Quantitative EEG Analysis of the Severely Injured Brain in Response to Language

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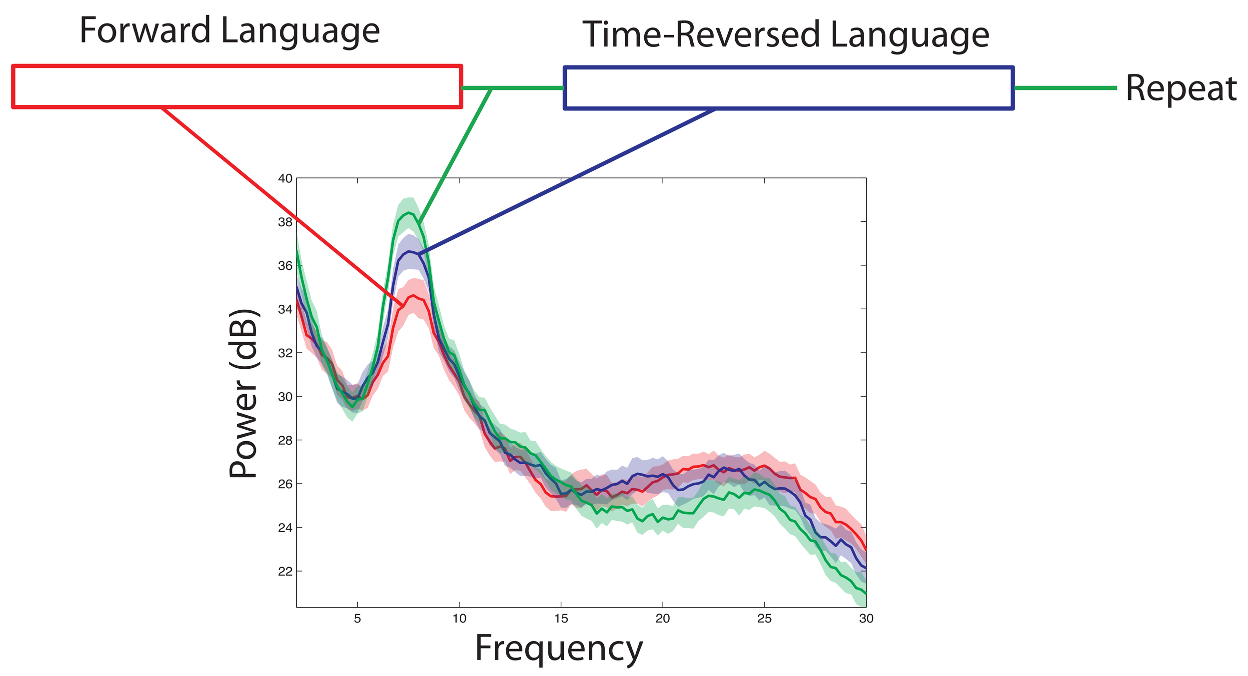
Introduction

In patients with disorders of consciousness (DOC), residual cognition can be masked by motor deficits. The use of fMRI or EEG as a response measure bypasses the need for an overt behavioral response, allowing paradigms based on these measures to demonstrate residual cognitive abilities in minimally conscious patients with severe motor deficits. However, existing paradigms, which ask the patient to imagine a motor act on command, nevertheless require the execution of a complex volitional act. This has been shown to lead to false negative results in some cases. Here, we present a new, entirely passive, EEG-based paradigm for the identification of language processing. Since this approach does not require the performance of an active task, it significantly expands the tools for identification of cognitive function in patients with severe brain injury.

Methods

Subjects listened to 2-3 minute, personally meaningful stories recorded by family members, alternating with time-reversed versions of the same recordings. Time-reversed stories serve as a useful control condition as they preserve many of the basic acoustical properties of spoken language, without syntactic or semantic content. EEG was recorded from 37 individually attached scalp electrodes.

