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Somatosensory Networks in Humans and Macaque Monkeys During Rest

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Abstract:
The brain uses a sophisticated functional network design to integrate and segregate its constituent nodes on different time scales in order to process information. It is crucial to recognise and comprehend the network structure in terms of the underlying anatomical connection and the topographic organisation in order to comprehend the network's function. Here, we demonstrate that the resting-state network for somatosensory region 3b consists of subnetworks that are signatures of specific topographic representations.

1. Introduction:

The term "somatosensory networks" refers to the neural pathways and brain areas that are involved in the processing and integration of sensory information from the body. This information includes touch, temperature, pain, and proprioception, which is the knowledge of one's bodily position and movement. Involved in these networks include not just the main and secondary somatosensory cortices, but also additional areas such as the insula, thalamus, and basal ganglia. The somatosensory system is very important in many different areas of human perception, such as the capacity to be aware of one's own body, the planning of movements, and the sensations of touch and pain. A dysfunction in the processing of somatosensory information may result in a number of neurological illnesses, including neuropathic pain, phantom limb syndrome, and somatosensory neglect, amongst others.

The secondary somatosensory cortex (SII) is thought to be a unimodal sensory cortex that aids in the processing of tactile information for object identification and proprioceptive information for motor control. It is situated in the upper bank of the lateral sulcus (UBLS). Researchers have found bimodal neurons in the parietal operculum (PO) region caudal to the SII in awake macaque monkeys studying neural responses to somatosensory and visual stimulation throughout the PO (Robinson and Burton 1980b, c; Dong et al. 1994), but they have never found visually responsive neurons in the SII.

The SII has been shown to be a unimodal sensory region in studies of nonhuman primates, but recent investigations of human brain activity have shown that vision may have an influence on SII activity. Using functional magnetic resonance imaging (fMRI), Bremmer et al. (2001) investigated the human brain's motion processing system and showed that moving visual stimulus activates the superior intraparietal area (SII) as well as cortical region in the deep intraparietal sulcus (IPS) and ventral premotor area. Multiple studies have established that seeing a touch on another person's body activates the social interaction network

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(SII; Keysers et al., 2004; Keysers et al., 2010). Recent research (Agnew and Wise 2008; Gazzola and Keysers 2009; Nummenmaa et al., 2014) demonstrates that seeing the activities of others also engages the SII.

Whether or whether visual effects on the SII are unique to humans is an intriguing research subject in light of the disparity between electrophysiological investigations in monkeys and human brain-imaging studies. Recent research using radioactive deoxyglucose in macaque monkeys by Raos et al. (2014) demonstrates that the SII is among the cortical areas most strongly stimulated by seeing forelimb motions. This finding prompted us to investigate whether or not macaque monkeys' SII contains neurons that process visual information.

2. Methodology:

The preprocessed pictures from each session were utilised for the BOLD activation analysis without any smoothing being applied, and the stimulus blocks that were represented by a boxcar model were convolved with a hemodynamic response function that was built in SPM. In addition, covariates of no relevance were included to the generic linear regression model that included the head motion parameters as variables. The univariate analyses were only performed on the region of interest (ROI), which comprised the somatosensory area 3b in both monkeys and humans and was located on either hemisphere.

Macaque monkeys:

Since the spinal cord injury was located on the left side of all of the animals, the BOLD-fMRI study focused on the right hemisphere. According to what was previously published (Dutta et al., 2014), the computed statistical parametric maps were thresholded by using uncorrected p values of less than 0.005 for normal responses and less than 0.02 for reorganised responses. Subject-specific activations were then mapped using SPM slice view or MRIcron software version 1 (Rorden and Brett, 2000). This was done on the associated high-resolution structural T1 images. On the other hand, for the functional localizer investigation, ROI masked analysis was carried out in region 3b throughout both halves of the brain. The subject-specific activation maps were then translated to standard INIA19 template space (Rohlfing et al., 2012) by utilising FSL's linear and nonlinear registration tools FLIRT and FNIRT (Jenkinson et al., 2002). This allowed for the comparison visualisation of BOLD activity. Using CARET version 5.616, the thresholded beta maps were drawn on the partly inflated fiducial cortical surface (Van Essen et al., 2001).

Humans:

A masked univariate analysis with a region of interest (ROI) centred on area 3b was carried out for the functional localizer experiments in humans in order to locate the active BOLD clusters induced by facial and hand stimulation. (Fonov et al., 2009) Statistical parametric maps were thresholded at p 0.05 (FWER corrected), and then they were displayed on the standard template picture (ICBM 2009a Nonlinear Symmetric template).

