Figures and figure supplements

Development of visual cortex in human neonates is selectively modified by postnatal experience

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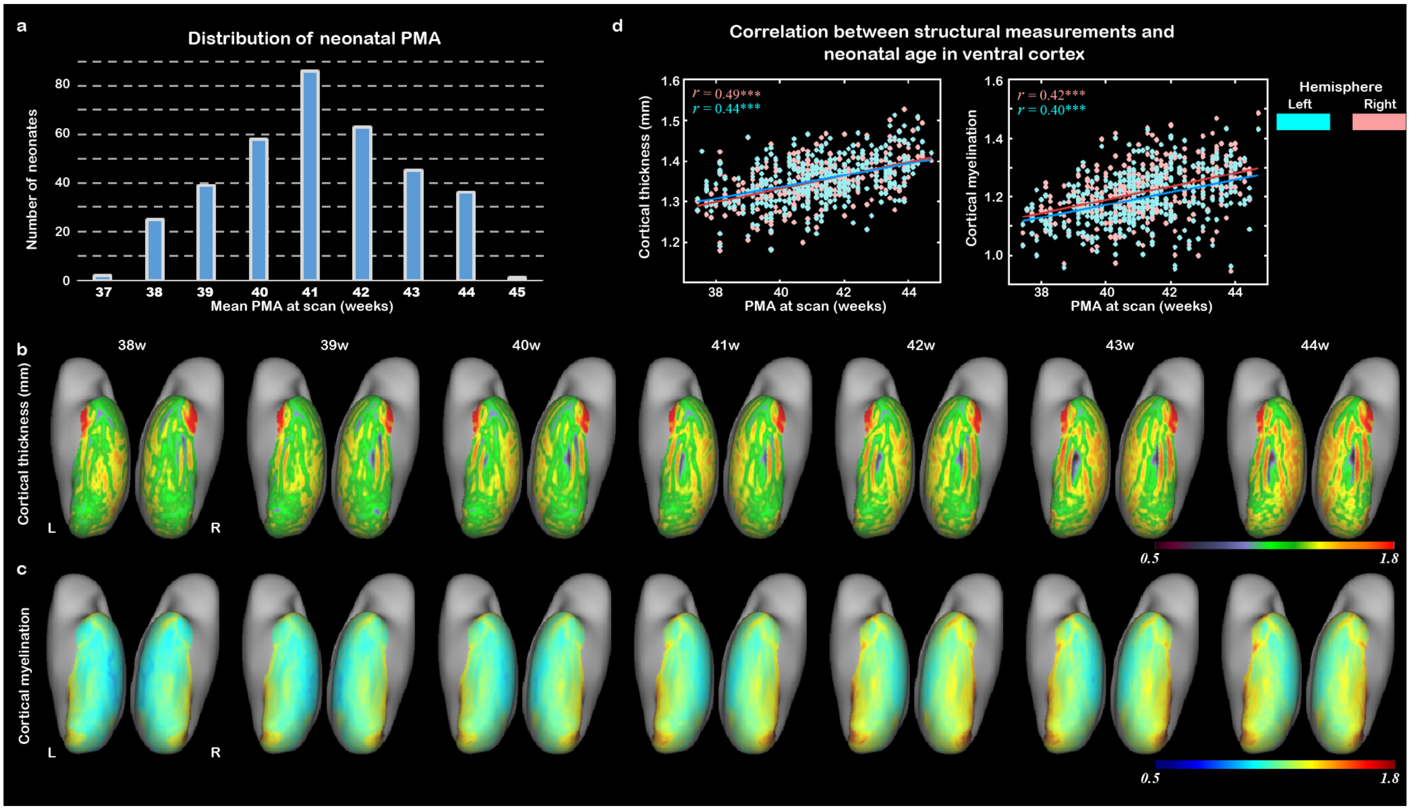

Figure 1. The development of cortical structural properties in human newborns. (**a**) The distribution of neonatal postmenstrual age (PMA) at scan in the study population. (**b**) The averaged cortical thickness (CT) and (**c**) the averaged cortical myelination (CM) from 38 to 44 weeks of PMA in the ventral cortex. (**d**) The correlation between CT/CM and PMA in right (peach) and left (blue) ventral cortex (***p<0.001).

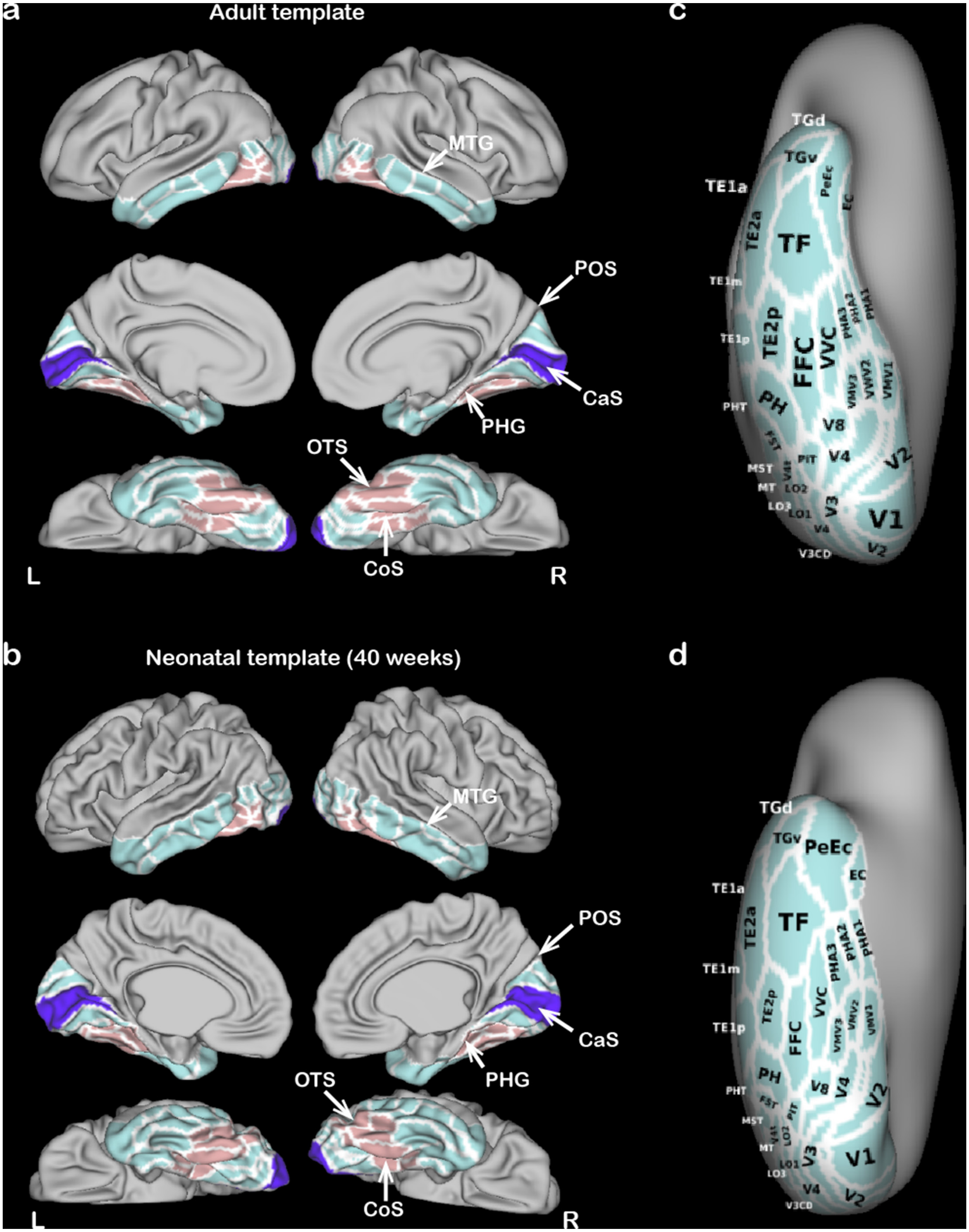

Figure 1—figure supplement 1. The 34 ROIs of the ventral cortex in the adult and neonatal space. The ventral cortex was parcellated into 34 regions of interest (ROIs) in HCP-MMP atlas (**a**), which was projected onto a neonatal template at 40 weeks of postmenstrual age (PMA) (**b**). White arrows indicate the homologous landmarks in the two atlases: (1) the parietooccipital sulcus (POS) was the posterior-upper boundary within the ventral cortical mask; (2) the middle temporal gyrus (MTG) and parahippocampal gyrus (PHG) served the lateral and medial boundary; (3) the calcarine sulcus (CaS)

Figure 1—figure supplement 1 continued on next page

Figure 1—figure supplement 1 continued

contoured the primary visual cortex (V1, purple regions); and (4) the occipitotemporal sulcus (OTS) and the collateral sulcus (CoS) were landmarks in the higher-level visual cortex (pink regions). The detailed labels of each ROI were mapped in the ventral view of adult (**c**) and neonatal (**d**) very-inflated atlas in the right hemisphere. The area descriptions are provided in ***Figure 1—source data 1***.

