



Review article

Development of brain networks and relevance of environmental and genetic factors: A systematic review



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ABSTRACT

This study conducted a systematic review to synthesize findings on the development of functional and structural brain networks from the prenatal to late adolescent period. In addition, evidence for environmental and genetic influences on the development of brain networks was reviewed. Ninety two studies fulfilled the inclusion criteria. Diffusion MRI findings indicated that clustering decreases, local and global efficiency increase and modularity stabilizes or decreases with age. Structural covariance findings indicated that local efficiency, global efficiency and modularity, may stabilize in adolescence. Findings for resting-state functional MRI were mixed. Few studies have investigated genetic or environmental influences on development of structural or functional networks. For functional networks, genetic effects have been reported with few significant environmental factors. While no studies of this nature were found for structural networks, other research has provided evidence of age-related changes in heritability of white matter volume, fractional anisotropy, and cortical thickness. Further research is required to understand the development of brain networks and the relevance of environmental and genetic factors.

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1. Introduction

Understanding how the human brain is connected is an overarching goal of neuroscience research, and one that is attracting significant attention. Although our knowledge of brain connectivity has expanded greatly due to technological advances in techniques such as Magnetic Resonance Imaging (MRI), there is much that we are yet to understand. The human brain can be represented as complex networks of structurally and functionally interconnected regions. Analyses of these whole brain networks can be classified into two broad domains: structural networks, which are based on macroscopic links between regions, and functional networks, which are based on correlated activity between regions (Power et al., 2010). Given the profound brain changes that occur from infancy to young adulthood, it is especially important to consider networks within a developmental context (Khundrakpam et al., 2013; Menary et al., 2013; Power et al., 2010; Rubia, 2013). Establishing network trajectories for typical development is likely to increase our understanding of maturational brain changes and may allow for a more accurate understanding of relationships between brain networks, cognition and behavior during development (Vértes and Bullmore, 2015). Furthermore, tracking networks across development may serve an important function in understanding the nature of disruptions and neurodevelopmental disorders (Dennis and Thompson, 2013).

A number of recent reviews have focused on the development of brain networks, reflecting the rapidly growing interest in this area. In particular, Vértes and Bullmore (2015) and Dennis and Thompson (2013) have provided recent overviews of brain network development, including structural and functional MRI and diffusion tensor imaging studies. Power et al. (2010) reviewed resting-state functional MRI (rs-fMRI) studies with the aim of characterizing the development of functional networks. Finally, Evans (2013) recently reviewed anatomical MRI studies and considered the influence of genetic and environmental factors on the development of structural networks. Although these reviews have provided excellent descriptions of the developmental formation of complex brain networks, a systematic review of the literature has not yet been conducted, limiting our ability to investigate similarities and differences in patterns across different aspects of structural and functional brain development. Further, a thorough investigation of the extent to which environmental and genetic factors influence the development of both structural and functional networks is likely to be essential in informing strong scientific and translational models of optimal brain development.

In this paper, a systematic process was applied to synthesize findings on the impact of environmental and genetic factors on the development of brain networks. The review focused on the developmental period between birth and late adolescence but also included results from in-utero and young adults where other literature was lacking. As the research question is broad, the findings are reviewed in two stages – 1. The development of structural and

functional brain networks and 2. Environmental and genetic factors that influence the development of brain networks. The first section aims to identify typical developmental trends in brain networks and is appropriately brief given that other comprehensive reviews exist. Where possible, graph theory, a mathematical modelling approach, is used as a common framework for comparing findings across different modalities. The second section aims to identify environmental and genetic factors that influence the development of brain networks. Finally, the significance of these findings is discussed, with the hope that this will generate further discussion amongst researchers regarding typical development of brain networks.

2. Methods

The systematic review was conducted in line with the PRISMA statement, a checklist for the reporting of systematic reviews and meta-analyses (Moher et al., 2010).

2.1. Eligibility criteria

Studies of brain network or connectivity development with or without genetic and/or environmental factors in human populations were explored for inclusion in this review. No publication date or publication status restrictions were imposed. Criteria for exclusion were: (a) paper not published in English; (b) dissertations, book reviews, conference proceedings, or editorials; (c) methods papers; and (d) atypical development.

2.2. Information sources

Online searches of Scopus (Elsevier, 1960–present) and Medline (Ovid, 1860–present) were initially performed in February 2015 and repeated in August 2015 using relevant search terms (e.g., [connectome] AND [child OR adolescent OR infant]). The search strategies for each database are summarized and presented in Fig. 1. Due to the broad nature of the review, the search was carried out in two parts, the first focused on the development of brain networks and the second on the influences of genetic and environmental factors on these networks. Abstracts were examined for references to the research question and if the study appeared relevant, then the full text was retrieved. Reference lists of identified articles were searched for additional studies.

2.3. Study selection

The study selection process is presented visually in Fig. 1 and can be summarized as follows. Initially, retrieved papers from each database were compared to remove duplicate records. Papers were then screened for eligibility based on their title and abstract, and where necessary the full text publication was reviewed. *Types of imaging modalities:* Studies were included if they investigated

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