Coordinated Anatomical Growth of Motor, Sensory, and Visual Networks in Early Infancy

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Purpose

Using regional cortical thickness (C_{TH}) growth trajectories for whole brain correlation analysis, Raznahan et al (1) have recently demonstrated that brain regions sharing a similar function exhibit a similar C_{TH} growth trajectory, implying that different brain functional networks may possess unique sets of structural growth trajectories. In this study, we tested the hypotheses that coordinated anatomical growth is present in early infancy and incorporating additional parameters (gray and white matter volumes) will further improve the specificity of discerning brain structural networks than that using C_{TH} alone.

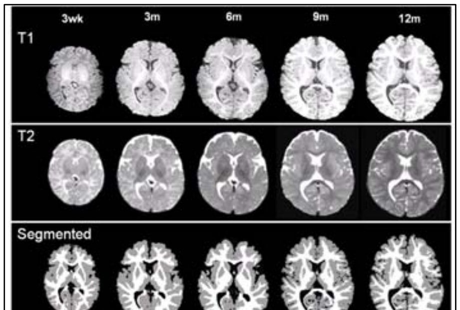

Fig 1

Methods

A total of 37 normal and healthy subjects were recruited to undergo a longitudinal MR imaging study where each subject was scanned every 3 mons starting from birth till yr 1 and again at 18 mons old. All images were acquired using a 3T Siemens scanner (TIM TRIO, Siemens) with a 32 channel head coil, allowing parallel imaging to shorten acquisition time. No sedation was employed and all subjects were imaged during natural sleep. MP-RAGE (3 min 25 sec, parallel factor = 2) and TSE T2 (3 min and 50 sec, parallel factor = 2) images were processed with a standard pipeline, including image resampling, bias correction, skull stripping, tissue segmentation, and surface reconstruction. Images from all subjects were co-registered on the MNI template and parcellated into 90 cortical ROIs (AAL). Three quantitative measures from each ROI were obtained from each subject, including gray matter (GM) and white matter (WM) volumes and C_{TH}. More detailed descriptions of the approaches used for obtaining these three parameters can be found in (2) (3). In short, GM/WM volumetric measures were obtained using a longitudinally guided level-sets method that is dedicated for consistent infant image segmentation (Fig. 1). For C_{TH}, the cortical surfaces of the mean image of the aligned longitudinal images of the same subject were reconstructed by a deformable surface approach. The cortical surfaces at the individual time points were then reconstructed by jointly deforming copies of the mean cortical surfaces to the respective images across time. C_{TH} was then computed as the average of the closest distances between corresponding vertices on inner and outer cortical surfaces. The growth trajectories of GM, WM, and C_{TH} of the motor (pre-central gyrus), sensory (post-central gyrus), and visual (calcarine) areas were separately chosen as the reference functions for correlation analysis among 78 cortical ROIs out the 90 ROIs. A correlation coefficient (cc) >0.4 was used as threshold. Specifically, after Fisher-Z transformation of the correlation matrices, they were averaged, inverse Fisher-z transformed, and cc>0.4 applied, revealing the brain regions with a similar combined growth trajectory of GM, WM, and C_{TH} for each functional area, separately.

Results

14 (out of 37) subjects completed all 6 time points. Of which, one subject exhibited severe motion related artifacts. Therefore, results below were obtained from the 13 subjects who completed all 6 time points. The coordinated anatomical growth combining GM/WM/C_{TH} growth trajectories for the motor/sensory/visual structural networks is shown in Fig. 2 (left panel), respectively, whereas results using C_{TH} growth trajectory alone similar to that conducted by Raznahan et al (1) are shown in right panel. Evidently, the integration of all three parameters reveals more focal brain regions consistent with the known motor/sensory/visual networks when compared to that using C_{TH} alone (right panel), which appears rather diffuse. In addition to both pre- and post-central gyri as one would have expected for the motor and sensory networks, it is interesting to note that the superior temporal lobe (left for motor and bilateral for sensory) exhibits a similar combined growth trajectory as the motor/sensory areas (left panel). This finding may be consistent with the well understood interaction between motor/sensory and speech comprehension (4). More importantly, the potential interaction between the primary visual area and the orbital frontal and lateral prefrontal areas for attentional tasks has been widely reported (5).

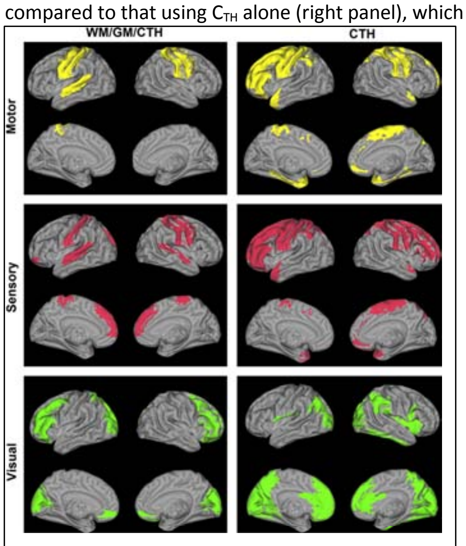

Fig. 2

Conclusions

Our results, for the first time, demonstrate the coordinated anatomical growth in early infancy. By combining GM and WM volume together with C_{TH} growth trajectories, our results reveal motor, sensory and visual structural networks. Comparing to the structural networks identified using C_{TH} alone as that by Raznahan et al, the inclusion of GM and WM volumes appears to improve the specificity of these networks since more localized brain regions, consistent with the known motor/sensory/visual brain functional networks are identified when all three parameters were employed. Given the lack of approaches capable of discerning brain structural networks in early infancy, our approach may offer a means to explore higher order brain functional development such as language and attentional networks during early brain development.

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