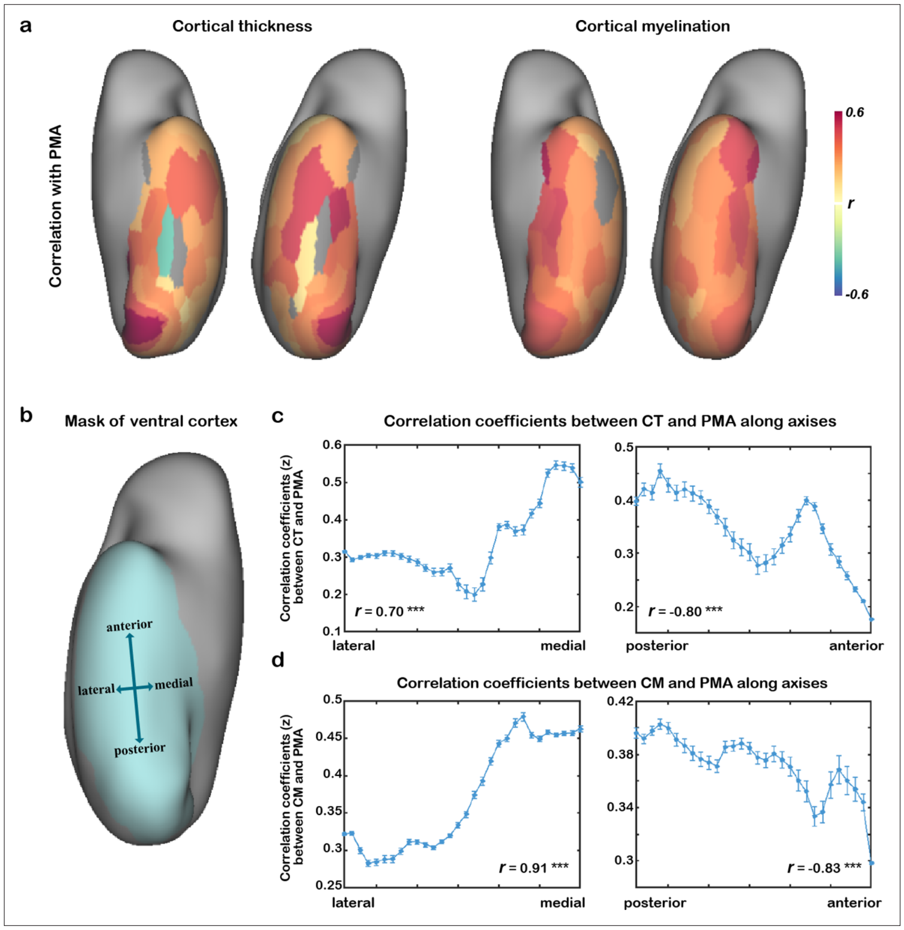

Figure 1—figure supplement 2. Spatial variation of cortical structure development in the ventral cortex. The correlation maps between cortical thickness (CT) or cortical myelination (CM) and postmenstrual age (PMA) in ventral cortex (**a**). To quantify the spatial variation of the development, we divide the ventral cortex into 30 segments with equal length along anterior–posterior or medial–lateral axes (**b**). The correlation coefficients between postmenstrual age (PMA) and CT/CM were averaged across all vertexes in each segment and plotted along the two axes (**c, d**). Error bar indicates the standard error within the segment. ***p<0.001.

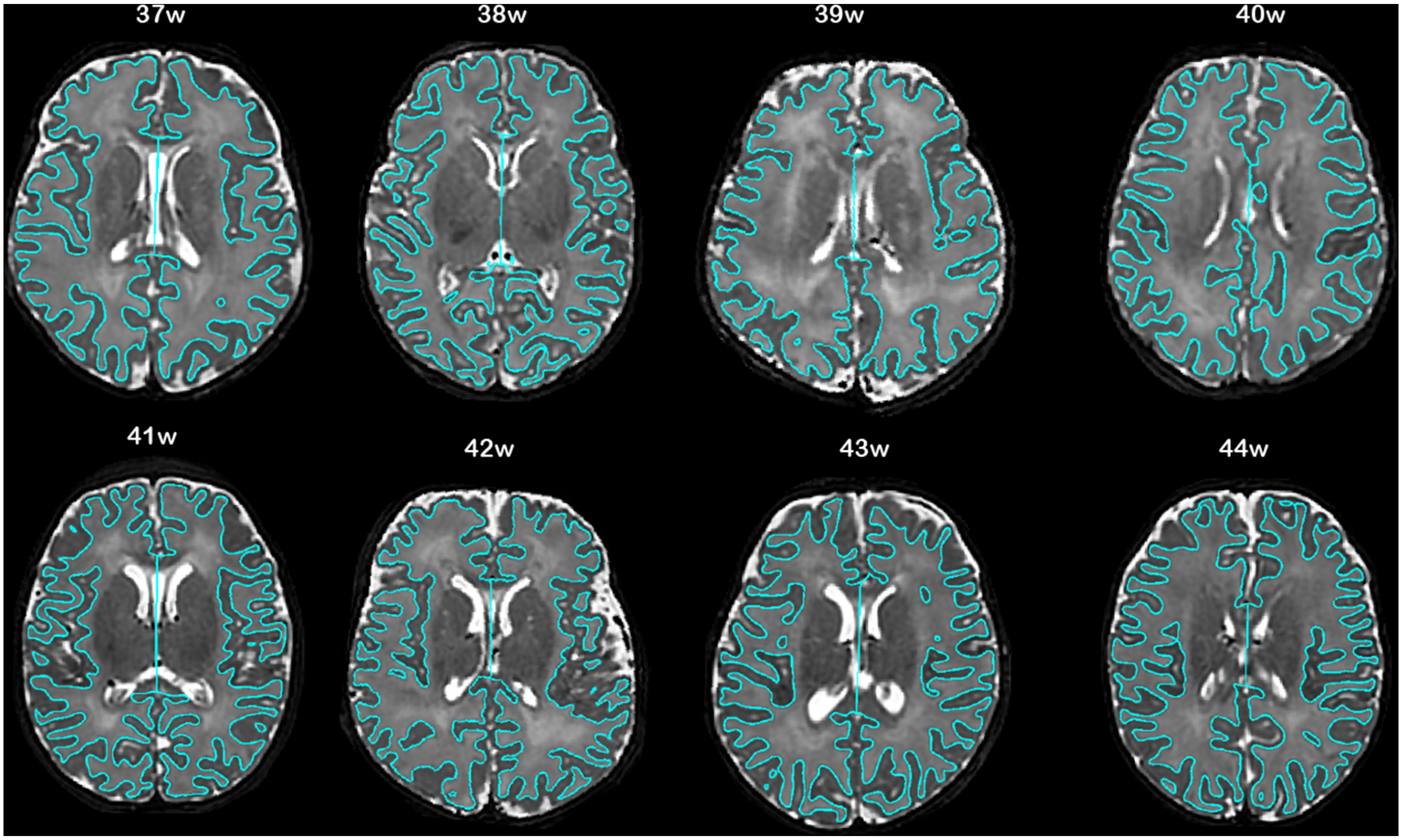

Figure 1—figure supplement 3. Example segmentations of subjects scanned at 37–44 weeks. The outlines indicate the boundary between white and gray matter.

