## The Neuroscience of Intelligence

This new edition provides an accessible guide to advances in neuroscience research and what they reveal about intelligence. Compelling evidence shows that genetics plays a major role as intelligence develops from childhood, and that intelligence test scores correspond strongly to specific features of the brain assessed with neuroimaging. In detailed yet understandable language, Richard J. Haier explains cutting-edge techniques based on DNA and the imaging of brain connectivity and function. He dispels common misconceptions, such as the belief that IQ tests are biased or meaningless. Readers will learn about the real possibility of dramatically enhancing intelligence and the positive implications this could have for education and social policy. The text also explores potential controversies surrounding neuro-poverty, neuro-socioeconomic status, and the morality of enhancing intelligence for everyone.

**Richard J. Haier** is Professor Emeritus at the University of California, Irvine, USA. He received a PhD from Johns Hopkins University. He pioneered the use of neuroimaging to study intelligence in 1988 and has given invited lectures at meetings sponsored by the National Science Foundation, the National Academy of Sciences, the Defense Advanced Research Projects Agency, the European Molecular Biology Organization, and Cold Spring Harbor Laboratory. In 2013, he created video lectures, *The Intelligent Brain,* for The Great Courses. In 2016, he served as President of the International Society for Intelligence Research and became Editor-in-Chief of *Intelligence*. In 2020, he received the Life Time Achievement Award from the International Society of Intelligence Research. He is the co-editor of *The Cambridge Handbook of Intelligence and Cognitive Neuroscience* (2021) and the co-author of *The Science of Human Intelligence* (due 2023). Dr. Haier has discussed intelligence research on many podcasts including with Jordan Peterson, Scott Barry Kaufman, and Lex Fridman.

**Cambridge Fundamentals of Neuroscience in Psychology**

Developed in response to a growing need to make neuroscience accessible to students and other non-specialist readers, the *Cambridge Fundamentals of Neuroscience in Psychology* series provides brief introductions to key areas of neuroscience research across major domains of psychology. Written by experts in cognitive, social, affective, developmental, clinical, and applied neuroscience, these books will serve as ideal primers for students and other readers seeking an entry point to the challenging world of neuroscience.

**Books in the Series**

*The Neuroscience of Expertise* by Merim Bilalić
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*The Neuroscience of Addiction* by Francesca Mapua Filbey
*The Neuroscience of Sleep and Dreams,* 2e, by Patrick McNamara
*The Neuroscience of Intelligence,* 2e, by Richard J. Haier

# The Neuroscience of Intelligence

## SECOND EDITION

**Richard J. Haier**

*University of California, Irvine*

CAMBRIDGE
UNIVERSITY PRESS

To my family, who changed the orbit of my life, and

To the memory of my father who died too young, and

To the memory of my mother who carried on, and

To the memory of my grandparents who sacrificed for a future they could scarcely imagine.

"Forty years of Haier's research and thinking about the neuroscience of intelligence have been condensed into this captivating book. He consistently gets it right, even with tricky issues like genetics. It is an intelligent and honest book."

**Robert Plomin,** *Institute of Psychiatry, Professor of Psychology and Neuroscience, King's College London.*

"An original, thought-provoking review of modern research on human intelligence from one of its pioneers."

**Aron K. Barbey,** *Director, Decision Neuroscience Laboratory, Professor in Psychology, Neuroscience, and Bioengineering, Beckman Institute for Advanced Science and Technology, University of Illinois at Urbana-Champaign*

"Deftly presenting the latest insights from genetics and neuroimaging, Haier provides a brilliant exposition of the recent scientific insights into the biology of intelligence. Highly timely, clearly written, certainly a must-read for anyone interested in the neuroscience of intelligence!"

**Danielle Posthuma,** *Professor of Complex Trait Genetics, VU University Amsterdam, The Netherlands*

"The trek through the maze of recent work using the modern tools of neuroscience and molecular genetics will whet the appetite of aspiring young researchers. The author's enthusiasm for the discoveries that lie ahead is infectious. Kudos!"

**Thomas J. Bouchard, Jr.,** *Emeritus Professor of Psychology, University of Minnesota*

"Richard Haier invites us to a compelling journey across a century of highs and lows of intelligence research, settling old debates and fueling interesting questions for new generations to solve. From cognitive enhancement to models predicting IQ based on brain scans, the quest to define the neurobiological basis of human intelligence has never been more exciting."