3. Result:

Seed-to-voxel correlation analysis: Somatosensory resting-state network

An exploratory seed-based correlation analysis was performed in order to assess the resting-state network organisation, and the seeds for this study were the full area 3b as well as various representations of body parts. As will become clear in the next descriptions (Figures 1 and 2), the architecture of the networks that were active during rest was generally comparable in humans and monkeys.

According to the findings, the functional connection network of area 3b is not the same for the various representations of the different body parts. In addition to this, it was shown that seed-ROIs located in either of the hemispheres had identical connection patterns, which suggests that the networks are independent of laterality (Figure 1). The seed-to-voxel connectivity study brought to light the nodes of a connectivity network, which served as a guide for the ROI-ROI analysis detailed below.

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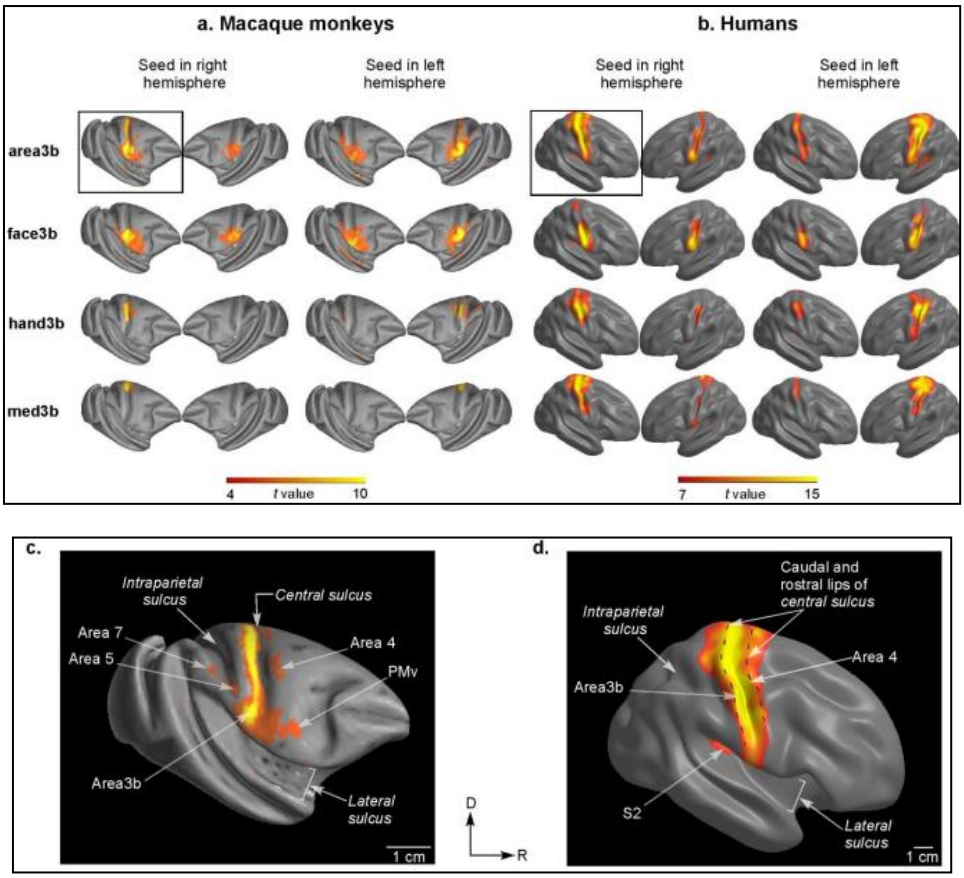
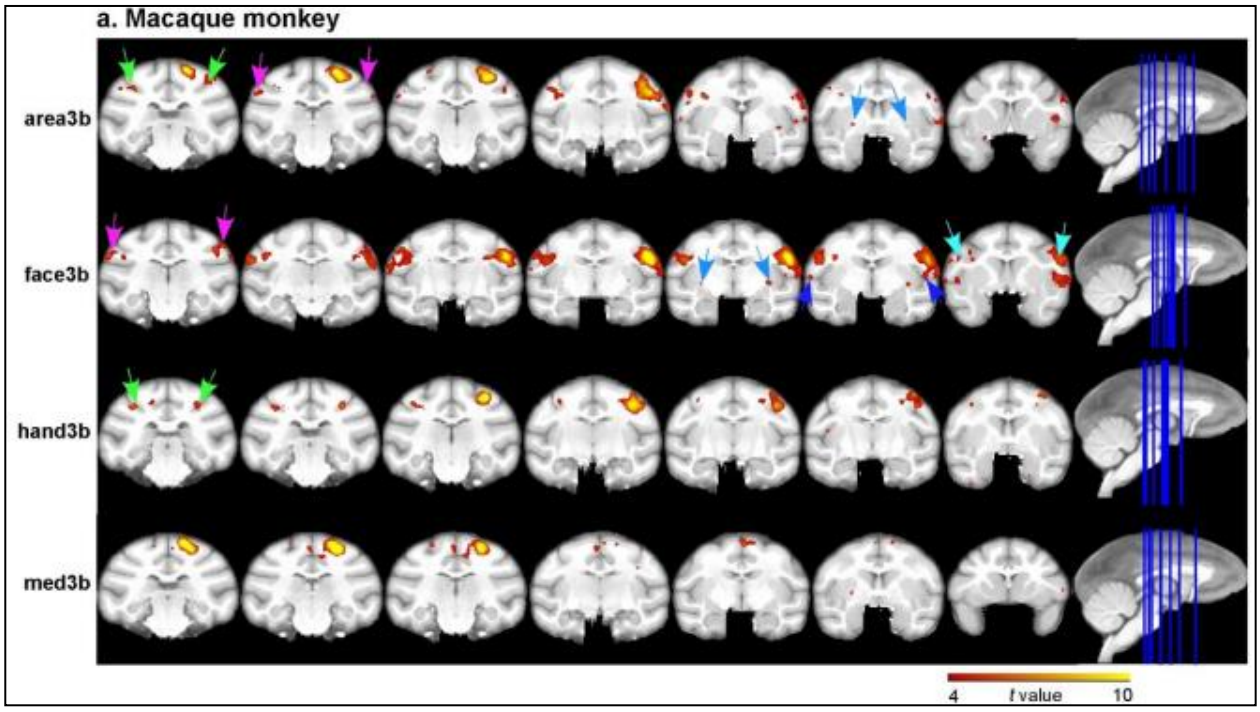