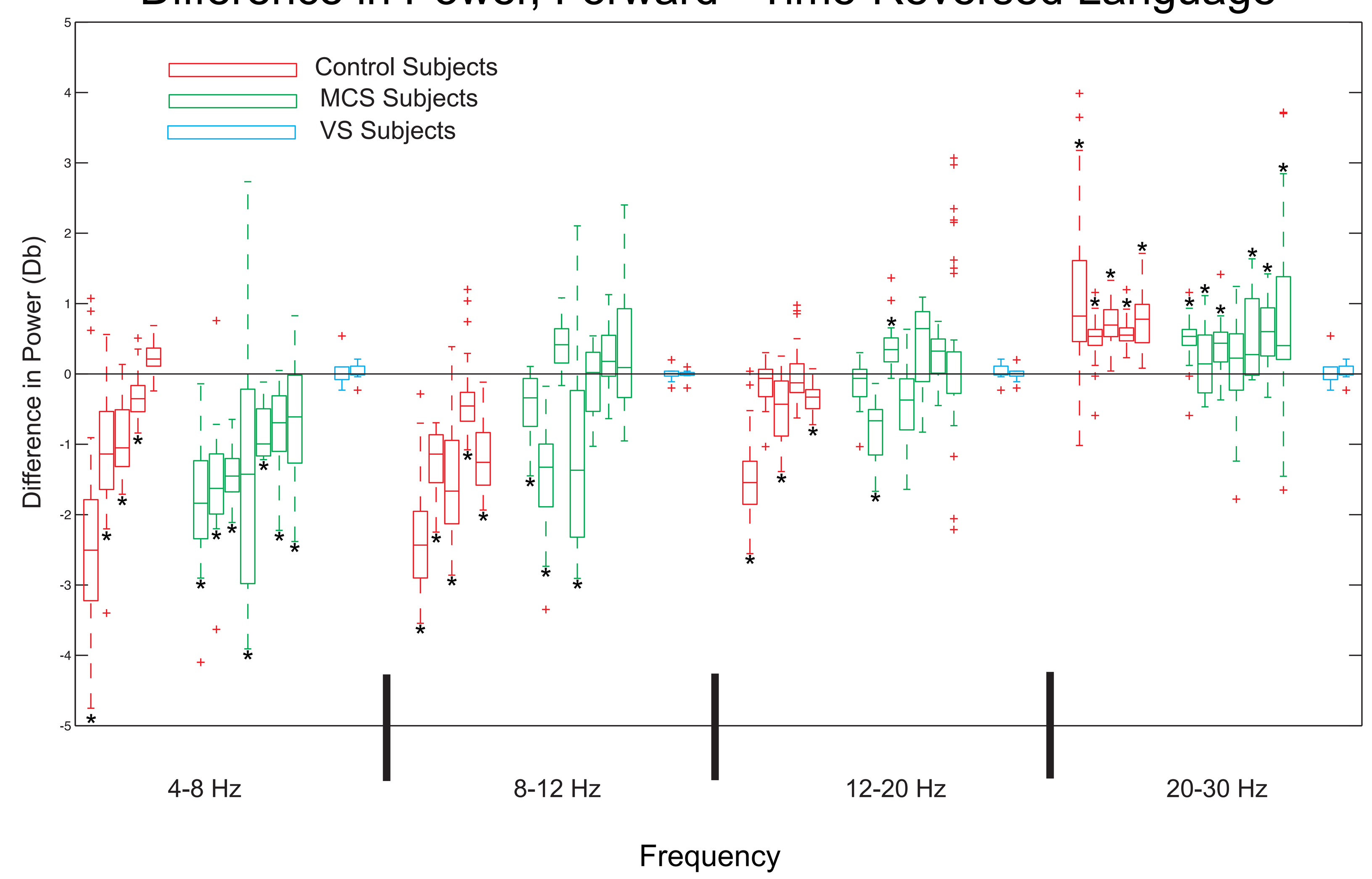


5 control subjects, 7 minimally conscious state (M1-7) subjects, and 2 vegetative state (V1-2) subjects were studied.

Patient ID	Etiology	Age/Gender	CRS-R Score (max 23)
M1	TBI	57/F	11
M2	TBI	19/F	19
M3	HIE	59/F	15
M4	TBI	40/M	11
M5	CVA	25/F	14
M6	TBI	44/M	14
M7	TBI	32/M	21
V1	TBI	21/M	6
V2	TBI	41/M	4

