Typical patterns of myelin neurodevelopment and cognitive abilities in babies and toddlers

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Purpose

The establishment of normal myelination is essential to normal neurodevelopment, allowing fast inter-neuronal communication. These pathways underlie higher cognitive functions and their interruption has been related to neurodevelopmental and psychiatric disorders. Using independent component analysis (ICA) we aim to blindly segment quantitative myelin maps according to their developmental trajectories. We hypothesise that anatomical networks will have similar trajectories and the myelination of each network will relate to specific cognitive domains.

Methods

272 infants and toddlers aged 93-2040 days (mean 713.5 days, 115 female) were scanned during normal non-sedated sleep or while watching a movie. To calculate quantitative myelin content images, an multi-component relaxometry sequence was used; mcDESPOT (Deoni et al, 2012). The resulting myelin content images were registered to a common space using a multi-level registration approach. The high flip angle T1-weighted image (in register with the myelin image) was registered first to an age specific template and then to a common pediatric template using the ANTS package (Avants et al, 2009). This registration was then applied to the myelin content image. The resulting normalized MWF images were concatenated into a single 4D image and smoothed by a 3mm FWHM Gaussian kernel. This series of images was used as input to a probabilistic independent component analysis (ICA) using melodic (part of FSL, Beckmann and Smith, 2005). The number of components was calculated in melodic automatically using Bayesian information criterion. Finally, the degree to which each IC was represented in each subject was correlated with cognitive markers (Mullen Scales for Early Learning) of fine motor skill, language and visual receptive skills, after controlling for age and gender.

Results

The decomposition resulted in 40 independent components representing white matter regions that showed consistent trajectories of myelination across subjects. Of these, most (32) showed a positive relationship with cognitive abilities ($p<0.05$, corrected for multiple comparisons using FDR, significant relationship marked as red in fig 1).

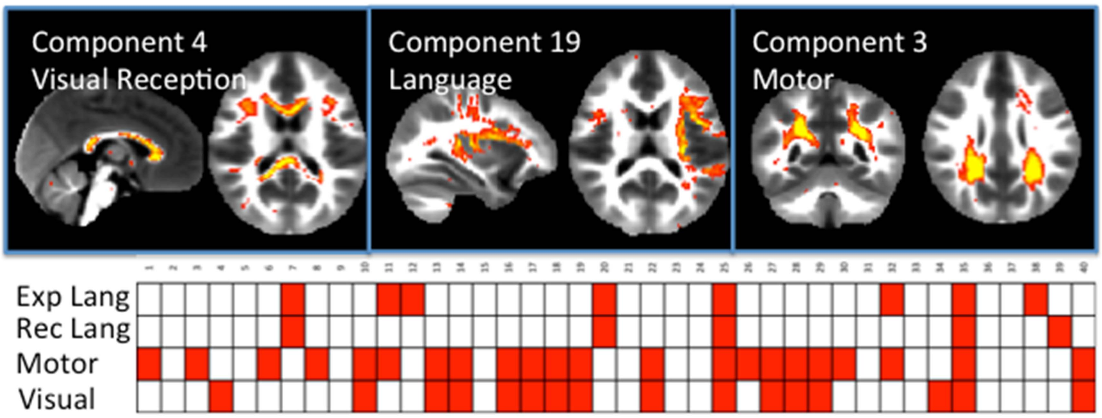

Figure 1: Example independent components (top) and how they relate to the 4 cognitive domains (bottom). Boxes are shaded in red if the cognitive domain correlates significantly to each independent component.

Discussion

These results indicate the progressive myelination of cortical and subcortical *systems*. Their trajectories and anatomical localization related strongly to cognitive ability in this large group of typically developing children. Moreover, ICA parcellates out anatomically meaningful white matter bundles, such as the arcuate fasciculus in fig 1 (middle).

References: Avants et al, Neuroimage, 49, 2457-2466, 2010 | Deoni et al, Neuroimage; 63, 1038-1053, 2012 | Beckmann & Smith Neuroimage, 25, 294‐311, 2005