BRAIN CONNECTIVITY: NATURE VS NURTURE

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Introduction

The debate on whether brain connectivity develops by nature or nurture is highly significant to child development. Identifying the roles of nature and nurture will lead to innovative education, parenting, and societal approaches unconstrained by gender differences. The brain connectivity network is defined by a collection of nodes and links between pairs of nodes. It is composed of neural populations of synapses and individual brain cells that send and receive messages across the body. The major modes of brain connectivity are structural, functional, and effective connectivity. Current theories on development by nature shows correlation of brain connectivity with cerebral cortical folding patterns. On the other hand, recent studies showing minimal cognitive disparity in children suggest a development pattern by nurture. This poster explores different claims and experiments performed by other researchers on brain connectivity and discusses a feasible explanation by combining current theories on brain development.

Nature Case 1: Genetics and Developmental Psychology

Increasing numbers of twin and adoption studies suggest that the heritability of general cognitive ability occurs during development. The increase in magnitude of genetic influence in development implies that the same genes may have greater effects. This is supported by longitudinal genetic research on age-to-age change. The idea, called the *genotype-environment correlation*, suggests that small genetic differences snowball as subjects go through life creating environments that are correlated with genetic propensities. Psychological environments can be considered as extended phenotypes of individuals, "reflecting genetic differences among individuals as they select, modify, and construct their environments" (Plomin, 2004).

Nature Case 2: Cortical Folding Patterns

Luders et al. (2004) concluded that females have greater structural complexities than males based on cortical structural folding. Statistically significant differences in cortical complexity were observed in the inferior frontal, superior frontal, and parietal regions (Figure 1). Luders et al. (2004) speculated that this difference might also contribute to gender-specific abilities (e.g., the ability for women outperform men in some cognitive skills).

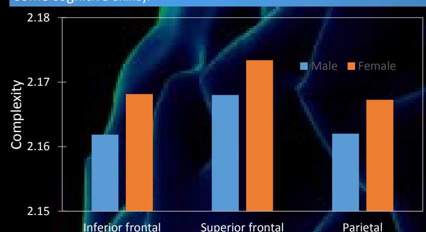

Figure 1: Brain Complexity
(right hemisphere only, data from Luders et al., 2004)

Nature Case 3: Sex Differences in the Structural Connectome

A *connectome* is a map of neural connections in the brain. Ingalhalikar et al. (2014) found conspicuous and significant sex differences that suggest fundamentally different connectivity patterns in males and females. Most connections in the cerebrum that were stronger in males were within hemispheres (*intrahemispheric*), while those that are stronger in females were between hemispheres (*interhemispheric*). The reverse pattern existed in the cerebellum (Figure 2).

This study showed a progression of sex differences from children to mid-adolescence. The connection differences in part explained the demonstrated female strengths in attention, memory, and social cognition, and the male strengths in special processing and motor and sensorimotor speed,.

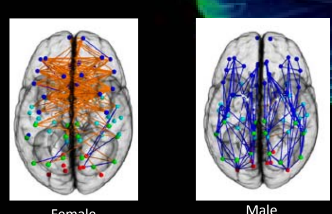

Figure 2: Connection Analysis
(blue = intrahemispheris, orange = interhemispheric)
Source: Ingalhalikar et al., 2014

Nurture Case 1: Effects of Reading on Connectivity

Some studies have demonstrated short-term changes in functional connectivity from cognitive and emotional interventions. Berns et al. (2013) used functional magnetic resonance imaging (fMRI) tool to identify patterns of correlated activity called *resting-state networks* or RSNs. They tracked changes in RSNs daily over 3 weeks, during which individuals read a complete novel.

One network in particular was activated by reading the previous night. This network was concentrated around the left angular and supramarginal gyri and had connections to the medial prefrontal cortex (including language function and perception). Correlations of brain activity in this network rose sharply after reading began and decayed quickly after their reading of the novel was completed.

Nurture Case 2 - Repetitive Motor Learning

Fu et al. (2012) studied apical dendrites of layer 5 pyramidal neurons in the motor cortex of mice using transcranial two-photon microscopy and found that 1/3 of new dendritic spines were formed in clusters during the learning phase. These clusters of neighboring spine pairs were much more persistent than their non-clustered counterparts during and after the learning sessions. This finding suggests that learning leads to repetitive activation of the brain connections and induces clustering of dendrites. In other words, active learning strengthens brain connectivity on dendritic level.

Nurture Case 3: Experience Stimulates the Brain

In his review, Chugani (1998) reported that researchers scanned and observed regions of baby brains with positron-emission tomography (PET) and measured the activity in stem and sensory cortex. Results showed that brain cells developed in the fetus begin to connect as synapses when the child was born. Connection was stimulated by experience and learning. When a critical period of learning ends, brain plasticity is diminished which decreases the child's ability to acquire cognitive abilities (e.g., visual system and language).

Conclusions

To summarize, we evaluated the published work on nature- and nurture-related influences on children's brain connectivity. The studies show moderately different asymmetric patterns in children's brain network efficiencies and suggest that these differences are closely related to their behavioral differences. Most regions in the brain that exhibited significant hemisphere-related differences are affected by both genetic and environmental factors. It appears that a model including both nature and nurture factors could be profitable for describing differences in brain functional connectivity in children. Further research studies should be conducted to examine whether differences in brain connectivity patterns are altered during normal development or by the environment.

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