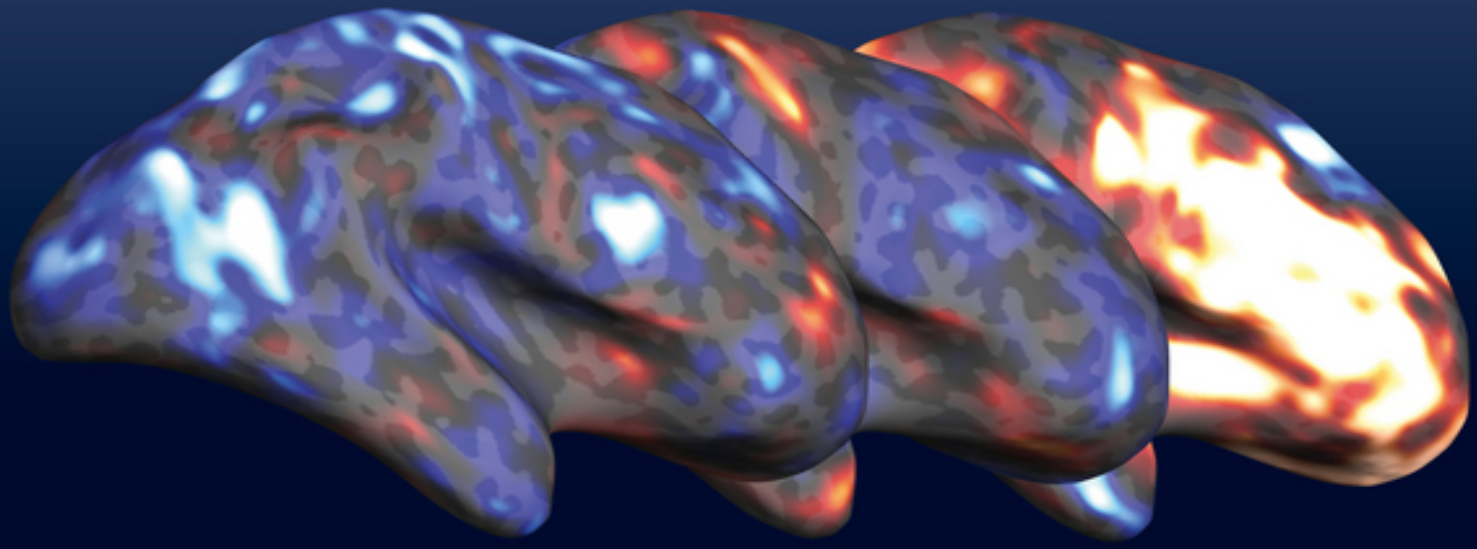

DEVELOPMENTAL COGNITIVE NEUROSCIENCE

Fourth Edition

Mark H. Johnson and
Michelle de Haan

with website

WILEY Blackwell

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Preface to the First Edition

In the first chapter of this book I describe some of the factors responsible for the recent emergence of a subdiscipline at the interface between developmental psychology and cognitive neuroscience. I have chosen to refer to this new field as “developmental cognitive neuroscience,” though it has been known under a number of other terms such as “developmental neurocognition” (de Boysson-Bardies, de Schonen, Jusczyck, McNeilage, & Morton, 1993). Though a series of edited volumes on the topic has recently appeared, like most newly emerging disciplines there is a time lag before the first books suitable for teaching appear. This book and the Reader which I edited in 1993 (Johnson, 1993) are initial attempts to fill the gap. While some may believe these efforts to be premature, my own view is that the lifeblood of any new discipline is in the students and postdocs recruited to the cause. And the sooner they are recruited, the better.

Is developmental cognitive neuroscience really significantly different from other fields that have a more extended history, such as developmental neuropsychology or cognitive development? Clearly, it would be unwise to rigidly demarcate developmental cognitive neuroscience from related, and mutually informative, fields. However, it is my belief that the emerging field has a number of characteristics that makes it distinctive. First, while there is some disagreement about exact definitions, the fields of developmental neuropsychology and developmental psychopathology focus on atypical development, while commonly comparing them to normal developmental trajectories. In contrast, cognitive neuroscience (including the developmental variant outlined in this book) focuses on

normal cognitive functioning, but uses information from deviant functioning and development as “nature’s experiments” which can shed light on the neural basis of normal cognition. This book is therefore not intended as an introduction to the neuropsychology of developmental disorders. For such information the reader is referred to the excellent introductions by Cicchetti and Cohen (1995) and Spreen, Risser, and Edgell (1995).

