Quantitative analysis of changes in EEG power in response to language and music stimuli in severe brain injury

Daniel J. Thengone, Jonathan C. Bardin, Mary M. Conte, Jonathan D. Victor, Nicholas D. Schiff

Department of Neurology and Neuroscience, Weill Cornell Medical College, New York, NY, 10065

dat2011@med.cornell.edu

553.18
SFN2012

INTRODUCTION

Recent neuroimaging studies have demonstrated that some patients with disorders of consciousness (DOC) may have significant cognitive abilities that may be masked by their limited motor abilities. Thus, the development of electroencephalographic (EEG) measurements to evaluate their cognitive abilities, as an alternative to ordinary bedside testing, is important. Previous studies of DOC subjects have shown a selective EEG response to presentation of speech stimuli in a substantial proportion of the subjects studied. Measuring brain responses to music is likely to represent a complementary assay of cognitive function in DOC patients, because music represents a domain that is independent of language. Neuro-anatomical differences in cortical processing of language and music also suggest that EEG assessments of these domains are independent probes of the integrity of integrative cortical response to auditory stimuli.

METHODS

Recording

EEG was recorded using 37 electrodes silver-collodion disc electrodes placed in an enhanced 10-20 system using the Natus XLTEK system in the patient subjects. In normal controls, EEG was recorded using the 128 channel HydroCel Sensor net. Signals were amplified and digitized at 250 Hz. Simultaneous video recordings were obtained.

Speech Stimuli

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.

Music Stimuli

Subjects listened to two pieces of music on each of the 3 trials per testing session (2 - 3 sessions per patient). Subjects listened to one piece of music that was personally meaningful, and another that was unfamiliar to them, each lasting 1-2 minutes.

Analysis

We calculated power spectral density for each Hjorth Laplacian channel for at least 80 artifact-free 3-sec segments, using Thomson's multitaper method, as implemented by the Chronux toolbox in MATLAB

SUBJECTS

7 control subjects (NC 1-7) and 2 patients in the minimally conscious state (PS 1-2) were studied.

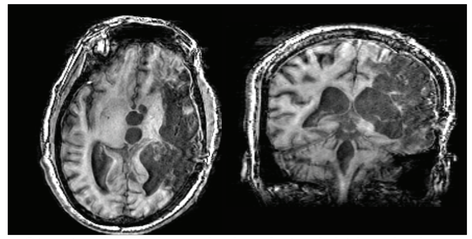
Patient Subject	Age/Gender	Etiology	CRS-R score (max 23)
PS1	55/M	TBI	16
PS2	27/F	hypoxic ischemic	9

Control Subject	Age/Gender	Handedness	Musician
NC1	24/M	R	Y
NC2	29/M	R	N
NC3	23/M	R	Y
NC4	36/M	L	N
NC5	19/F	R	N
NC6	22/F	R	N
NC7	28/F	R	Y

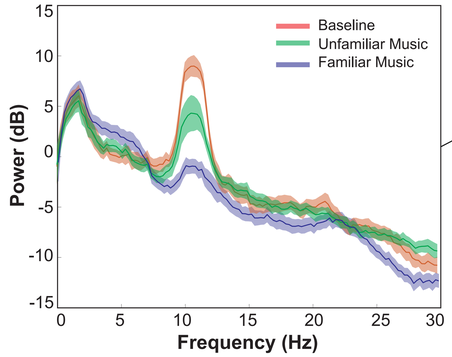
PATIENT SUBJECTS

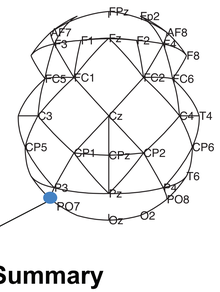
PS 1

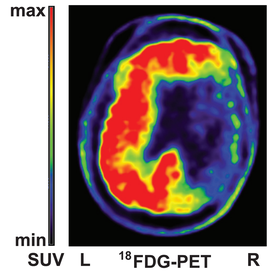
- Right-handed male with trauma followed by vasospasm with ischemia to entire right hemisphere, cerebral hemorrhage and herniation.
- Behavioral assessments using JFK Coma Recovery Scale demonstrated evidence for emergence from minimally conscious state MCS (functional object use), with CRS-R motor function subscale score = 6 on some but not all examinations.
- Resting metabolic activity measured by ^{18}FDG-PET in the left hemisphere showed a normal pattern, while the right hemisphere demonstrated only small regions of metabolic activity in remaining midline cortical regions.



Structural MR shows ischemia to right hemisphere





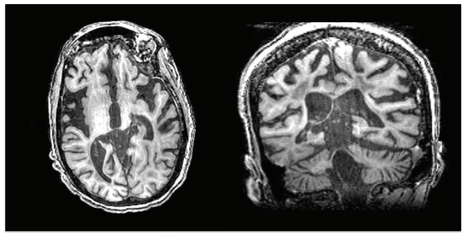


Summary

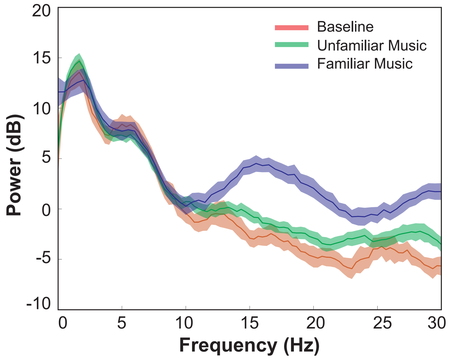
Power spectrum shows relative desychronization in the 8 - 12 Hz range during the presentation of personally meaningful music in the Laplacian occipital channels PO7 (shown), O1, POz and Oz.
During the presentation of forward speech, power spectrum shows desychronization in the same frequency range in channel T5 in addition to the left and midline occipital channels.