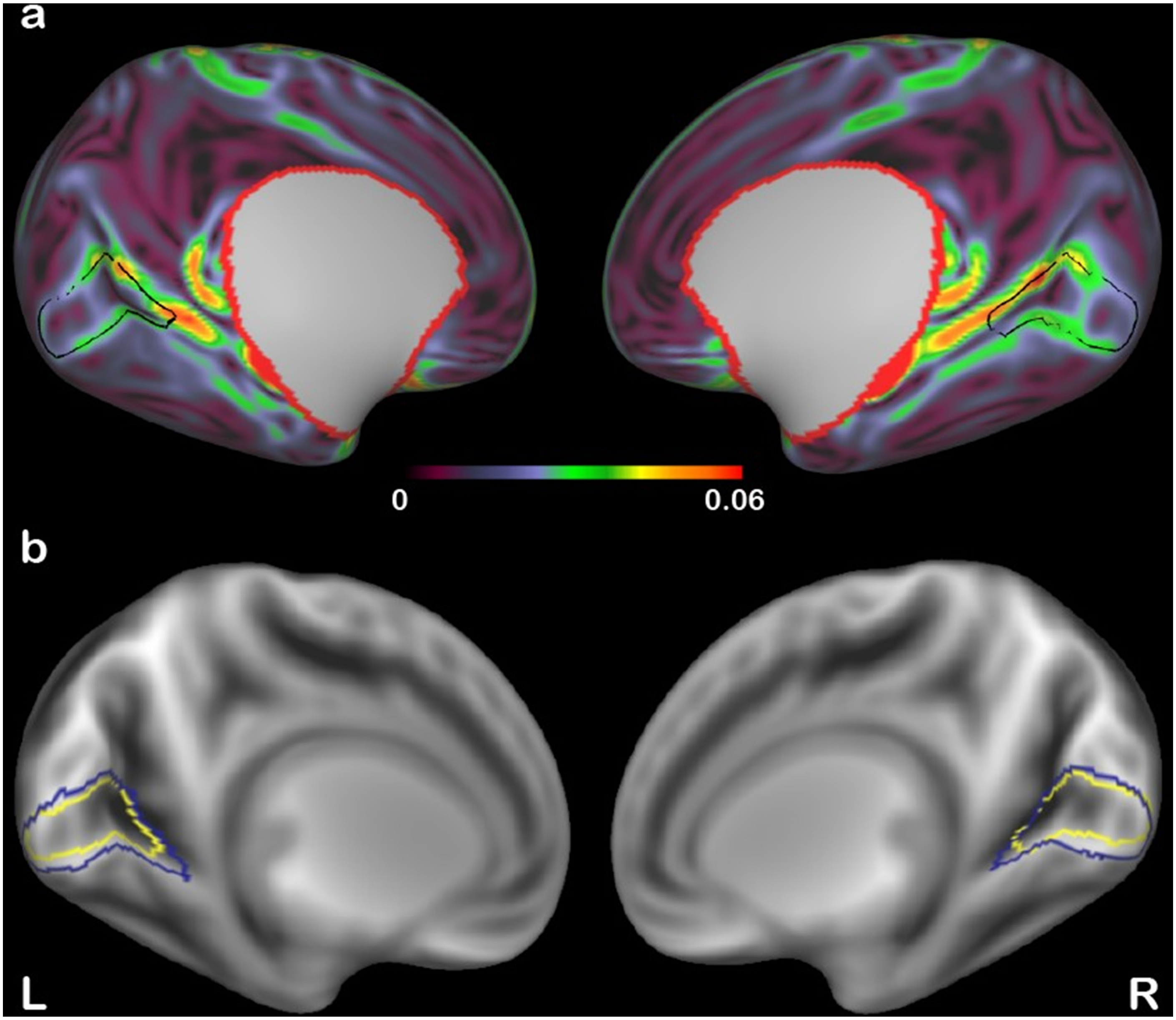

Figure 1—figure supplement 4. Comparison of the area V1 created by manual and registered methods. (**a**) The gradient map of cortical myelination in the neonates, where the black line depicts the manually delineated V1 contours. (**b**) Comparison of the V1 area transformed from adult space (yellow) and manually delineated V1 contour according to the myelin gradient (blue). The dice coefficient between them were 0.83 and 0.80 for the right and left hemispheres, respectively.

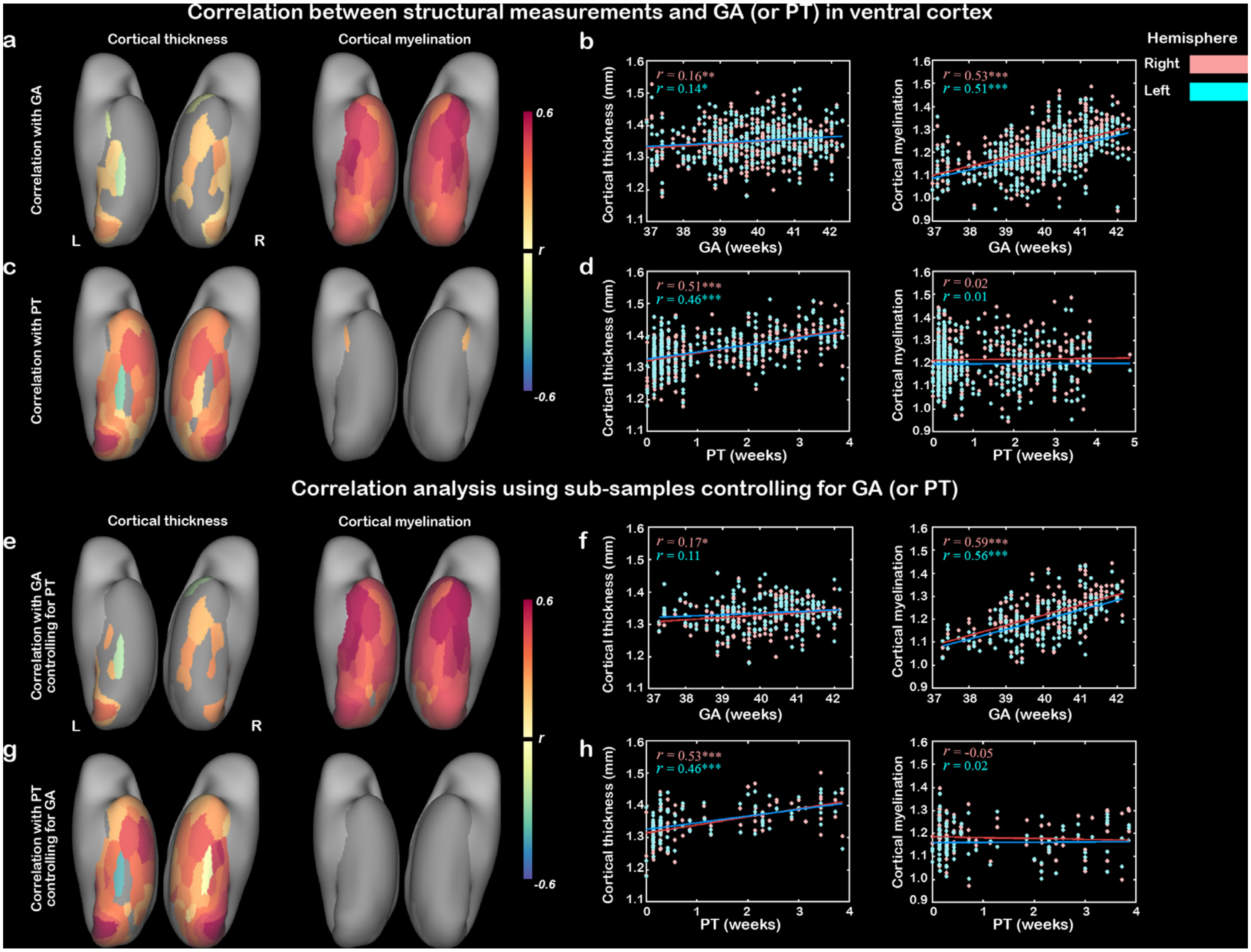

Figure 2. Contribution of postnatal time and gestational age on the development of cortical thickness and cortical myelination. The correlation maps between cortical thickness (CT)/cortical myelination (CM) and gestational age (GA) (**a, b**) or postnatal time (PT) (**c, d**) in ventral cortex. (**e–h**) Validation analysis using two subsamples: the first subsample included infants who underwent the scans within 3 days after birth to control for the postnatal time (**e, f**) and the second subsample included infants whose GA ranged from 39 to 40 weeks to control for the prenatal time (**g, h**). Note: correlation coefficients in the nongray areas were significant after false discovery rate (FDR) correlation (FDR $q < 0.05$); * p<0.05, **p<0.05, ***p<0.001 by Pearson correlation.

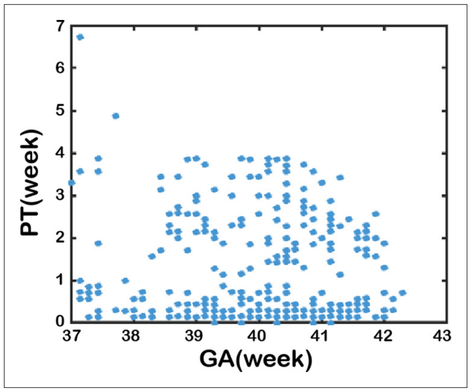

Figure 2—figure supplement 1. Relationship between gestational age (GA) and postnatal time (PT). The Pearson correlation between them was not significant (r = –0.08, p>0.1).

