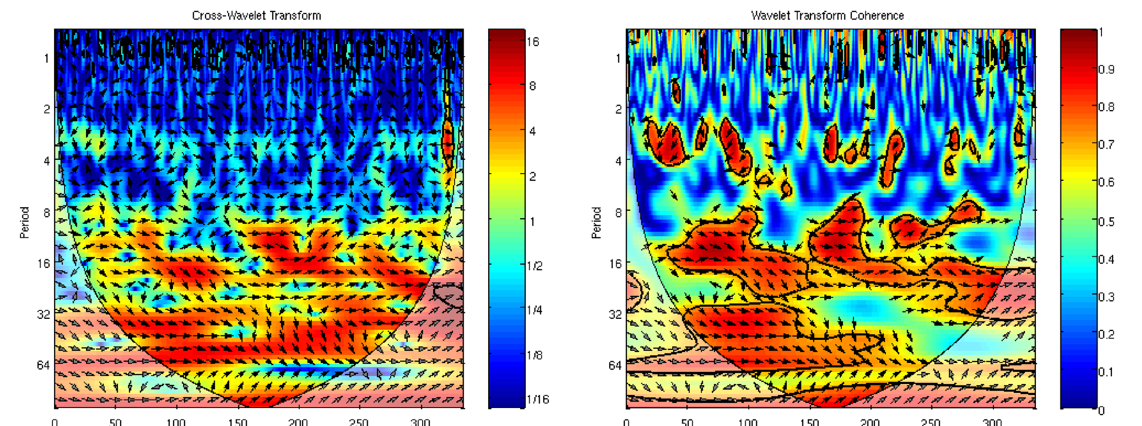
Methods

•Activated regions resulting from 2-back vs. 0-back (pictured right) and 0-back vs. 2-back were used as seeds for correlation analysis with rest-state data [8]. The MarsBar toolbox was employed to manage ROIs [13].

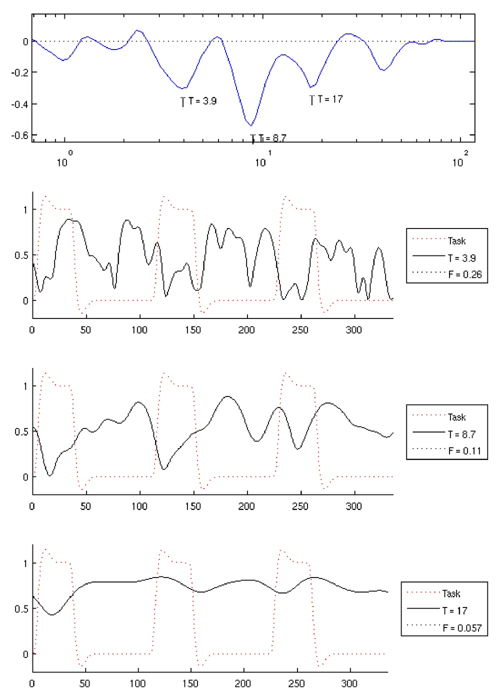


•ROIs were selected from correlation maps most similar to the RSNs in [7] (example pictured right).





