Increased Functional Connectivity between Occipitotemporal Cortex and Frontoparietal Attention Network during Visual Processing

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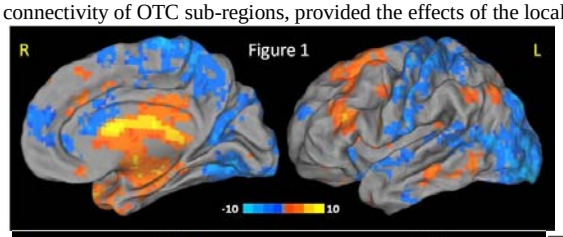
Introduction: A number of areas in the human occipitotemporal cortex (OTC) are specialized for processing particular types of sensory stimuli [1-4]. These include the lateral occipital complex (LOC), an object-selective area; the fusiform face area (FFA), a face-selective area; the parahippocampal place area (PPA), a scene-selective area; and the extrastriate body area (EBA), a body part-selective area. We reported earlier that, when these areas were defined using appropriate functional localizers, the OTC sub-regions exhibited both common and differential connectivity patterns with other neocortical regions [5, 6]. Studies have shown that it may be possible to examine "resting-state" functional connectivity from residuals derived from general linear regression (GLR) modeling of block-paradigm fMRI data [7]. In this study, we compared the functional connectivity maps of OTC sub-regions generated with seed-based cross-correlation analysis (CCA) from resting-state fMRI data, with those obtained from the residuals of OTC functional localizers.

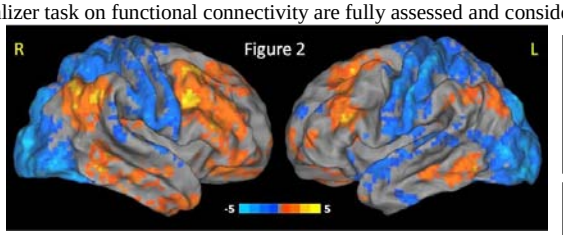
Methods: Twenty right-handed normal subjects (10 male; median age ~22 yrs) were scanned in a Siemens 3T Tim Trio scanner using a 12-channel array receive-only head coil. Informed consent was obtained from all participants and the protocol was approved by the Emory Institutional Review Board. Participants underwent an 11-minute resting state functional connectivity MRI (REST) scan during which they lay quietly in the scanner with their eyes open while scans were acquired with an axial whole-brain gradient echo EPI (TR/TE = 3000/24 ms, FA = 90°, in-plane resolution = 3 mm x 3 mm; 48 slices with thickness 3 mm). Subsequently, four OTC functional localizer fMRI scans were performed with a similar whole-brain EPI sequence (42 3.5 mm sagittal slices, TR = 2000 ms). The OTC localizer task paradigm consisted of 12 sec blocks of body, object, scene, face or scrambled pictures, interspersed with 14 sec (average) periods of fixation. There were 15 stimulus blocks in each of the 4 localizer runs. The fMRI (both localizer and REST) time-series were motion-corrected, spatially normalized to the MNI template, followed by spatial smoothing with a FWHM = 5 mm isotropic gaussian kernel. Brain activation to localizer fMRI scans was assessed with standard GLR modeling using the AFNI software suite. The residuals (RSDL) from the GLR modeling (for each of the 4 runs), as well as the REST scan were then low-pass filtered (cutoff frequency = 0.1 Hz). ROI-averaged reference vectors (from REST and RSDL time-series) were obtained from 5mm spherical seed ROIs placed at centers of activation in EBA, LOC, FFA and PPA seen in body, object, face and scene localizer fMRI scans. CCA with reference seed vectors were performed on both REST and RSDL scans. Mixed-effects ANOVA was performed to assess the functional connectivity networks of EBA, LOC, FFA and PPA, as well as differences in functional connectivity between the 4 regions, in the REST and RSDL scans, and to further assess differences in functional connectivity maps obtained from REST and RSDL data. The resultant statistical parametric maps were clustered and significance of activation was assessed using Monte Carlo modeling to correct for multiple comparisons [8].