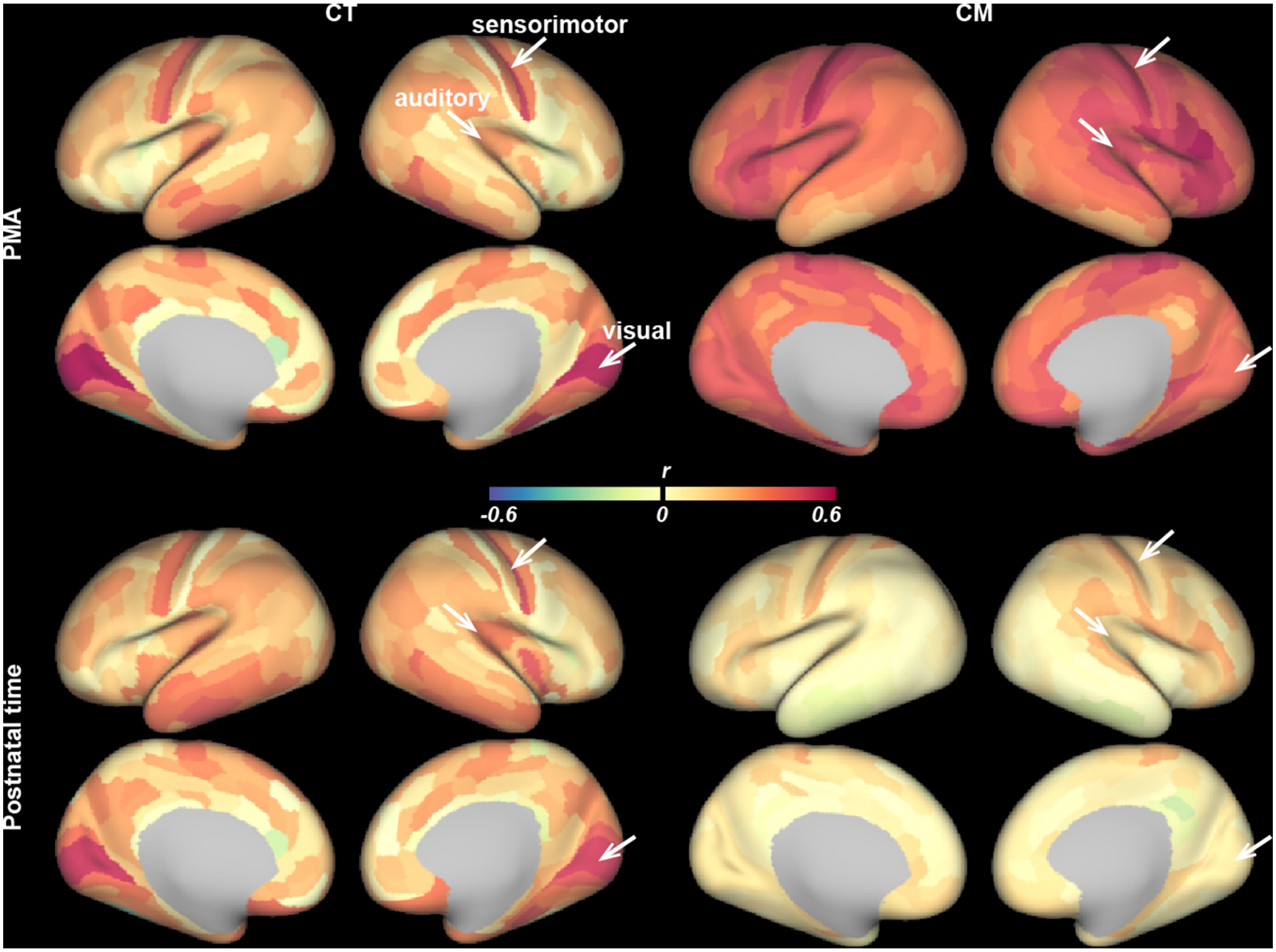

Figure 2—figure supplement 2. The correlation coefficient maps between postmenstrual age (PMA) or postnatal time (PT) and the structural measurements (cortical thickness [CT] or cortical myelination [CM]) across the whole brain. The primary sensory areas such as V1 (visual), primary auditory area (auditory), and central sulcus (sensorimotor) demonstrated the most prominent increase of CT with respect to both PMA and PT, suggesting the universal effect of postnatal sensory experience on the development of CT.

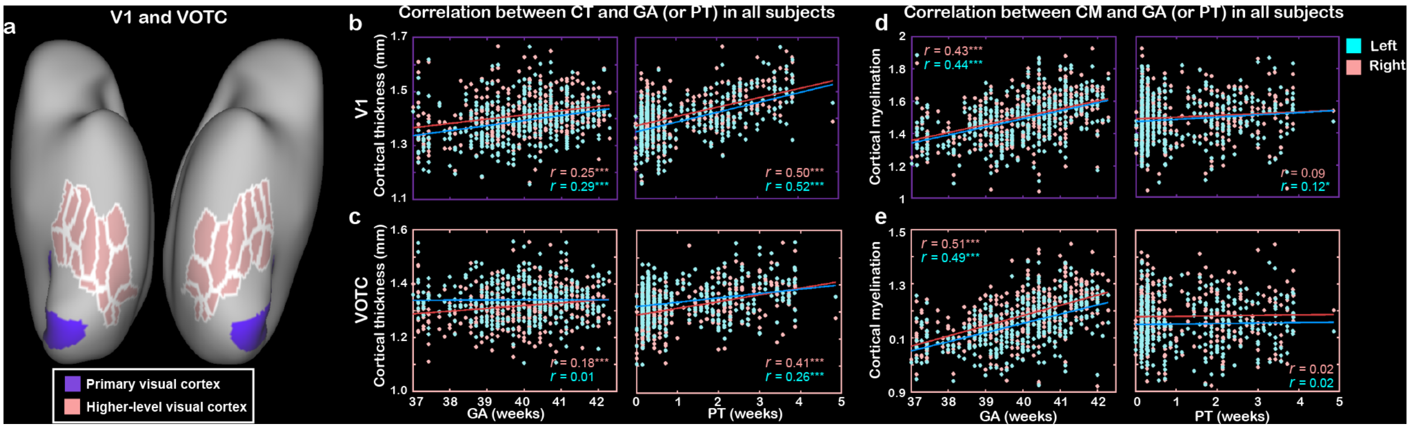

Figure 3. The development of cortical thickness (CT) and cortical myelination (CM) in primary visual cortex (V1) and higher-level visual cortex (VOTC) in human newborns. (**a**) Definitions of V1 and VOTC. Correlation between CT (**b, c**) or CM (**d, e**) and gestational age (GA) or postnatal time (PT) in V1 and VOTC. *p<0.05, ***p<0.001.