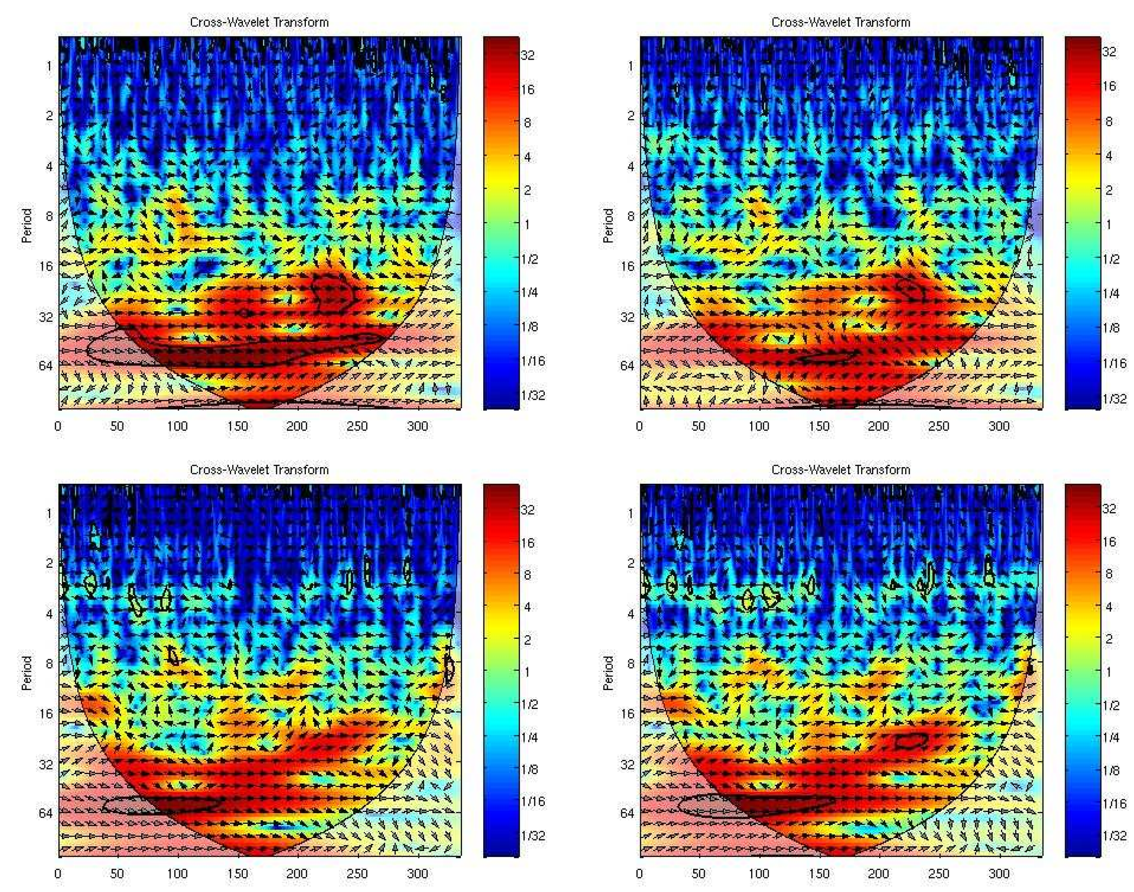
•CWT and WTC were computed for all possible pairs of ROIs using a software package [6,14]. The diagrams show common power (CWT, above left) and phase coherence (WTC, above right) at a given frequency band. Black arrows indicate phase difference. X-axis is time in seconds.



•The correlation between the paradigm and the WTC for each frequency was computed. X-axis in top sub-figure is the period (in seconds), same as Y-axis of CWT and WTC.