Results & Discussion: Functional connectivity of the REST data has been reported elsewhere [5,6]. Figure 1 shows the differences in functional connectivity to the EBA (collapsed across right and left hemisphere seeds) between the RSDL (collapsed across 4 runs) and the REST data. The RSDL functional connectivity to EBA was reduced (corrected $p < 0.05$) compared to REST, in the default mode network (DMN) areas: posterior cingulate, prefrontal cortex and lateral parietal cortex; as well sensorimotor areas of primary (S1) and secondary (S2) somatosensory and primary motor (M1) cortices, Brodmann area (BA) 5, anterior IPL and superior temporal gyrus (STG), and anterior portion of cingulate gyrus. On the other hand, the RSDL data showed increased EBA functional connectivity compared to REST, with areas in the frontoparietal attention network: posterior IPL, superior parietal lobule (SPL), pre-supplementary motor area (pre-SMA), and dorsolateral prefrontal cortex (DLPFC). Both LOC (Figure 2) and FFA (not shown) also exhibited stronger connectivity with frontoparietal attention network and weaker connectivity with sensorimotor regions, in RSDL. EBA, LOC and FFA also exhibited stronger functional connectivity with thalamus, basal ganglia, anterior insula, BA38, and medial temporal lobe in RSDL compared to REST.

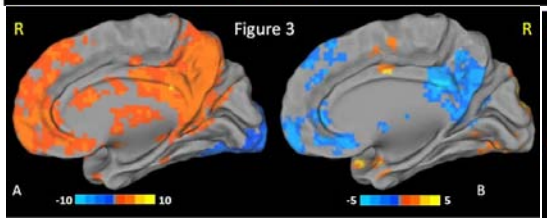
Figure 3A presents the right EBA (REBA) vs. right LOC (RLOC) contrast during REST, showing higher (corrected $p < 0.05$) functional connectivity of DMN areas with REBA compared to RLOC. Figure 3B shows differences in the REBA vs. RLOC contrast between RSDL and REST scans (corrected $p < 0.05$). DMN functional connectivity differences between REBA and RLOC were attenuated in RSDL compared to REST. Figure 4A presents the RLOC vs. right FFA (RFFA) contrast during REST, showing higher connectivity of frontoparietal attention networks to RFFA compared to RLOC. These differences were accentuated (Figure 4B) in the RSDL condition compared to REST.

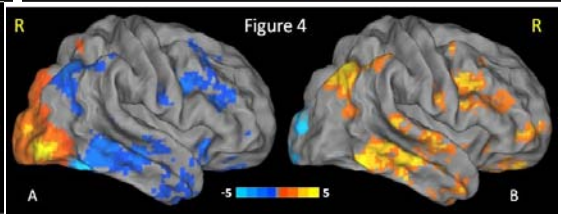
These results suggest that there are important differences in functional connectivity maps obtained from residuals of the localizer fMRI data, and resting state fMRI performed prior to the localizers. The increased connectivity in frontoparietal attention networks is consistent with the increased attention and working memory demands of the localizer task compared to REST. The results are consistent with studies [9,10] that show functional connectivity networks are affected by the cognitive task performed prior/during their assessment. Results indicate that it is feasible to utilize the residuals from OTC localizer fMRI data to assess underlying functional connectivity of OTC sub-regions, provided the effects of the localizer task on functional connectivity are fully assessed and considered.





Surface renderings of RSDL – REST differences (t-contrast maps; corrected $p < 0.05$) in functional connectivity to (**Figure 1**) EBA and (**Figure 2**) LOC.





Surface renderings of t-contrast maps (corrected $p < 0.05$) of (**Figure 3A**) REBA – RLOC during REST; (**Figure 3B**) RSDL – REST contrast of the REBA – RLOC differences; (**Figure 4A**) RLOC – RFFA during REST; and (**Figure 4B**) RSDL – REST contrast of the RLOC – RFFA differences.

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