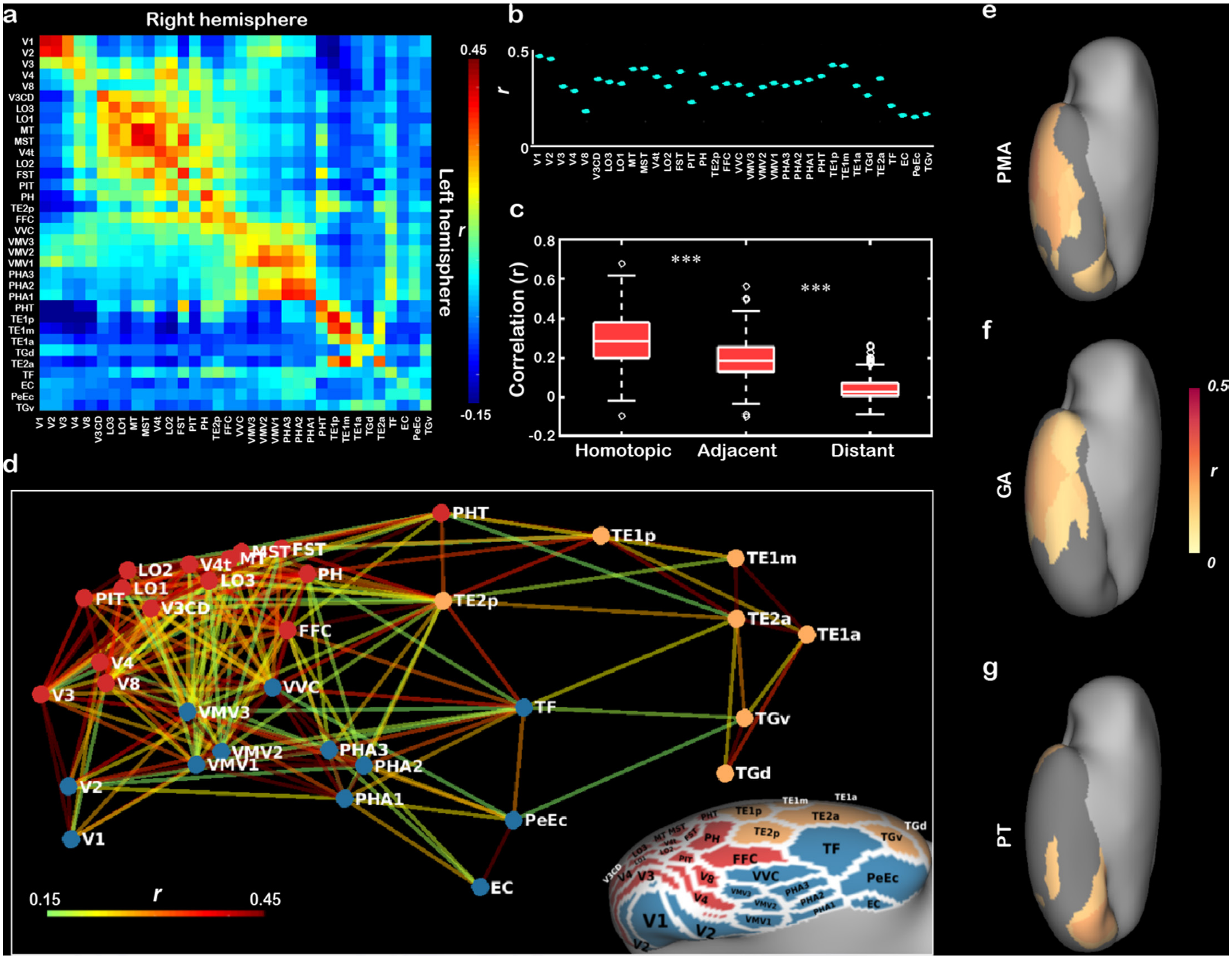

Figure 4. The innate functional organization of ventral cortex within 1 day after birth and its development in the first month of age in human newborns. (**a**) The pairwise correlation matrix describes the functional correlations among 34 regions of interest (ROIs) across hemispheres in ventral cortex. (**b**) The scatter graph illustrates the correlation coefficients (*r*) between 34 pairs of bilateral homotopic areas. (**c**) The box graph depicts the comparison between homotopic, adjacent, and distant connections at birth. (**d**) Multidimensional scaling and community groups obtained from the pairwise connections between 34 ipsilateral ROIs in right ventral cortex and the corresponding projection on the cortical surface. The color of the nodes in (**d**) indicates the cluster identity in the community structure analysis, and the color of the lines connecting the nodes indicates the functional correlation (*r* value) between two nodes. The correlation coefficient maps between the homotopic correlation and postmenstrual age (**e**), gestational age, (**f**) or postnatal time (**g**) in 34 ROIs are mapped onto the cortical surface, and the nongray areas indicated the significant correlations after false discovery rate (FDR) correlation (FDR $q < 0.05$). ***$p<0.001$.

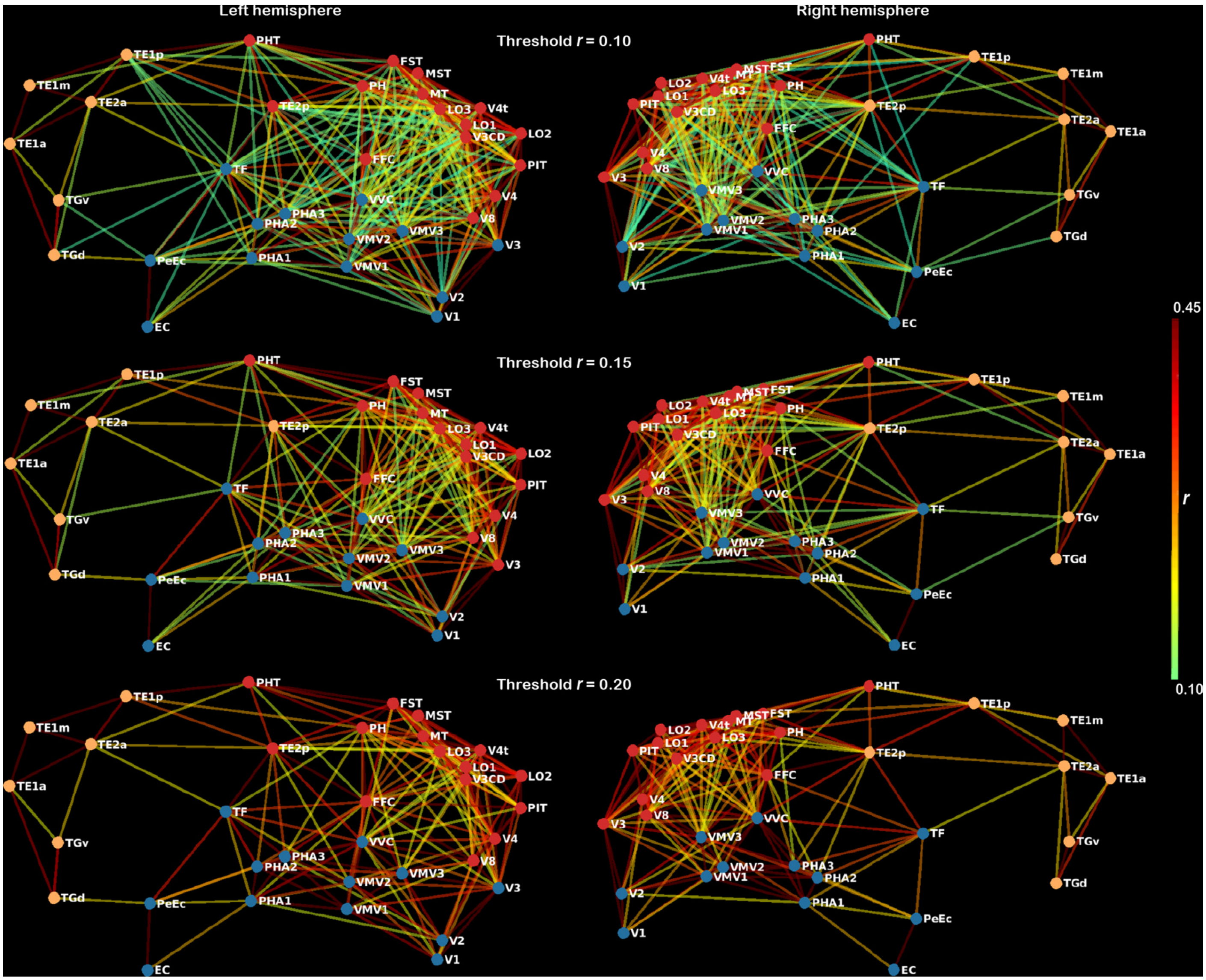

Figure 4—figure supplement 1. Multidimensional scaling and community groups based on pairwise ipsilateral connections between 34 regions of interest (ROIs) in the left or right ventral cortex. The results were similar between left and right cortex, and similar in the networks constructed using different thresholds of correlation coefficient *r* from 0.1 to 0.2. The color of the nodes indicates the cluster identity in the community structure analysis, and the color of the lines connecting the nodes indicates the functional correlation *r* between two nodes.