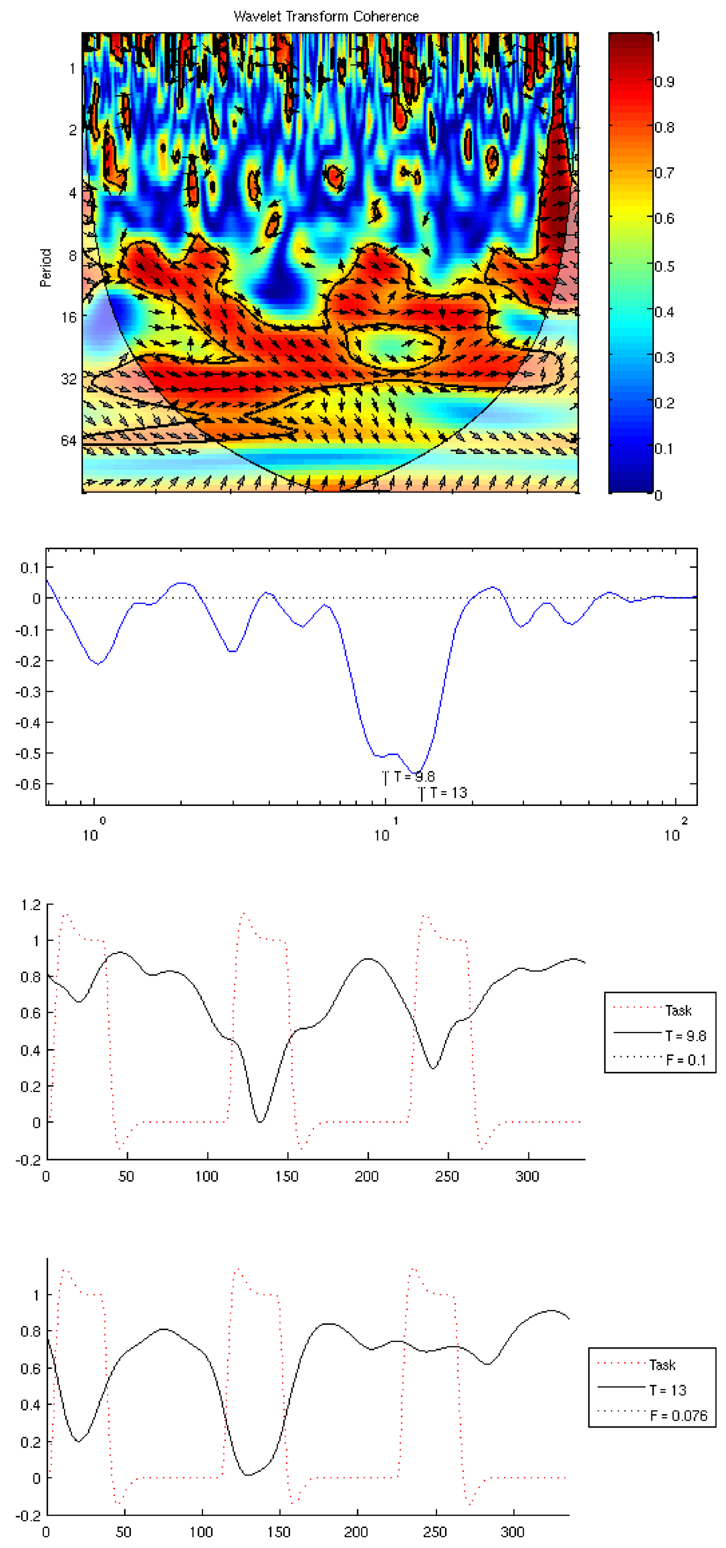
Results

•The CWT of all pairs of ROIs in a given RSN are similar. The CWT of pairs of ROIs in different RSNs are much less similar. (Below, top row relates to ROIs from RSN2 [7], bottom row relates to ROIs from RSN4 [7].) Thus, concurrent RSNs have a distinct time-frequency profile.



Results (continued)

•Some pairs of ROIs showed a marked correlation between the paradigm and the WTC at some frequencies, hinting at modulations caused by the WM task. However, the reproducibility of this observation was poor. (Below, strong correlation between WTC and the paradigm for 0.1 Hz.)



Conclusions

•We developed an automatic method to analyze time-frequency connectivity in fMRI. To our knowledge, this is the first implementation of this kind of approach in fMRI.

•Results indicate that different RSNs show a specific time-frequency profile as captured by the CWT.

•Some pairs of ROIs show marked attenuation, at certain frequencies, related to transition between WM and non-WM task – more subjects need to be analyzed for significance.

Future Work

•Perform a similar, automatic analysis for the phase difference (similar to [3]).

•Implement statistical significance for the correlation between WTC and the paradigm.

•Acquire data from more subjects.

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