Second, unlike many in cognitive development, this book adopts the premise that information from brain development is more than just a useful additional source of evidence for supporting particular cognitive theories. Rather, information about brain development is viewed as both changing and originating theories at the cognitive level. Third, developmental cognitive neuroscience restricts itself to issues at the neural, cognitive, and immediate environmental levels. In my view it is a hazard of some interdisciplinary fields that the focus of interest is diffused across many different levels of explanation. This is not to deny the importance of these other levels, but a mechanistic interdisciplinary science needs to restrict both the domains (in this case aspects of cognitive processing) and levels of explanation with which it is concerned. Finally, developmental cognitive neuroscience is specifically concerned with understanding the relation between neural and cognitive phenomena. For this reason, I have not discussed evidence from the related field of developmental behavior genetics. In general, developmental behavior genetics tends to be concerned with correlations between the molecular level (genetics) and gross behavioral measures such as IQ. With some notable exceptions, little effort is made to specifically relate these two levels of explanation via the intermediate neural and cognitive levels. Having pointed out the different focus of developmental cognitive neuroscience, my hope is that

this book is written to be both accessible and informative to those in related and overlapping disciplines.

The above comments go some way to explaining the choice of material that I have presented in the book. However, I have no doubt that there is a substantive amount of excellent experimentation and theorizing that could have been included but was not. Since this is intended as a brief introduction to the field, I have chosen to focus on a few particular issues in some detail. Of course, the choice of material also reflects my own biases and knowledge since the book is intended as an introductory survey of the field as viewed from my own perspective. I apologize in advance for the inevitable omissions and errors.

The book is aimed at the advanced-level student and assumes some introductory knowledge of both neuroscience and cognitive development. Students without this background will probably need to refer to more introductory textbooks in the appropriate areas. I also hope that the book will attract developmentalists with an interest in learning more about the brain, and cognitive neuroscientists curious as to how developmental data can help constrain their theories about adult functioning. But most of all I hope that the book inspires readers to find out more about the field, and to consider a developmental cognitive neuroscience approach to their own topic.

Preface to the Fourth Edition

In the nearly two decades since publication of the first edition of this book, the field of developmental cognitive neuroscience (DCN) has continued to expand very rapidly, and the volume of papers published in specialized and generalist journals make the job of reviewing and summarizing this information increasingly formidable. In addition, the range of evidence encompassed within the field now extends to the underlying genetics and epigenetics. Thus, and as in previous editions, the selection of material inevitably involves our biases, but with a focus on topics in which a specifically DCN approach has been taken. This inevitably means that there are topics in the parent disciplines of cognitive development or developmental neuroscience that are not addressed in this book.

As the field matures, researchers and funders are increasingly interested in applying the knowledge we have gained to practical real-world problems, such as developing the best brain-based strategies for formal school education. Thus, in this fourth edition we have emphasized new research that underpins application to important clinical, educational, and societal issues. In particular, we have added a new chapter on the emerging topic of educational neuroscience (Chapter 12).

In line with the previous edition, we include “key discussion points” at the end of each chapter, which can be used in association with the teachers’ website associated with the book (www.wiley.com/go/johnson/dcn) that has essay, short answer, and multiple choice test questions as well as downloadable figures. Also, as in previous editions, we provide many pointers to further reading, allowing the

book to be used as a springboard for more detailed exploration of the field.

We continue to be indebted to many colleagues and collaborators for educating and informing us on a variety of topics. We also thank our publisher for their continued commitment to the book and Luba Prout for her invaluable contribution to the production of this edition.