Figure 1: somatosensory cortex of (a, c) macaque monkeys and (b, d) humans in Seed to voxel resting-state functional connectivity.



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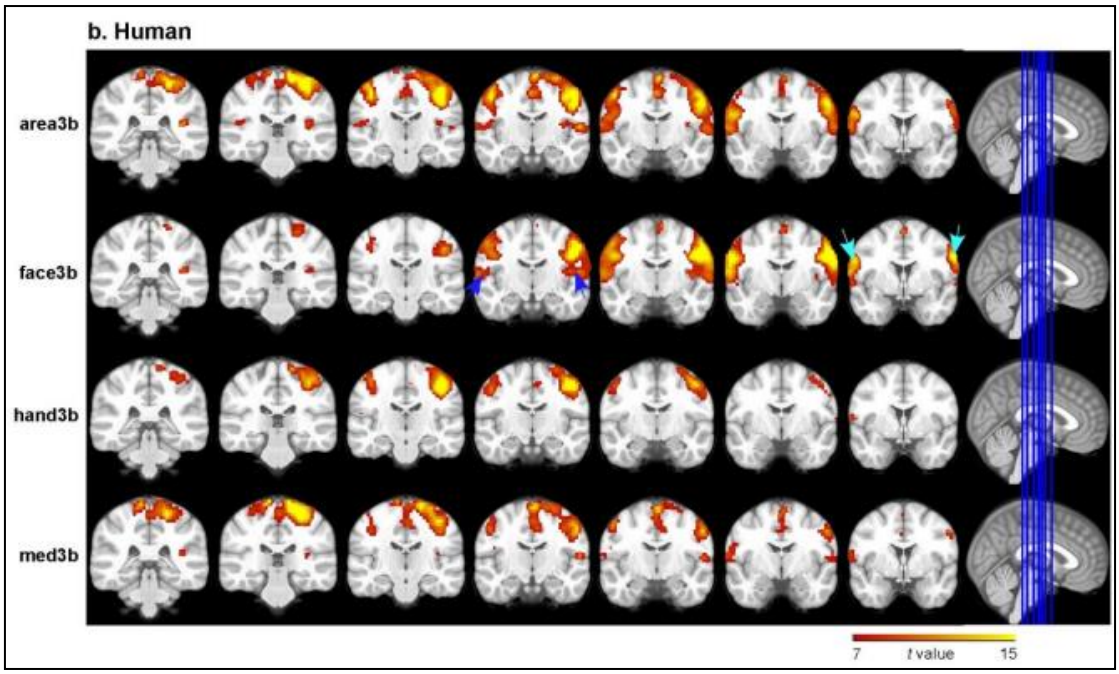
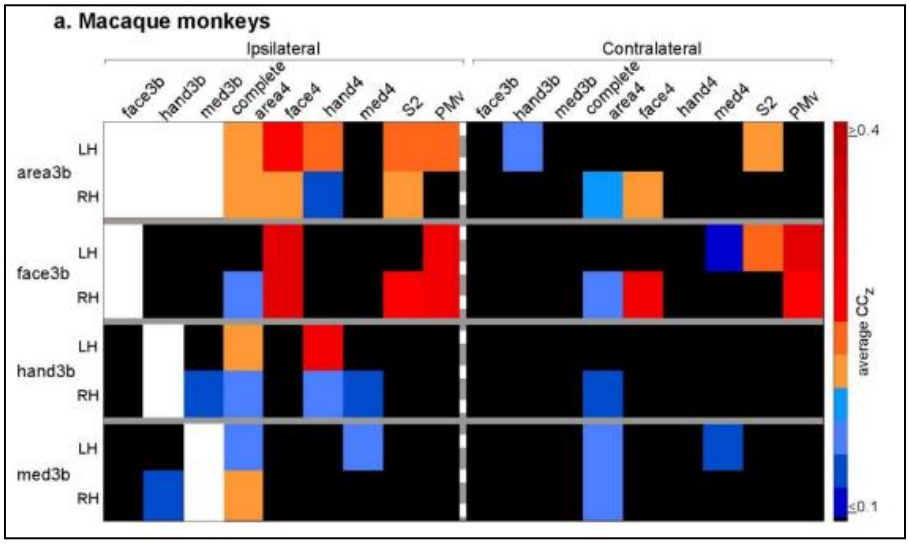


Figure 2: (a) monkeys and (b) humans shown on a series of coronal slices in Seed-to-voxel correlations in area 3b of the right hemisphere

The region is represented topographically in a variety of ways. 3b makes a unique contribution to the overall entire area. 3b the operational connection of functions: ROI-ROI correlations

A ROI to ROI study was undertaken, employing ROIs created in the seed as well as the target networked regions