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Tangled webs: Tracing the connections between genes and cognition

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Abstract

The rise of molecular genetics is having a pervasive influence in a wide variety of fields, including research into neurodevelopmental disorders like dyslexia, speech and language impairments, and autism. There are many studies underway which are attempting to determine the roles of genetic factors in the aetiology of these disorders. Beyond the obvious implications for diagnosis, treatment and understanding, success in these efforts promises to shed light on the links between genes and aspects of cognition and behaviour. However, the deceptive simplicity of finding correlations between genetic and phenotypic variation has led to a common misconception that there exist straightforward linear relationships between specific genes and particular behavioural and/or cognitive outputs. The problem is exacerbated by the adoption of an abstract view of the nature of the gene, without consideration of molecular, developmental or ontogenetic frameworks. To illustrate the limitations of this perspective, I select two cases from recent research into the genetic underpinnings of neurodevelopmental disorders. First, I discuss the proposal that dyslexia can be dissected into distinct components specified by different genes. Second, I review the story of the *FOXP2* gene and its role in human speech and language. In both cases, adoption of an abstract concept of the gene can lead to erroneous conclusions, which are incompatible with current knowledge of molecular and developmental systems. Genes do not specify behaviours or cognitive processes; they make regulatory factors, signalling molecules, receptors, enzymes, and so on, that interact in highly complex networks, modulated by environmental influences, in order to build and maintain the brain. I propose that it is necessary for us to fully embrace the complexity of biological systems, if we are ever to untangle the webs that link genes to cognition.

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1. Introduction

In recent years we have witnessed some extraordinary advances in the field of molecular genetics (Collins, Green, Guttmacher, & Guyer, 2003). Since this research area has the potential to impact on a diverse range of other disciplines within the natural sciences, such advances are having a pervasive influence on multiple fields of biology. Human cognition is no exception; the past decade has seen a dramatic increase in the number and scale of research programmes exploiting molecular approaches for studying the human brain. There are now many laboratories worldwide investigating the role of genetic factors in developmental learning disorders (Fisher & DeFries, 2002; Fisher, Lai, & Monaco, 2003; Folstein & Rosen-Sheidley, 2001; Grigorenko, 2001) using the same molecular techniques that are being applied to common human traits such as heart disease, hypertension, diabetes, asthma, arthritis and so on (Botstein & Risch, 2003). Biologists are now in possession of an exciting and powerful new toolkit for tackling their favourite research questions. However, as is often the case, there is a catch. Although the emerging molecular methods are deceptively easy to wield, the answers they present are far from straightforward. Making sense of them requires a novel mindset, one which is rooted in complexity and unfamiliar to many. In the present article I begin by outlining the basic concepts that underlie molecular genetic analyses of developmental disorders. I then go on to argue that the common misconception of the gene as an abstract entity, able to elusively control aspects of cognition, may impede attempts to connect genes with cognition. Finally, I illustrate the key issues by considering a selection of pertinent examples from recent studies of developmental dyslexia and speech and language disorders. This is not intended as a general review of the field; I specifically focus on cases that best demonstrate the pitfalls of adopting an abstract view of the gene, and that highlight the importance of integrating data from multiple levels of analyses. I propose that we need to fully embrace the inherent molecular complexity of developmental systems, if we want to further our understanding of genetic influences on human cognition.

2. Back to basics

As I illustrate elsewhere in this article, it is quite possible to carry out genetic analyses with only an abstract perception of the nature of a gene. The relevant methods are easily transposable to virtually any trait of interest (assuming that such a trait has at least some heritable basis). However, a proper appreciation of the significance of genetic findings must depend on a solid foundation in basic molecular concepts, and it is worth briefly revisiting these before proceeding further. Given the blaze of