Acknowledgements

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Abbreviations

2D
two-dimensional

ADHD
attention deficit/hyperactivity disorder

ANS
approximate number system

ASL
American Sign Language

BOLD
blood oxygen level dependent

CA1
cornu ammonis 1 area of the hippocampus

CA3
cornu ammonis 3 area of the hippocampus

CANTAB
Cambridge Neuropsychological Testing Automated Battery

COMT
catechol-O-methyltransferase gene

CT
computed tomography

DAT1
dopamine active transporter 1 gene

DLPC
dorsolateral prefrontal cortex

DNA
deoxyribonucleic acid

DSP4

N-(2-chloroethyl)-N-ethyl-2-bromobenzylamine neurotoxin

DTI
diffusion tensor imaging

EEG
electroencephalography, electroencephalogram

ERO
event-related oscillations

ERP
event-related potential

FEF
frontal eye fields

FFA
fusiform face area

FG
fusiform gyrus

FMR1
gene Fragile X mental retardation 1 gene

fMRI
functional magnetic resonance imaging

FOXP2
gene forkhead box protein P2 gene

GABA
gamma-aminobutyric acid

GBG
Geschwind, Behan, and Galaburda model of hemispheric differences

HD
high density

HD-ERP
high-density event-related potential

HM

initials of a patient with amnesia

IMM/IMVH
intermediate and medial part of the mesopallium

IPS
intra parietal suclus

IQ
intelligence quotient

IS
interactive specialization

ISI
interstimulus interval

KBCC
knowledge-based cascade correlation

LGN
lateral geniculate nucleus

LTC
lateral temporal complex

MGN
medial geniculate nucleus

MNS
mirror neuron system

MPFC
medial prefrontal cortex

MRI
magnetic resonance imaging

MT
middle temporal visual cortical area

MTL
medial temporal lobes

NIRS
near infrared spectroscopy

PET
positron emission tomography

PFC
prefrontal cortex

PKU
phenylketonuria

RNA
ribonucleic acid

SES
socioeconomic status

SIPN
Social Information Processing Network

SLI
specific language impairment

SOA
stimulus onset asynchrony

SP
spike potential

STS
superior temporal sulcus

TPH2
tryptophan hydroxylase gene 2

TV
television

V1
primary visual cortex

VWFA
visual word form area

WS
Williams syndrome

About the Companion Website

This book is accompanied by a companion website:

www.wiley.com/go/johnson/developmentalcognitiveneuroscience

The website includes:

- Multiple choice questions and an answer guide

The material is available freely but you will need an instructor password to access the answers to the multiple choice questions.

1
The Biology of Change

In this introductory chapter we discuss a number of background issues for developmental cognitive neuroscience, beginning with historical approaches to the nature–nurture debate. Constructivism, in which biological forms are an emergent produc3t of complex dynamic interactions between genes and environment, is presented as an approach to development that is superior to accounts that seek to identify preexisting information in genes or the external environment. However, if we are to abandon existing ways of analyzing development into “innate” and “acquired” components, this raises the question of how we should best understand developmental processes. One scheme is proposed for taking account of the various levels of interaction between genes and environment. In addition, we introduce the difference between innate representations and architectural constraints on the emergence of representations within neural networks. Following this, a number of factors are discussed that demonstrate the importance of the cognitive neuroscience approach to development, including the increasing availability of brain imaging and molecular approaches. Conversely, the importance of taking a developmental approach to analyzing the relation between brain structure and cognition is reviewed. In examining the ways in which development and cognitive neuroscience can be combined, three different perspectives on human functional brain development are discussed: a maturational view, a skill learning view, and an “interactive specialization” framework. Finally, the contents of the rest of the book are outlined.

1.1 Viewpoints on Development

As every parent knows, the changes we can observe during the growth of children from birth to adolescence are truly amazing. Perhaps the most remarkable aspects of this growth involve the brain and mind. Accompanying the fourfold increase in the volume of the brain during this time are numerous, and sometimes surprising, changes in behavior, thought, and emotion. An understanding of how the developments in brain and mind relate to each other could potentially revolutionize our thinking about education, social policy, and disorders of mental development. It is no surprise, therefore, that there has been increasing interest in this new branch of science from grant-funding agencies, medical charities, and even presidential summits. Since the publication of the first edition of this book in 1997, this field has become known as *developmental cognitive neuroscience*.