indicated previously, such as main somatosensory and motor areas, as well as S2 and PMv. This allowed for a more in-depth assessment of the findings from the seed-based analysis that was mentioned before. Calculating the average time series correlations between each ROI-ROI pair allowed for an investigation into the degree of connectedness that exists between correlated areas. In order to better depict the findings, color-coded connection matrices were generated using averaged Fisher-z transformed correlation coefficients (CCZ) for the ROI-ROI pairings in both humans and macaque monkeys (Fig. 3.3).



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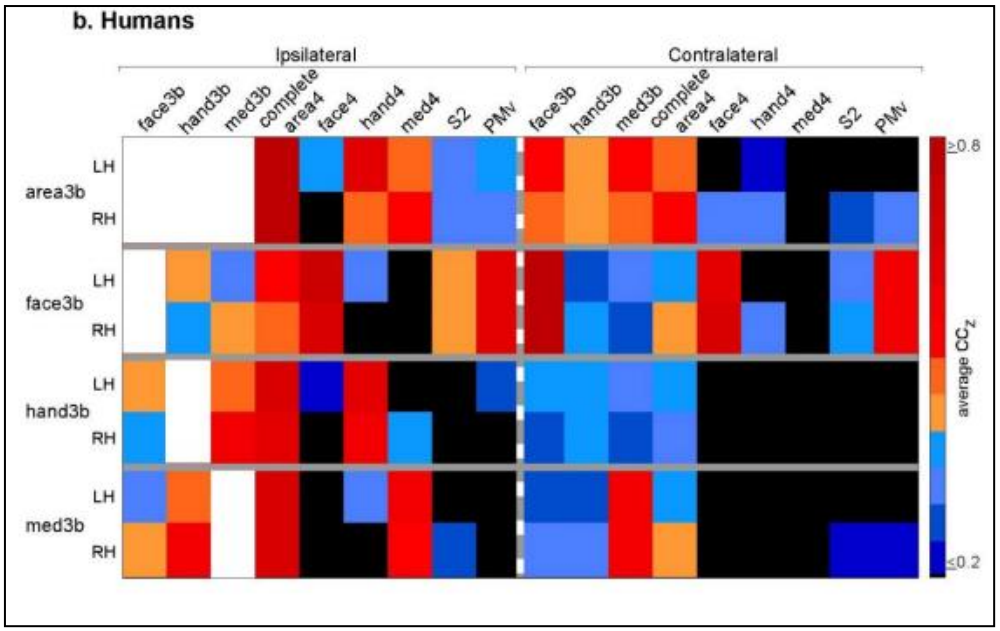