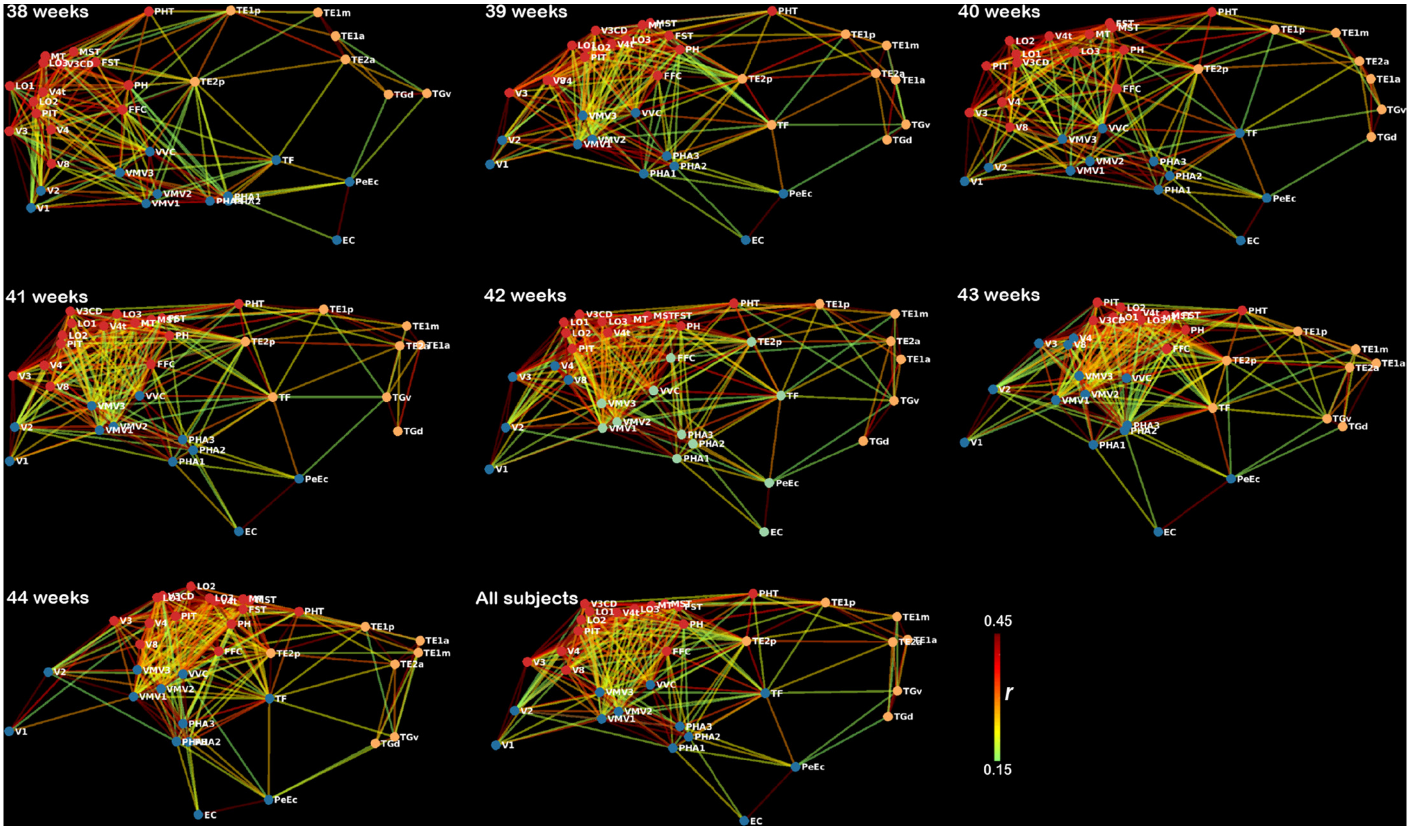

Figure 4—figure supplement 2. Functional networks of right ventral cortex for each postmenstrual age (PMA) week from 38 to 44 weeks based on multidimensional scaling. We found similar three-cluster network structure in the infants at different PMA (except for 42 weeks), and subtle fluctuation was observed in the boundary between different clusters at different PMA.

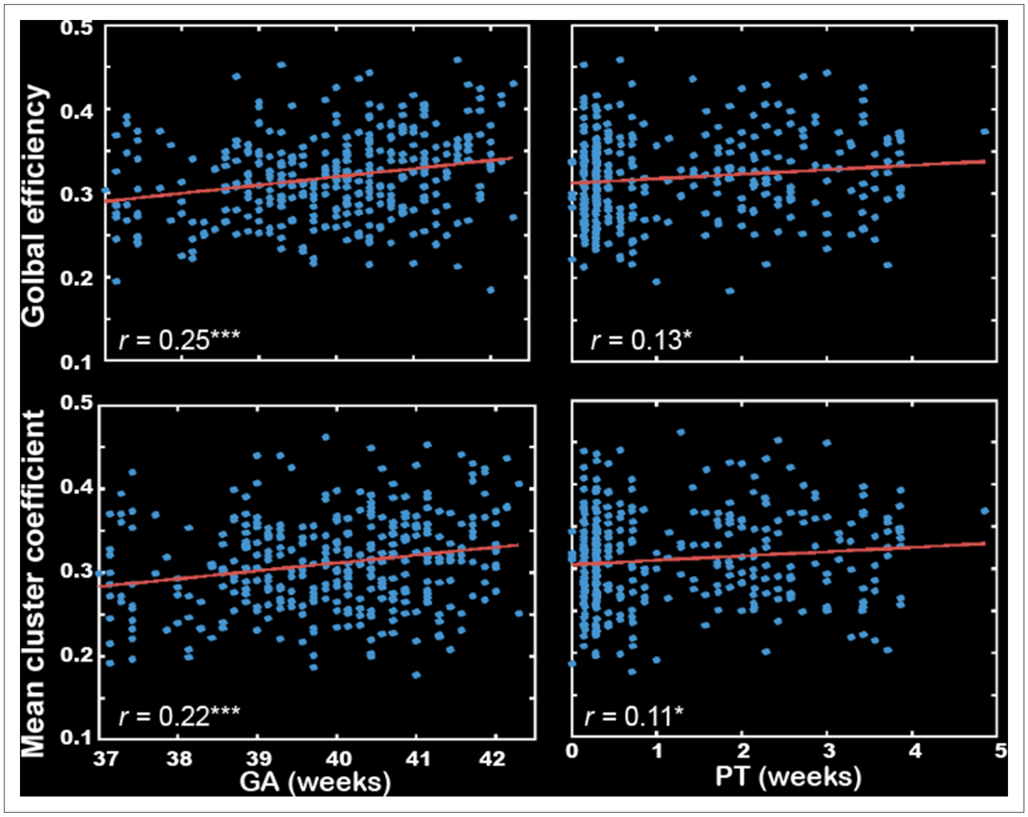

Figure 4—figure supplement 3. The correlation between global efficiency or mean cluster coefficient of the right hemisphere and gestational age (GA) or postnatal time (PT). *p<0.05, ***p<0.001.

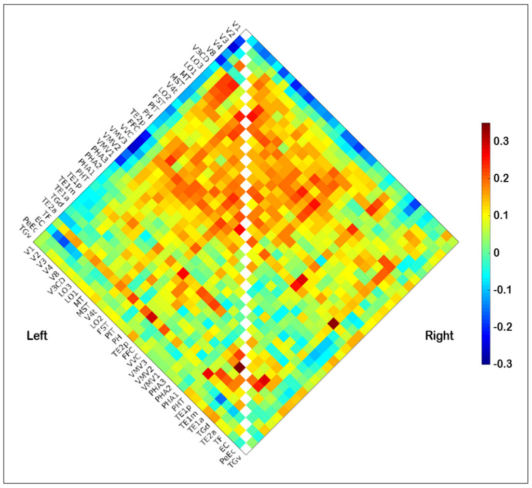

Figure 4—figure supplement 4. The correlations between ipsilateral functional connections and postmenstrual age. The left and right half matrix indicates the connections in the left and right hemispheres, respectively.