Developmental cognitive neuroscience has emerged at the interface between two of the most fundamental questions that challenge humankind. The first of these questions concerns the relation between mind and body, and specifically between the physical substance of the brain and the mental processes it supports. This issue is fundamental to the scientific discipline of *cognitive neuroscience*. The second question concerns the origin of organized biological structures, such as the highly complex structure of the adult human brain. This issue is fundamental to the study of *development*. In this book we will show that light can be shed on these two fundamental questions by tackling them both simultaneously, specifically by focusing on the relation between the postnatal development of the human brain and the emerging cognitive processes it supports.

The second of the two questions above, that of the origins of organized biological structure, can be posed in terms of *phylogeny* or *ontogeny*. The phylogenetic (evolutionary) version of this question concerns the origin of species and has been addressed by Charles Darwin and many others since. The ontogenetic version of this question concerns individual development within a life span. The ontogenetic question has been somewhat neglected relative to phylogeny, since some influential scientists have held the view that once a particular set of genes has been selected by evolution, ontogeny is simply a process of executing the "instructions" coded for by those genes. By this view, the ontogenetic question essentially reduces to phylogeny (e.g., so-called evolutionary psychology). In contrast to this view, in this book we argue that ontogenetic development is an active process through which biological structure is constructed afresh in each individual by means of complex and variable interactions between genes and their respective environments. The information is not in the genes, but emerges from the constructive interaction between genes and their environment (see also Oyama, 2000). However, since both ontogeny and phylogeny concern the emergence of biological structure, some of the same mechanisms of change have been invoked in the two cases.

Further Reading

Oyama (2000).

The debate about the extent to which the ontogenetic question (individual development) is subsidiary to the phylogenetic question (evolution) is otherwise known as the nature–nurture issue, and it has been central in developmental psychology, philosophy, and neuroscience.

Broadly speaking, at one extreme the belief is that most of the information necessary to build a human brain, and the mind it supports, is latent within the genes of the individual. While most of this information is common to the species, each individual has some specific information that will make them differ from others. By this view, development is a process of unfolding or triggering the expression of information already contained within the genes.

At the opposing extreme, others believe that most of the information that shapes the human mind comes from the structure of the external world. Some facets of the environment, such as gravity, patterned light, and so on, will be common throughout the species, while other aspects of the environment will be specific to that individual. It will become clear in this book that both of these extreme views are ill conceived, since they assume that the information for the structure of an organism exists (either in the genes or in the external world) prior to its construction. In contrast to this, it appears that biological structure emerges anew within each individual's development from constrained dynamic interactions between genes and various levels of environment, and it is not easily reducible to simple genetic and experiential components (Scarr, 1992).

It is more commonly accepted these days that the mental abilities of adults are the result of complex interactions between genes and environment. However, the nature of this interaction remains controversial and poorly understood, although, as we shall see, light may be shed on it by simultaneously considering brain and psychological development. Before going further, however, it is useful to review briefly some historical perspectives on the nature–nurture debate. This journey into history may help us avoid

slipping back into ways of thinking that are deeply embedded in the Western intellectual tradition.

Throughout the 17th century there was an ongoing debate in biology between the “vitalists” on the one hand and the “preformationists” on the other. The vitalists believed that ontogenetic change was driven by “vital” life forces. Belief in this somewhat mystical and ill-defined force was widespread and actively encouraged by some members of the clergy. Following the invention of the microscope, however, some of those who viewed themselves as being of a more rigorous scientific mind championed the preformationist viewpoint. This view argued that a complete human being was contained in either the male sperm (“spermists”) or the female egg (“ovists”). In order to support their claim, spermists produced drawings of a tiny, but perfect, human form enclosed within the head of sperm (see Figure 1.1). They argued that there was a simple and direct mapping between the seed of the organism and its end state: simultaneous growth of all the body parts. Indeed, preformationists of a religious conviction argued that God, on the sixth day of His work, placed about 200,000 million fully formed human miniatures into the ovaries of Eve or sperm of Adam (Gottlieb, 1992)!