Figure 3: Correlation matrices showing ROI-ROI resting state functional connectivity between different ROI's in ipsilateral and contra- lateral hemispheres of (a) monkeys and (b) humans

Connectivity with contralateral area 3b

In humans, the average values of Fisher's z-transformed correlation coefficient (CCz) indicated that the inter-hemispherical strength of correlations was strongest for face3b, followed by med3b and hand3b (Figure 4).

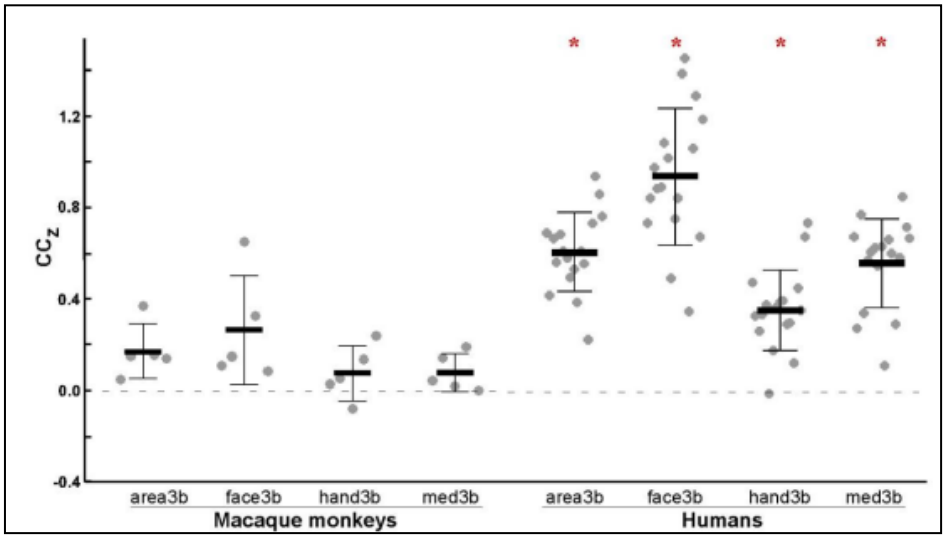

Figure 4: Inter-hemispheric homotopic functional connectivity of somatosensory region 3b in macaque monkeys and humans, as well as the somatotopic ROI's

Functional connectivity with S2 and PMv

Face3b in human brains from both hemispheres showed substantial connection with S2 in both directions (Figure 5).