Group Results: Power Spectra

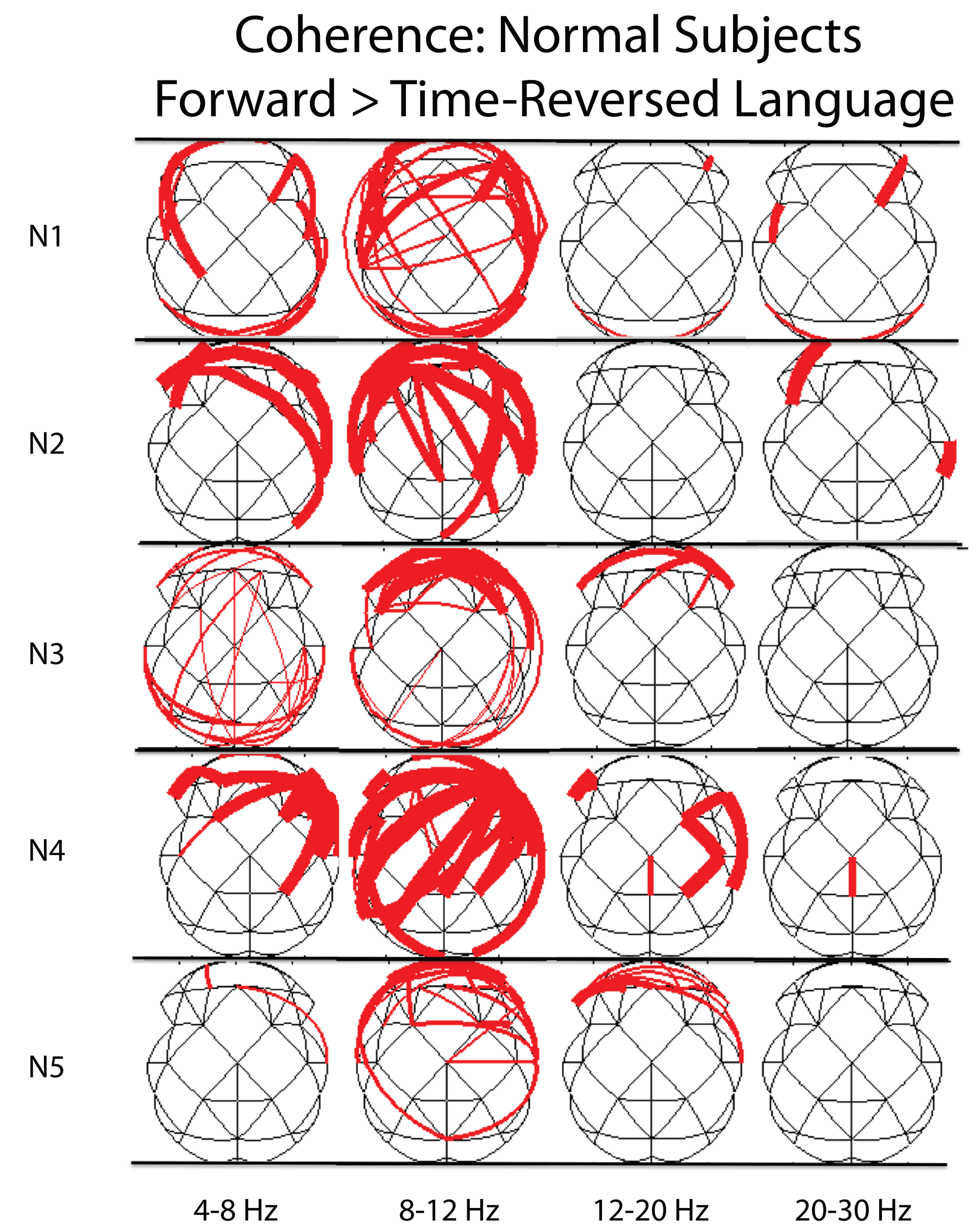
Difference in Power, Forward - Time-Reversed Language



