Selected references – Terry Jernigan

Brown, T. T. & Jernigan, T. L. (2012). Brain development during the preschool years. *Neuropsychology Review, 22,* 313-333.
Notes: The preschool years represent a time of expansive mental growth, with the initial expression of many psychological abilities that will continue to be refined into young adulthood. Likewise, brain development during this age is characterized by its "blossoming" nature, showing some of its most dynamic and elaborative anatomical and physiological changes. In this article, we review human brain development during the preschool years, sampling scientific evidence from a variety of sources. First, we cover neurobiological foundations of early postnatal development, explaining some of the primary mechanisms seen at a larger scale within neuroimaging studies. Next, we review evidence from both structural and functional imaging studies, which now accounts for a large portion of our current understanding of typical brain development. Within anatomical imaging, we focus on studies of developing brain morphology and tissue properties, including diffusivity of white matter fiber tracts. We also present new data on changes during the preschool years in cortical area, thickness, and volume. Physiological brain development is then reviewed, touching on influential results from several different functional imaging and recording modalities in the preschool and early school-age years, including positron emission tomography (PET), electroencephalography (EEG) and event-related potentials (ERP), functional magnetic resonance imaging (fMRI), magnetoencephalography (MEG), and near-infrared spectroscopy (NIRS). Here, more space is devoted to explaining some of the key methodological factors that are required for interpretation. We end with a section on multimodal and multidimensional imaging approaches, which we believe will be critical for increasing our understanding of brain development and its relationship to cognitive and behavioral growth in the preschool years and beyond
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Fjell, A. M., Walhovd, K. B., Brown, T. T., Kuperman, J. M., Chung, Y., Hagler, D. J., Jr. et al. (2012). Multimodal imaging of the self-regulating developing brain. *Proceedings of the National Academy of Sciences of the United States of America, 109,* 19620-19625.
Notes: Self-regulation refers to the ability to control behavior, cognition, and emotions, and self-regulation failure is related to a range of neuropsychiatric problems. It is poorly understood how structural maturation of the brain brings about the gradual improvement in self-regulation during childhood. In a large-scale multicenter effort, 735 children (4-21 y) underwent structural MRI for quantification of cortical thickness and surface area and diffusion tensor imaging for quantification of the quality of major fiber connections. Brain development was related to a standardized measure of cognitive control (the flanker task from the National Institutes of Health Toolbox), a critical component of self-regulation. Ability to inhibit responses and impose cognitive control increased rapidly during preteen years. Surface area of the anterior cingulate cortex accounted for a significant proportion of the variance in cognitive performance. This finding is intriguing, because characteristics of the anterior cingulum are shown to be related to impulse, attention, and executive problems in neurodevelopmental disorders, indicating a neural