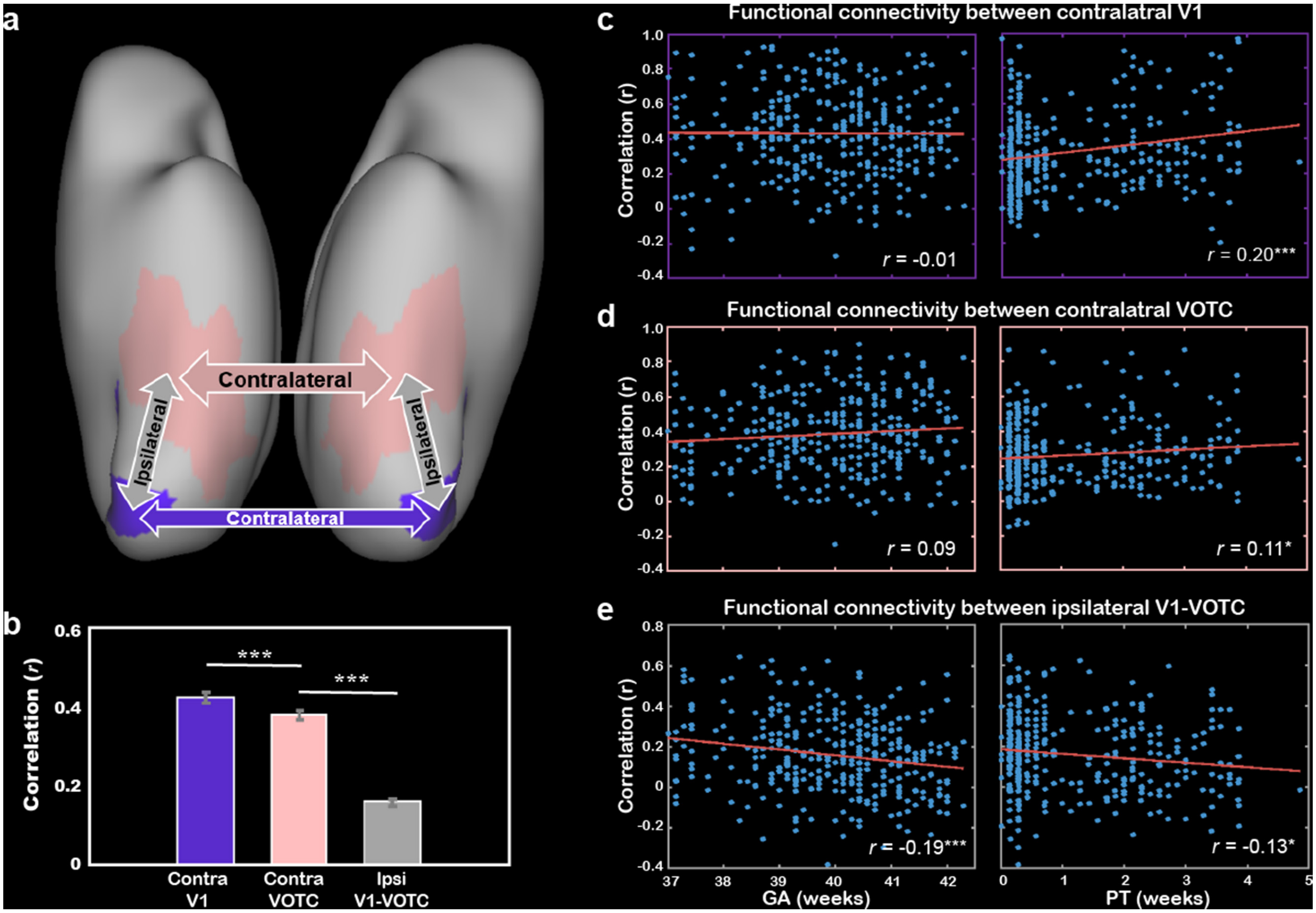

Figure 5. The development of the functional connections between bilateral primary visual cortex (V1) and higher-level visual cortex (VOTC) and their cross-correlations. (**a**) The connections of interest include the homotopic connection between bilateral V1 (purple), bilateral VOTC (peach), and the averaged ipsilateral connections between V1 and VOTC in each of the hemispheres (gray). (**b**) Comparison of the three types of connections in the infants within 1 day after birth (no postnatal experience). The correlation between gestational age (GA) or postnatal time (PT) and bilateral V1 connection (**c**), bilateral VOTC connection (**d**), and ipsilateral connection between V1 and VOTC (**e**). The values in the bracket indicate the partial correlation coefficient controlling for postmenstrual age (PMA) of infants. Contra, contralateral; Ipsi, ipsilateral; *p<0.05; **p<0.01, ***p<0.001.

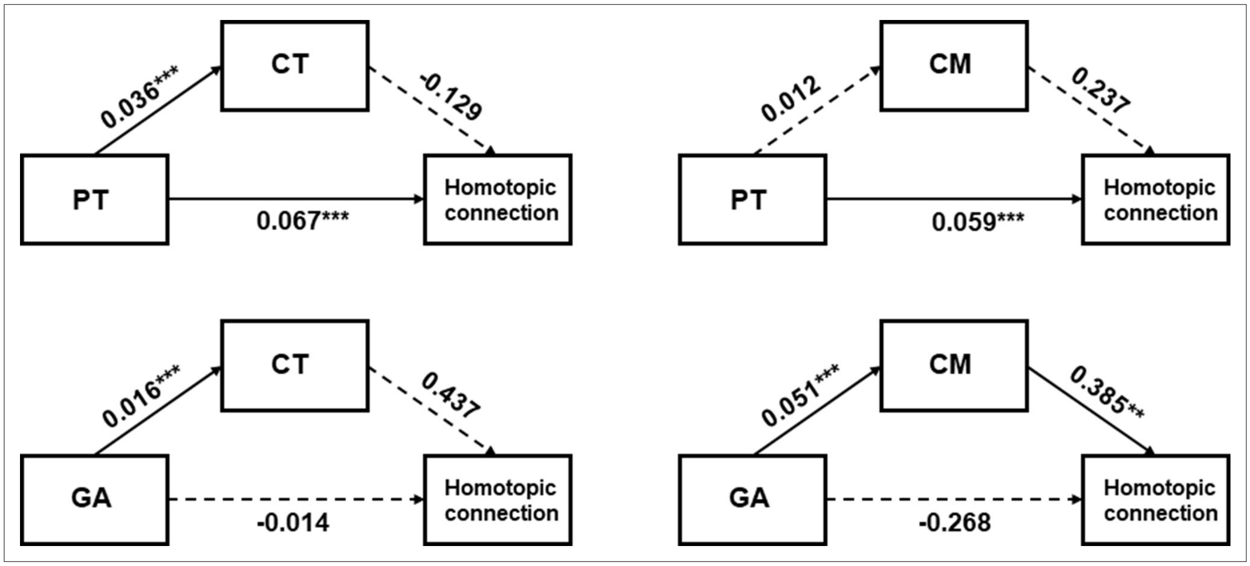

Figure 6. Mediation analysis between the developmental factors (gestational age [GA] or postnatal time [PT]), homotopic functional connection between bilateral V1, and structural features (cortical thickness [CT] or cortical myelination [CM]). Homotopic connection between bilateral V1 was set as an independent variate, while the developmental factor was a dependent variate, and the structural features (CT or CM) was the mediated variate. **p<0.01, ***p<0.001.