**Emiliano Santarnecchi,** *Associate Professor, Berenson-Allen Center for Noninvasive Brain Stimulation, Harvard Medical School*

"Loud voices have dismissed and derided the measurement of human intelligence differences, their partial origins in genetics, and their associations with brain structure and function. If they respect data, Haier's book will quieten them. It's interesting to think how slim a book with the title 'The Neuroscience of Intelligence' would have been not long ago, and how big it will be soon; Haier's lively book is a fingerpost showing the directions in which this important area is heading."

**Ian J. Deary,** *Professor Emeritus of Differential Psychology, University of Edinburgh*

"The biology of few psychological differences is as well understood as that of intelligence. Richard Haier pioneered the field of intelligence neuroscience and he is still at its forefront. This book summarizes the impressive state the field has reached, and foreshadows what it might become."

**Lars Penke,** *Professor of Biological Personality Psychology, Georg August University Göttingen*

"It increasingly appears that we are within years, not decades, of understanding intelligence at a molecular level – a scientific advance that will change the world. Richard Haier's *The Neuroscience of Intelligence* gives us an overview of the state of knowledge that covers not only his own field, the brain, but also recent developments in genetics, and he does so engagingly and accessibly for the non-specialist. I highly recommend it."

**Charles Murray,** *WH Brady Scholar Emeritus, American Enterprise Institute*

"This book was overdue: a highly readable and inspiring account of cutting-edge research in neuroscience of human intelligence. Penned by Richard Haier, the eminent founder of this research field, the book is an excellent introduction for beginners and a valuable source of information for experts."

**Dr. Aljoscha Neubauer,** *University of Graz, Austria, & past president of the International Society for the Study of Individual Differences*

"This book is 'A Personal Voyage through the Neuroscience of Intelligence'. Reading this wonderful volume 'forces thinking,' which can be said only about a very small fraction of books. Here the reader will find reasoned confidence on the exciting advances, waiting next door,

regarding the neuroscience of intelligence and based on the author's
three basic laws: 1) no story about the brain is simple, 2) no one study is
definitive, and 3) it takes many studies and many years to sort things out."

**Roberto Colom,** *Professor of Differential Psychology,*
*Universidad Autonoma de Madrid*

"Richard Haier's *The Neuroscience of Intelligence* is an excellent sum-
mary of the major progress made in the fields of psychology, genetics
and cognitive neuroscience, expanding upon the groundbreaking work
of "The Bell Curve." He addresses the many misconceptions and myths
that surround this important human capacity with a clear summary of the
vast body of research now extending into the human brain and genome."

**Rex E. Jung,** *Assistant Research Professor of Psychology,*
*University of New Mexico*

# Contents

*The color plate section can be found between pp. 76 and 77.*

## Preface to the First Edition

Why are some people smarter than others? This book is about what neuroscience tells us about intelligence and the brain. Everyone has a notion about defining intelligence and an opinion about how differences among individuals may contribute to academic success and life achievement. Conflicting and controversial ideas are common about how intelligence develops. You may be surprised to learn that the scientific findings about all these topics are more definitive than you think. The weight of evidence from neuroscience research is rapidly correcting outdated and erroneous beliefs.

I wrote this book for students of psychology and neuroscience, educators, public policy makers, and for anyone else interested in why intelligence matters. On one hand this account is an introduction to the field that presupposes no special background; on the other hand it is more in depth than popularized accounts in the mass/social media. My emphasis is on explaining the science of intelligence in understandable language. The viewpoint that suffuses every chapter is that intelligence is 100 percent a biological phenomenon, genetic or not; influenced by environment or not; and that the relevant biology takes place in the brain. That is why there is a neuroscience of intelligence to write about.

This book is not neutral but I believe it is fair. My writing is based on over 40 years of experience doing research on intelligence using mental ability testing and neuroimaging technology. My judgments about the research to include are based on the existing weight of evidence. If the weight of evidence changes for any of the topics covered, I will change my mind and so should you. No doubt, the way I judge the weight of evidence will not please everyone but that is exactly why a book like this elicits conversation, potentially opens minds, and with luck, fosters a new insight or two.

Be advised, if you already believe that intelligence is due all or mostly to the environment, new neuroscience facts might be difficult to accept. Denial is a common response when new information conflicts with prior beliefs. The older you are, the more impervious your beliefs may be. Santiago Ramon Cajal (1852–1934), the father of neuroscience, once wrote: "Nothing inspires more reverence and awe in me than an old man who knows how to change his mind" (Cajal, 1924). Students have no excuse.