PS 2

- Probable hypoxic ischemic injury
- Behavioral assessments showed evidence of the minmally consious state (MCS) (CRS-R score = 9). Patient had emotional reactions at bedside (smiling and laughter) when humorous stimuli were presented.

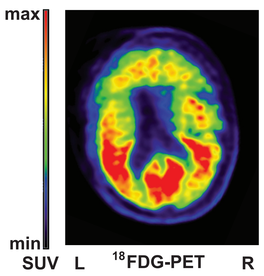


Structural MR shows global brain injury



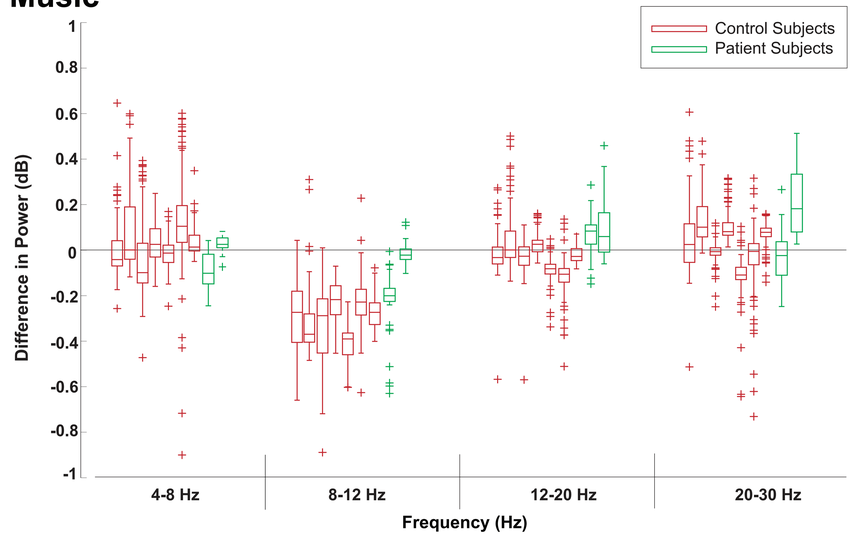
Summary

Spectral analysis shows significant increase in relative power above 14 Hz during the presentation of personally meaningful music in the occipital channels PO7 (shown) and O1. A global increase in power in the same frequency ranges is observed in multiple channels in both hemispheres.



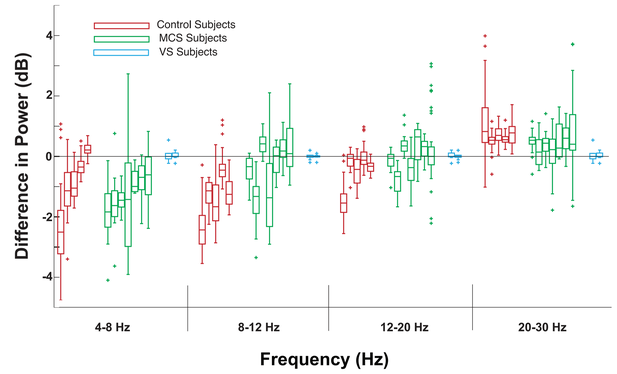
GROUP RESULTS

Music



Boxplot of difference in power between familiar and unfamiliar music across all artifact-free channels in each subject. The number of channels used for each subject varied in normals and the patients (110 ± 3 out of 128 channels in controls; 27 ± 2 out of 37 channels in patient subjects). Results show a decrease in alpha frequency power (8-12 Hz) during the presentation of familiar music in the normal subjects and in one patient subject (PS - 1). Increase in power is seen in the frequency range 20 - 30 Hz in normal controls and in PS - 2.

Language



Boxplot of difference in power between forward and time-reversed speech across all artifact-free channels in a separate group of subjects. Results show a decrease in low frequency power (4-12 Hz) and an increase in high frequency power (20-30 Hz; example MCS subject shown below). Low frequency changes were centered around 4-8 Hz for MCS subjects and 8-12 Hz for control subjects.

Bardin et al, SfN 2011

CONCLUSION

- **In PS - 1, power spectrum shows relative desychronization during the presentation of personally meaningful music in occipital channels in the left hemisphere in the frequency range 8 - 12 Hz .**
- **In PS - 2, power spectrum shows relative synchronization during the presentation of personally meaningful music in occipital channels in both hemispheres in the frequency range 14 - 30 Hz .**
- **These findings demonstrate that some patients with severe brain injury manifest an EEG response to personally meaningful music, whose spectral and topographic characteristics are distinct from the EEG response to personally meaningful speech.**

Funded by NIH RO1 HD051912, The Charles A. Dana Foundation and The James S. McDonnell Foundation