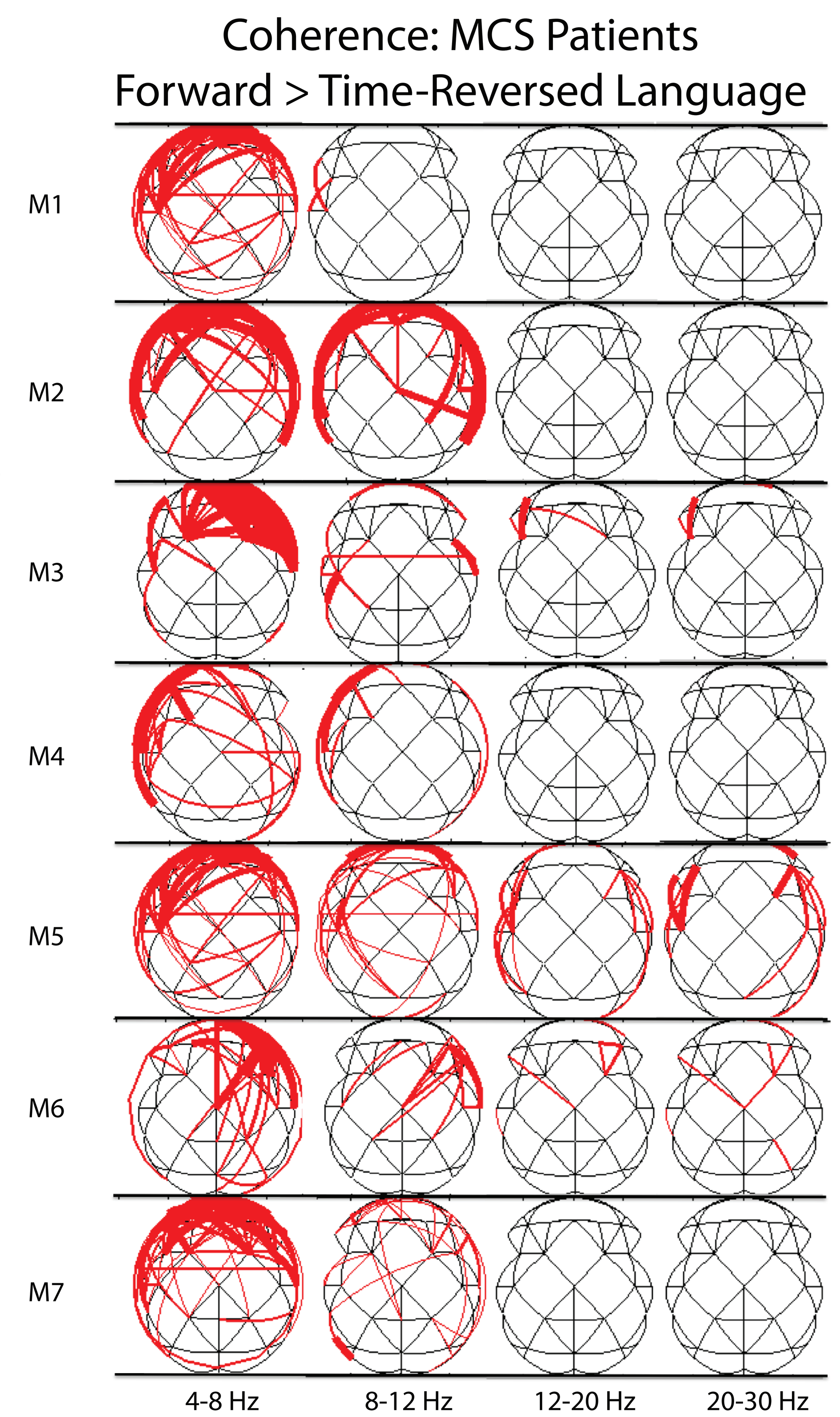
Boxplot of difference in power between forward and time-reversed language across all artifact-free channels in each subject. Results show a clear decrease in low-freq power (4-12 Hz) and an increase in high frequency power (20-30 Hz; example MCS subject shown below). Black stars represent a change that is significantly different from zero (p < .05). Low-frequency changes were centered around 4-8 Hz for MCS subjects and 8-12 Hz for control subjects. VS subjects showed no change in power.