foundation for self-regulation abilities along a continuum from normality to pathology. The relationship was strongest in the younger children. Properties of large-fiber connections added to the picture by explaining additional variance in cognitive control. Although cognitive control was related to surface area of the anterior cingulate independently of basic processes of mental speed, the relationship between white matter quality and cognitive control could be fully accounted for by speed. The results underscore the need for integration of different aspects of brain maturation to understand the foundations of cognitive development
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Chen, C. H., Panizzon, M. S., Eyler, L. T., Jernigan, T. L., Thompson, W., Fennema-Notestine, C. et al. (2011). Genetic influences on cortical regionalization in the human brain. *Neuron, 72,* 537-544.
Notes: Animal data demonstrate that the development of distinct cortical areas is influenced by genes that exhibit highly regionalized expression patterns. In this paper, we show genetic patterning of cortical surface area derived from MRI data from 406 adult human twins. We mapped genetic correlations of areal expansion between selected seed regions and all other cortical locations, with the selection of seed points based on results from animal studies. "Marching seeds" and a data-driven, hypothesis-free, fuzzy-clustering approach provided convergent validation. The results reveal strong anterior-to-posterior graded, bilaterally symmetric patterns of regionalization, largely consistent with patterns previously reported in nonhuman mammalian models. Broad similarities in genetic patterning between rodents and humans might suggest a conservation of cortical patterning mechanisms, whereas dissimilarities might reflect the functionalities most essential to each species
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Jernigan, T. L., Baare, W. F., Stiles, J., & Madsen, K. S. (2011). Postnatal brain development: structural imaging of dynamic neurodevelopmental processes. *Progress in Brain Research, 189,* 77-92.
Notes: After birth, there is striking biological and functional development of the brain's fiber tracts as well as remodeling of cortical and subcortical structures. Behavioral development in children involves a complex and dynamic set of genetically guided processes by which neural structures interact constantly with the environment. This is a protracted process, beginning in the third week of gestation and continuing into early adulthood. Reviewed here are studies using structural imaging techniques, with a special focus on diffusion weighted imaging, describing age-related brain maturational changes in children and adolescents, as well as studies that link these changes to behavioral differences. Finally, we discuss evidence for effects on the brain of several factors that may play a role in mediating these brain-behavior associations in children, including genetic variation, behavioral interventions, and hormonal variation associated with puberty. At present longitudinal studies are few, and we do not yet know how variability in individual trajectories of biological development in specific neural systems map onto similar variability in behavioral trajectories
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Madsen, K. S., Baare, W. F., Skimminge, A., Vestergaard, M., Siebner, H. R., & Jernigan, T. L. (2011). Brain microstructural correlates of visuospatial choice reaction time in children. *NeuroImage, 58,* 1090-1100.
Notes: The corticospinal tracts and the basal ganglia continue to develop during childhood and adolescence, and indices of their maturation can be obtained using diffusion-weighted imaging. Here we show that a simple measure of visuomotor function is correlated with diffusion parameters in the corticospinal tracts and neostriatum. In a cohort of 75 typically-developing children aged 7 to 13years, mean 5-choice reaction times (RTs) were assessed. We hypothesised that children with faster choice RTs would show lower mean diffusivity (MD) in the corticospinal tracts and neostriatum and higher fractional anisotropy (FA) in the corticospinal tracts, after controlling for age, gender, and handedness. Mean MD and/or FA were extracted from the right and left corticospinal tracts, putamen, and caudate nuclei. As predicted, faster 5-choice RTs were associated with lower MD in the corticospinal tracts, putamen, and caudate. MD effects on RT were bilateral in the corticospinal tracts and putamen, whilst right caudate MD was more strongly related to performance than was left caudate MD. Our results suggest a link between motor performance variability in children and diffusivity in the motor system, which may be related to: individual differences in the phase of fibre tract and neostriatal maturation in children of similar age, individual differences in motor experience during childhood (i.e., use-dependent plasticity), and/or more stable individual differences in the architecture of the motor system
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Vestergaard, M., Madsen, K. S., Baare, W. F., Skimminge, A., Ejersbo, L. R., Ramsoy, T. Z. et al. (2011). White matter microstructure in superior longitudinal fasciculus associated with spatial working memory performance in children. *Journal of Cognitive Neuroscience, 23,* 2135-2146.
Notes: During childhood and adolescence, ongoing white matter maturation in the fronto-parietal cortices and connecting fiber tracts is measurable with diffusion-weighted imaging. Important questions remain, however, about the links between these changes and developing cognitive functions. Spatial working memory (SWM) performance improves significantly throughout the childhood years, and several lines of evidence implicate the left fronto-parietal cortices and connecting fiber tracts in SWM processing. Here we report results from a study of 76 typically developing children, 7 to 13 years of age. We hypothesized that better SWM performance would be associated with increased fractional anisotropy (FA) in a left fronto-parietal network composed of the superior longitudinal fasciculus (SLF), the regional white matter underlying the dorsolateral pFC, and the posterior parietal cortex. As hypothesized, we observed a significant association between higher FA in the left fronto-parietal network and better SWM skills, and the effect was independent of age. This association was mainly accounted for by variability in left SLF FA and remained significant when FA measures from global fiber tracts or right SLF were included in the model. Further, the effect of FA in left SLF appeared to be mediated primarily by decreasing perpendicular diffusivity. Such associations could be related to individual differences among children in the architecture of fronto-parietal connections and/or to differences in the pace of fiber tract development. Further studies are needed to determine the contributions of intrinsic and experiential factors to the

development of functionally significant individual differences in fiber tract structure
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Bava, S., Thayer, R., Jacobus, J., Ward, M., Jernigan, T. L., & Tapert, S. F. (2010). Longitudinal characterization of white matter maturation during adolescence. *Brain Research, 1327*, 38-46.
Notes: BACKGROUND: Late adolescence is comprised of considerable developmental transitions, though brain maturational changes during this period are subtle and difficult to quantitatively evaluate from standard brain imaging acquisitions. To date, primarily cross-sectional studies have characterized typical developmental changes during adolescence, but these processes need further description within a longitudinal framework. METHOD: To assess the developmental trajectory of typical white matter development, we examined 22 healthy adolescents with serial diffusion tensor images (DTI) collected at a mean age of 17.8 years and 16-months later. Diffusion parameters fractional anisotropy, and mean, radial, and axial diffusivity were subjected to whole-brain voxelwise time point comparisons using tract-based spatial statistics. RESULTS: At follow-up, adolescents showed a significant change (>or=153 contiguous voxels each at $p<0.01$) in diffusion properties, including in bilateral superior longitudinal fasciculi, superior corona radiata, anterior thalamic radiations, and posterior limb of the internal capsule. Overall, correlations with cognitive performances suggested behavioral improvement corresponding with white matter changes. CONCLUSION: These longitudinal DTI findings support continued microstructural change in white matter during late adolescence, and suggest ongoing refinement of projection and association fibers into early adulthood
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Stiles, J. & Jernigan, T. L. (2010). The basics of brain development. *Neuropsychology Review, 20,* 327-348.
Notes: Over the past several decades, significant advances have been made in our understanding of the basic stages and mechanisms of mammalian brain development. Studies elucidating the neurobiology of brain development span the levels of neural organization from the macroanatomic, to the cellular, to the molecular. Together this large body of work provides a picture of brain development as the product of a complex series of dynamic and adaptive processes operating within a highly constrained, genetically organized but constantly changing context. The view of brain development that has emerged from the developmental neurobiology literature presents both challenges and opportunities to psychologists seeking to understand the fundamental processes that underlie social and cognitive development, and the neural systems that mediate them. This chapter is intended to provide an overview of some very basic principles of brain development, drawn from contemporary developmental neurobiology, that may be of use to investigators from a wide range of disciplines
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