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Review

Development of structure and function in the infant brain: Implications for cognition, language and social behaviour

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Abstract

Recent advances in cognitive neuroscience have allowed us to begin investigating the development of both structure and function in the infant brain. However, despite the rapid evolution of technology, surprisingly few studies have examined the intersection between brain and behaviour over the first years of life. Even fewer have done so in the context of a particular research question. This paper aims to provide an overview of four domains that have been studied using techniques amenable to elucidating the brain/behaviour interface: language, face processing, object permanence, and joint attention, with particular emphasis on studies focusing on early development. The importance of the unique role of development and the interplay between structure and function is stressed throughout. It is hoped that this review will serve as a catalyst for further thinking about the substantial gaps in our understanding of the relationship between brain and behaviour across development. Further, our aim is to provide ideas about candidate brain areas that are likely to be implicated in particular behaviours or cognitive domains.

Keywords: Development; Brain; Cognition; Language; Imaging; Infants

Contents

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1. Introduction

A rapidly expanding literature examines the role that different brain regions play in cognition and behaviour. Much of these data have come from animal models as well as lesion studies in animals and brain-injured patients. In addition, the body of research concerning the normal course of development for specific brain areas and their relation to skills in infancy is growing. The need for such research has been highlighted by the increasing emphasis on interdisciplinary approaches to cognitive neuroscience that encompasses the work of cognitive developmentalists, basic neuroscientists and imaging experts. However, the critical interdisciplinary studies examining brain and behaviour patterns prospectively and longitudinally across the first years of development have yet to be accomplished.

1.1. The importance of a multi-level approach

In order to fully understand brain and behaviour relations over the course of development, one must gather converging data from a variety of sources. The study of mature intact brains provides us with an idea of the endstate that the developing organism must reach. The morphological and physiological correlates of behaviour are much more easily defined and recorded in the adult than in the infant, so adult studies provide a rational starting point for the investigation of the developmental process. In addition, brain dysfunction provides a window onto which aspects of structure and function are necessary for the performance of particular tasks in adulthood. It is extremely important however, not to underestimate the role of development in this endeavour. One must consider the complex and still poorly understood processes that interact across early development to result in a normative brain, as well as how particular biological or genetic factors influence the brain's developmental trajectory. Animal models allow us to perturb the system as it develops and to study what effect this has on brain structure, brain function and behaviour. This is particularly valuable when lesions and malformations are present very early in development because, of course, the very best way to gather data on development is to study a developing organism. It is also critical to study both typically and atypically developing infants and children because changes in the developmental trajectory and the impairments to which they lead may highlight those aspects of structure and function which are decisive in achieving an optimal outcome.

1.2. Emerging methods for the study of developmental trajectories

In recent years, the refinement of existing methods and the development of state-of-the art brain-imaging methods has enabled scientists to ask well-focused questions about how the changing structure and connectivity of the brain influences emerging cognitive skills. One can now examine infant behaviour and measure brain structure and function either concurrently or very closely in time. Thus, changes in behaviour and brain function can be traced in relation to changes in brain structure. Several noninvasive brain-imaging techniques are currently available for use with younger children and infants. These include dense array electroencephalography/event-related potentials (EEG/ERPs) and near infra-red spectroscopy (NIRS), both of which have excellent temporal resolution for assessing function (e.g., Benasich et al., 2006; Baird et al., 2002), as well as magnetic resonance imaging (MRI), which provides good spatial localisation for investigating changes in brain structure (e.g., Als et al., 2004). In addition, an emerging technique, arterial spin labelling (ASL), uses MRI methodology to measure cerebral blood flow while the brain is at rest, without the need for contrast agents (Detre and Aslop, 1999; Alsop et al., 2000). There are also a few studies that have successfully used functional MRI (fMRI) to examine brain activation in young children and babies when they are performing a cognitive task or passively listening to sounds (e.g. Durston et al., 2002;