Novel Network-Based Approaches for Studying Cognitive Dysfunction in Behavioural Neurology

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D2.3 Specific behavioural and task-induced fMRI protocols for language and acoustic assessment

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Description

Specific behavioural and task-induced fMRI protocols for language and acoustic assessment: Pilot fMRI protocols will be used to assess and compare neural correlates of speech prosody impairment in patients with Parkinson’s disease and in age/matched healthy controls.

Introduction

Parkinsons disease (PD) is a progressive neurodegenerative disorder characterized by the loss of dopaminergic neurons. Besides typical motor symptoms such as bradykinesia, rigidity, postural instability and resting tremor, speech impairment is also very common and affects nearly 90% of PD patients during the course of their illness. This motor speech disorder, typically classified as hypokinetic dysarthria (HD), is characterized by monoloudness and monopitch, imprecise consonants, reduced stress, airflow insufficiency, irregular pitch fluctuations, aperiodicity, and inappropriate silences.
Our aim was to identify the neural correlates of altered speech rhythmicity in PD in terms of both structural and functional changes within the speech production network.

Methods

Participants

Our cohort consisted of 25 healthy controls (HC) with mean age of 66.48 and 34 PD patients with mean age of 68.50. All participants were right-handed and reported Czech as their first language. PD patients were examined in the ON medication state without dyskinesias. All subjects were clinically examined. Speech recordings were obtained from all participants and they also underwent an MRI examination using the 3T Siemens Prisma MR with reading task inside the scanner. Each subject signed an informed consent form and the local ethics committee approved the study.

Acoustic Analysis of Voice and Speech

Speech/voice acquisition inside the MR scanner brings many limitations, especially due to very strong background noise, small space around the head (which introduces spectral distortion in acoustic signal) and necessity to use a MR compatible microphone (that provides much worse characteristics than e.g. a professional condenser microphone). Therefore, we analyzed the neural correlates of speech rhythmicity indirectly, i.e. we used two protocols inside and outside the scanner, respectively. The protocol inside the scanner was used to activate brain regions responsible for speech planning, programming and execution. These activations were consequently correlated with acoustic measures extracted from speech/voice outside the scanner. Although this approach is indirect, it allows us to examine the functional neuroanatomy of speech production in HC and measure alterations in the structural and functional integrity of the speech network in PD. The protocol inside the MR scanner consisted of overt reading of short emotionally neutral sentences and watching a string of “Xs” (a baseline condition). Altogether, there were 48 sentence reading trials and 24 baseline trials in random order. The duration of all stimuli was 5 s with black screen in between them for period of 11 s.

The speech protocol performed outside the MR scanner contains reading (TSK1; reading a phonetically balanced paragraph containing 150 words; a patient could read the text for her-/himself in advance) and a diadochokinetic task (TSK2; rapid steady /pa/-/ta/-/ka/ syllables repetition as constant and long as possible, repeated at least 10 times; performed on one breath), i.e. the speech tasks most commonly used in the field of HD analysis that enable to assess the rhythmicity of speech. During the acquisition, we placed a large capsule cardioid microphone at a distance of approximately 20 cm from the patient's mouth. Acoustic signals were digitized using audio interface M-AUDIO Fast Track Pro with fs = 48 kHz sampling frequency and 16-bit resolution. The respective acoustic measures were extracted using software Praat and Matlab by a trained acoustic engineer who was blind to the patients' clinical data.

MRI Sequences and Processing

The following MRI sequences were used: magnetization prepared rapid gradient-echo (MPRAGE) high-resolution sequence (240 sagittal slices, slice thickness = 1 mm, TR = 2300 ms, TE = 2.36 ms, FA = 8°, FOV = 256 mm, matrix size 256256) and gradient-echo echo-planar imaging sequence during reading task (73 scans, 44 transversal slices, slice thickness = 3 mm, TR = 12000 ms, scan acquisition time = 2750 ms, TE = 33 ms, FA = 80°, FOV = 192 mm, matrix size 6464) acquired during reading task.
T1-weighted images were segmented and the DARTEL imported versions of grey matter and white matter were obtained for each subject. Normalization into standard MNI space was performed. Grey matter probability maps were Jacobian-modulated in order to preserve the original grey matter amount and smoothed using a spatial filter with the Gaussian kernel (FWHM = 6 mm). Lastly, the values of images were divided by total intracranial volume (TIV) to correct for the effects of overall brain size. The pre-processing of the functional data consisted of realignment and unwarping, normalization into standard anatomical space (MNI), and spatial smoothing using Gaussian filter kernel with FWHM of 5 mm.

Results

Based on the Mann-Whitney U test, we identified significant differences ($p < 0.05$) only in speech index of rhythmicity (SPIR, TSK1). Feature values were lower in PD as compare to HC, indicating that PD patients produced less rhythmical speech than controls.
In terms of grey matter volume within ROIs, PD patients were found to have significantly reduced grey matter volume in both left and right superior temporal gyrus ($p < 0.05$). The left and right STG volumes in PD patients correlated most significantly with the diadochokinetic regularity (DDK reg, TSK2, r = -g0.61 and -0.67 respectively, $p < 0.001$). The direction of the correlation was negative, meaning that lower GM volumes were associated with increased irregularity during the diadochokinesis, in other words with impaired speech rhythmicity in PD. In addition, the left and right STG volumes were positively correlated with the DDK rate (TSK2, $r = 0.39$), i.e. grey matter loss in PD was associated with reduced DDK rate.
Regarding activations in ROIs during the reading task performer in the scanner, no significant differences between PD and HC were observed. We further explored the relationship between acoustic features evaluating speech rhythmicity and speech task-induced BOLD signal increases within our ROIs. In HC, we observed negative correlations between the DDK reg variable acquired outside the scanner and BOLD signal increases in the left insula, left IFG, left putamen, as well as in the right putamen and right thalamus, meaning that increased activation in these regions was related to increased speech regularity, whereas in PD we observed inverse (positive) correlations between DDK reg and activations of the right IFG and right PMC, meaning that increased BOLD signaling these areas was associated with decreased regularity) . As for the DDK rate, a negative correlation with increased BOLD in

the left SMA was observed in HC, whereas in PD the DDK rate was negatively correlated with many cortical and subcortical regions including the right IFG, left STG, left thalamus and right cerebellum. In PD, we further observed negative correlation between articulation rate (AR,TSK1, r = -0.41) and BOLD signal in the left SMA while no significant correlations were found in HC subjects.