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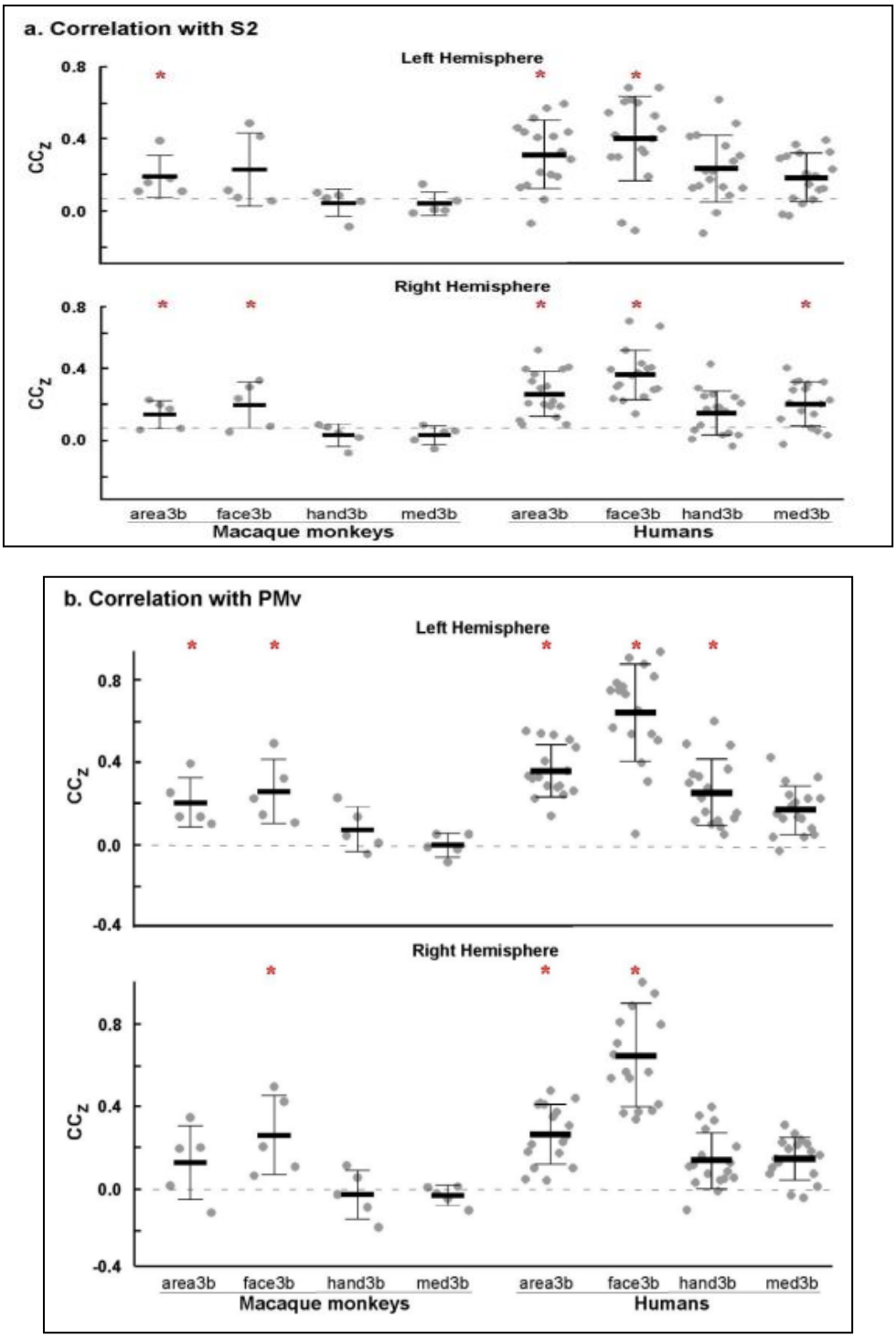

Figure 5: somatosensory ROIs Correlation coefficients (CCz) in macaque monkeys and humans with ipsilateral (a) S2 and (b) PMv

4. Discussion:

Several mammalian species, including humans, monkeys, cats, ferrets, rats, and mice, have had their resting-state functional connectivity networks described (Biswal et al., 1995; Lu et al., 2012; Popa et al., 2009; Stafford et al., 2014; Vincent et al., 2007; Zhou et al., 2016). Many different functional brain networks have been identified by using resting-state networks as a tool (Biswal et al., 1995; Cordes et al., 2000; De Luca et al., 2005; Fox et al., 2006; Fox et

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al., 2005; Greicius et al., 2003; Lowe et al., 1998; Raichle et al., 2001; Seeley et al., 2007). Gusnard et al. (2001) and Simpson et al. (2001) argue that the latter facilitates emotional processing and self-referential behaviour. De Luca et al., 2005; Hampson et al., 2006; Seeley et al., 2007; Tavor et al., 2016; Vincent et al., 2006) have all shown that resting-state networks can predict which parts of the brain would be active during stimulus-driven activation and which parts will be active during different cognitive tasks. In addition to its usage as a biomarker for sick brains (Greicius, 2008; Zhang and Raichle, 2010), changes in intrinsic functional connectivity have also been used to pinpointing the position and size of cortical regions (Glasser et al., 2016; Gordon et al., 2016).

5. Conclusion:

The current work expands our knowledge of the typical pattern of spontaneous connection and illustrates how it changes across distinct body part representations in somatosensory region 3b in both macaque monkeys and humans. This study was carried out in macaque monkeys and humans. In each and every fMRI session that was obtained for both species, the somatosensory ROIs defined separate functional subnetworks that essentially followed the underlying anatomical connection patterns. This was the case regardless of which species was being studied. According to the findings, connection network analysis should focus on body component representations rather than taking into account the whole "somatomotor" region as a single entity.

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