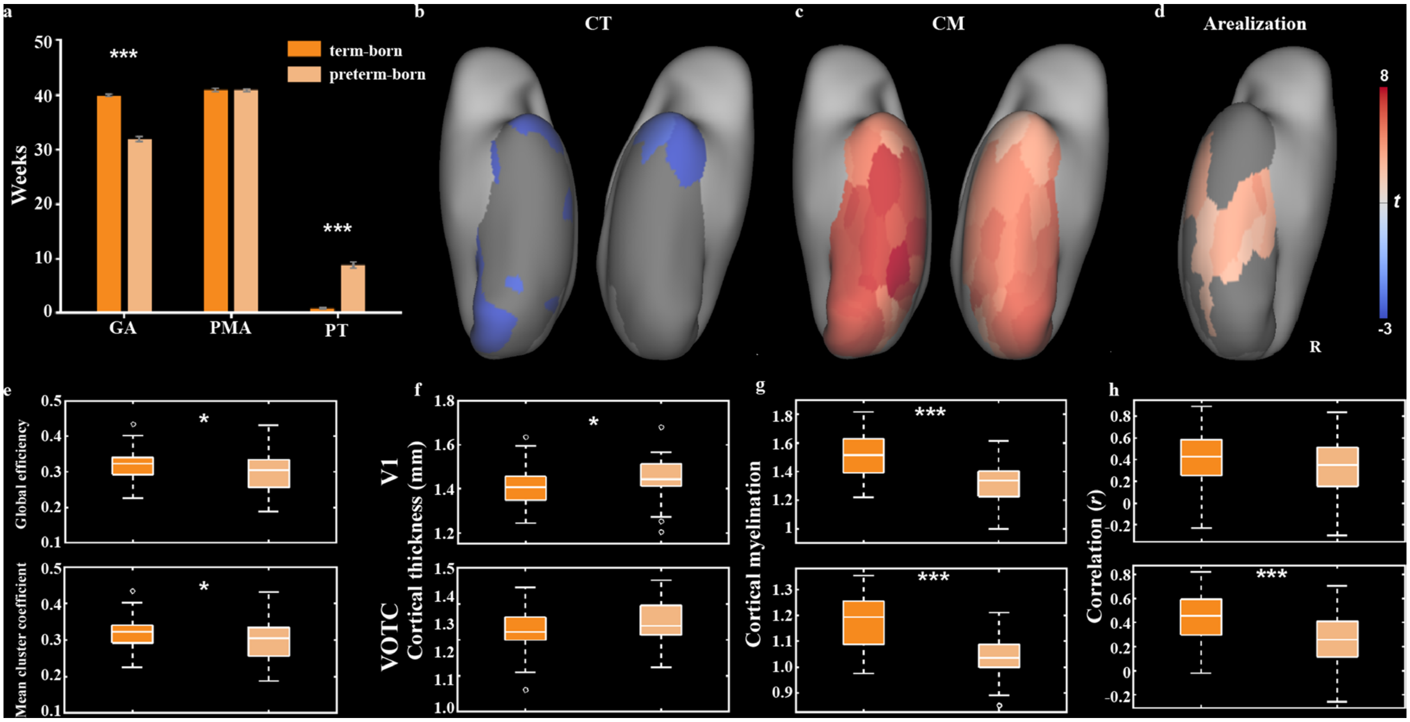

Figure 7. Comparison of structural and functional features between term- and preterm-born infants. (**a**) The comparison of gestational age (GA), postmenstrual age (PMA), and postnatal time (PT) between term-born and preterm-born infants. (**b–d**) The *t* maps of cortical thickness (CT), cortical myelination (CM), and arealization between two groups (term – preterm) in ventral visual cortex. Only the significantly different regions (false discovery rate [FDR] $q < 0.05$) are shown. (**e–h**) The box plots of structural and functional measurements between two groups, including the global coefficient and mean cluster coefficient of the ventral network (**e**), CT in V1 and VOTC (**f**), CM in V1 and VOTC (**g**), and functional connectivity between contralateral V1 and VOTC (**h**). *p<0.05, **p<0.01, ***p<0.001 by two-sample *t*-test.

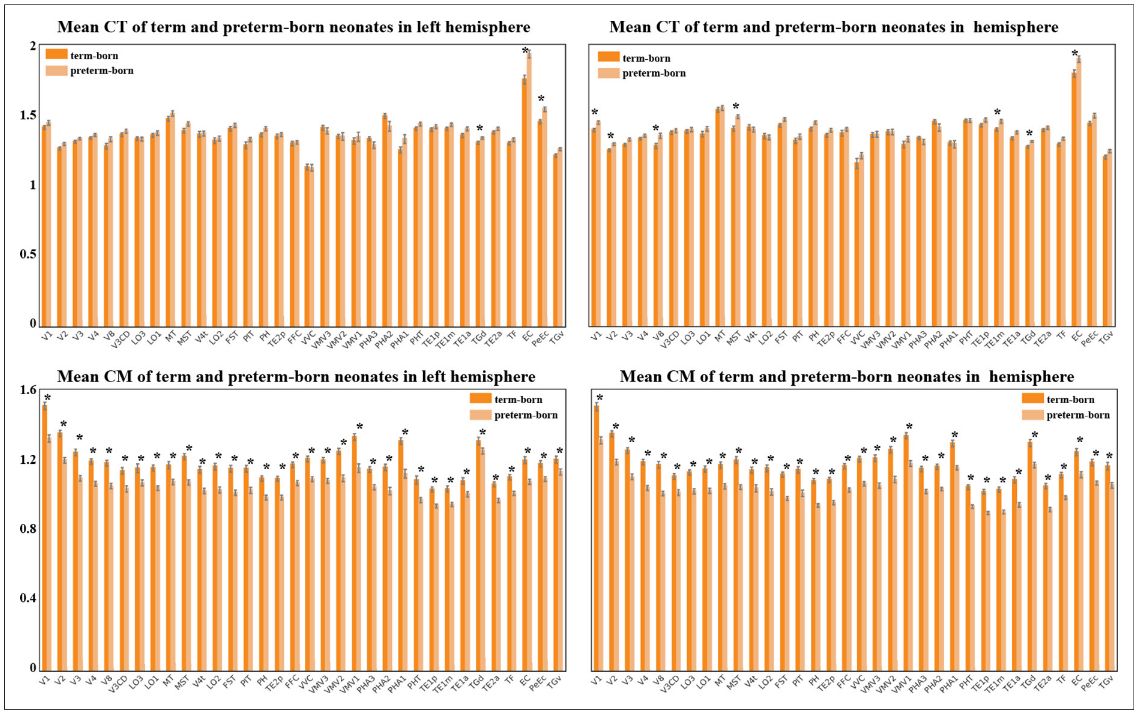

Figure 7—figure supplement 1. The mean cortical thickness (CT) and mean cortical myelination (CM) in each of the 34 regions of interest (ROIs) in the ventral visual cortex compared between term and preterm-born infants. *p<0.05.

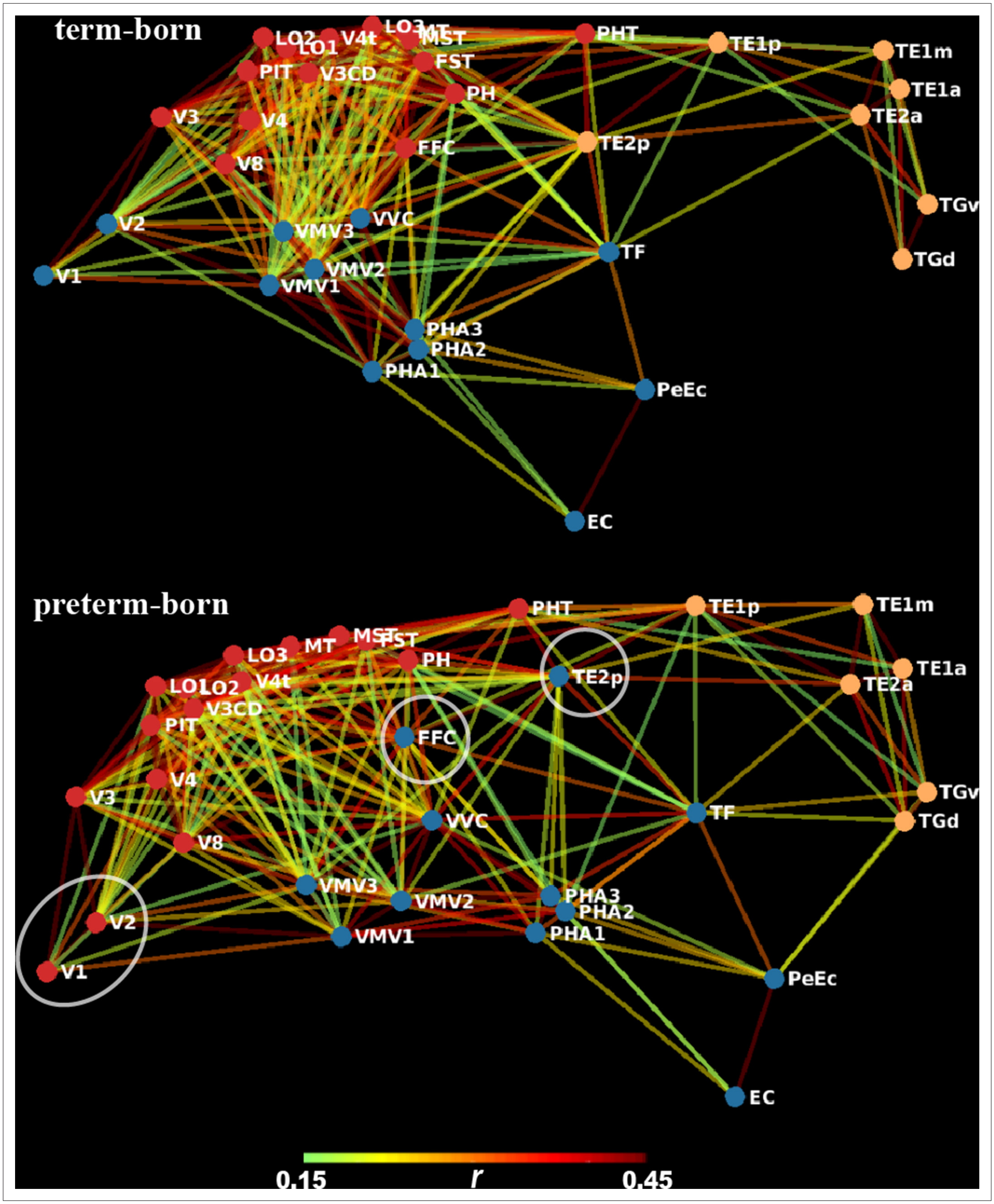

Figure 7—figure supplement 2. Functional networks of right ventral cortex in term-born and preterm-born infants, based on multidimensional analysis.