Group Results: Coherence

Coherence: Normal Subjects
Forward > Time-Reversed Language

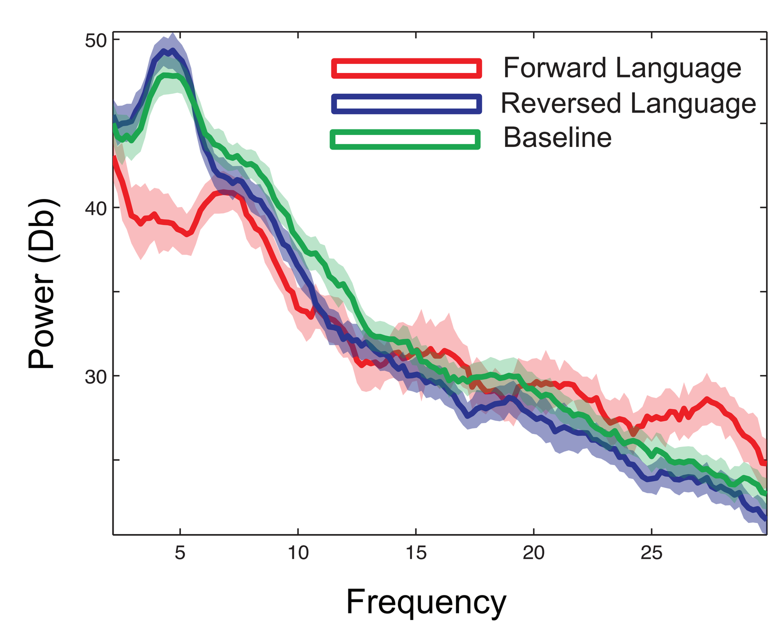


Coherence: MCS Patients
Forward > Time-Reversed Language

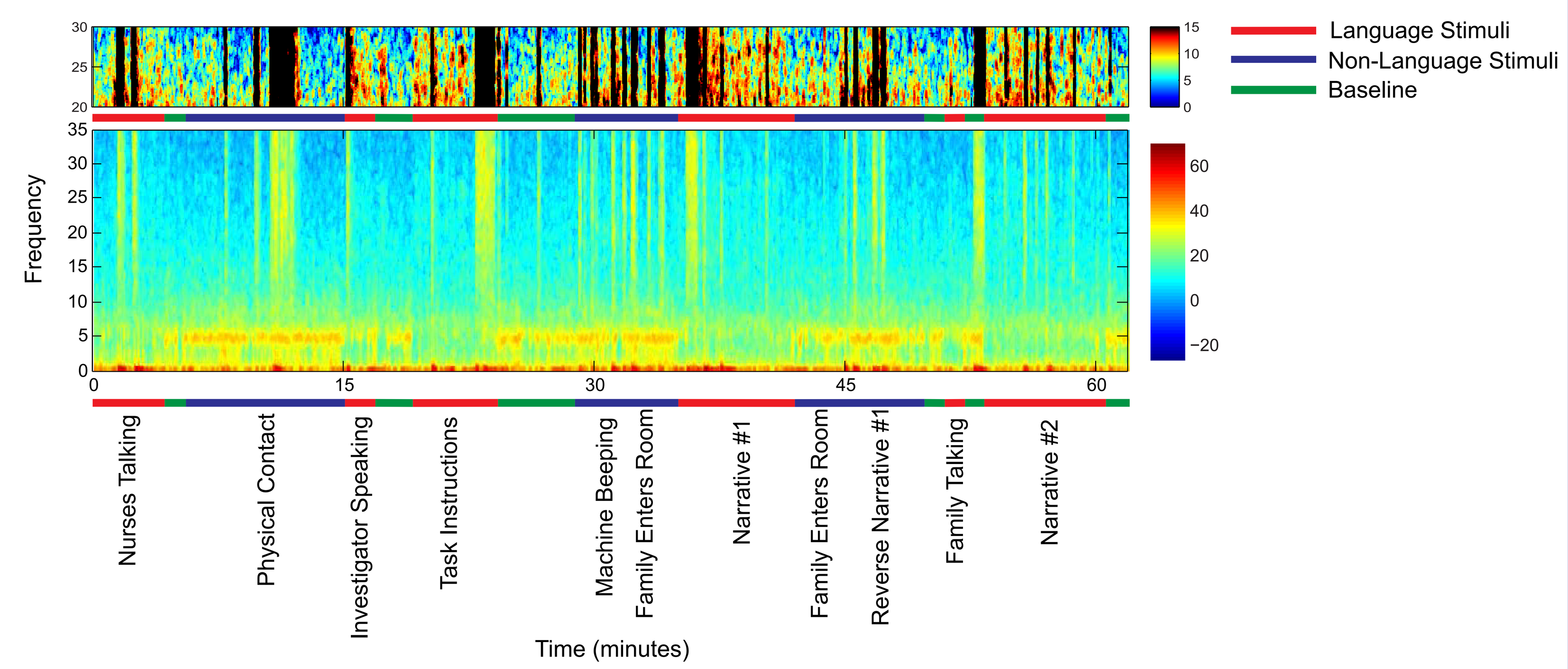


Headmaps of coherence results for all control and MCS subjects. Lines are displayed when the coherence between channels is significantly greater in forward vs time-reversed language presentation (p<.01). Coherence between and among frontal/temporal channels is primarily increased from 4-12 Hz, with a concentration in the 4-8 Hz band for the MCS patients and the 8-12 Hz band for the control subjects. No significant changes were seen in the VS subjects.

Single-Subject Results: M1



Power spectrum shows clear low-freq desynchronization and high-freq increase in power to forward language only.



Spectrogram over 1 hour of data shows that effect is not specific to recorded stimuli: natural language in the patient room also has the same effect. Non-language stimuli has no effect.

Conclusions

Spectral analysis reveals robust changes in power and coherence with forward vs time-reversed language. These changes are seen in control and MCS but not VS subjects, suggesting this method might be useful in stratifying subjects with disorders of consciousness.

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