The challenge of neuroscience is to identify the brain processes necessary for intelligence and discover how they develop. Why is this important? The ultimate purpose of all intelligence research is to enhance intelligence. Finding ways to maximize a person's use of their intelligence is one goal of education. It is not yet clear from the weight of evidence how neuroscience can help teachers or parents do this. Finding ways to increase intelligence by manipulating brain mechanisms is quite another matter and one where neuroscience has considerable potential. Surely, most people would agree that increasing intelligence is a positive goal for helping people in the lower than normal range who often cannot learn basic self-care routines or employment skills. What then is the argument against enhancing intelligence so students can learn more, or adults can enjoy increased probability of greater achievement? If you have a negative reaction to this bold statement of purpose, my hope is that by the end of this book you reconsider.

Three laws govern this book: (1) No story about the brain is simple; (2) no one study is definitive; (3) it takes many years to sort out conflicting and inconsistent findings and establish a compelling weight of evidence. With these in mind, Chapter 1 aims to correct popular misinformation and summarizes how intelligence is defined and measured for scientific research. Some of the validity data will surprise you. For example, childhood IQ scores predict adult mortality. Chapter 2 reviews the overwhelming evidence that there are major genetic effects on intelligence and its development. Conclusive studies from quantitative and molecular genetics leave no doubt about this. Since genes always work through biological mechanisms, there must be a neurobiological basis for intelligence, even when there are environmental influences on those mechanisms. Genes do not work in a vacuum; they are expressed and function in an environment. This interaction is a theme of "epigenetics" and we will discuss its role in intelligence research.

Chapters 3 and 4 delve into neuroimaging and how these revolutionary technologies visualize intelligence in the brain, and indicate the neurobiological mechanisms involved. New twin studies of intelligence, for example, combine neuroimaging and DNA analyses. Key results show common genes for brain structure and intelligence. Chapter 5 focuses on enhancement. It begins with critiques of three widely publicized but incorrect claims about increasing IQ and ends with electrical brain stimulation. So far, there is no proven way to enhance intelligence but I explain why there is a strong possibility that manipulation of some genes and their biological processes may achieve dramatic increases. Imagine a moonshot-like national research effort to reach this goal; guess which nation apparently is making this commitment (it is not the United States).

Chapter 6 introduces several astonishing neuroscience methods for studying synapses, neurons, circuits, and networks that move intelligence research even deeper into the brain. Soon we might measure intelligence based on brain speed, and build intelligent machines based on how the brain actually works. Large collaborative efforts around the world are hunting intelligence genes, creating virtual brains, and mapping brain fingerprints unique to individuals – fingerprints that predict intelligence. Overlapping neuro-circuits for intelligence, consciousness, and creativity are explored. Finally, I introduce the terms "neuro-poverty" and "neuro-SES" (social economic status) and explain why neuroscience advances in intelligence research may inform education policies.

Personally, I believe we are entering a Golden Age of intelligence research that goes far beyond nearly extinct controversies about whether intelligence can be defined or measured and whether genes are involved. My enthusiasm about this field is intended to permeate every chapter. If you are an educator, policy maker, parent, or student you need to know what twenty-first-century neuroscience says about intelligence. If any of you are drawn to a career in psychology or neuroscience and pursue the challenges of intelligence research, then that is quite a bonus.

## Preface to the Second Edition

A lot has happened since I submitted the final manuscript for the first edition of this book in 2015, but not much has changed. As I discovered writing this second edition in 2022, the weight of evidence for the key topics is even stronger now. This is due in no small way to a new generation of researchers who have access to more advanced technology and data analysis methods, and access to incredibly large databases that include DNA, neuroimaging, and cognitive testing. Intelligence research is subject to the same inevitable progress as all other areas of science driven mostly by observations and insights from methodological and technical advances. I am happy to report that the last seven years have sharpened our neuroscience understandings and the formulations of questions still to be answered.

This edition includes new sections on predicting intelligence measures from DNA using polygenic scores. The fact that such prediction is possible further debunks stubborn views that intelligence has little to do with genes and that intelligence cannot be assessed for scientific study. But, more importantly, these findings invigorate efforts to understand how gene expression influences intelligence. They open the door for molecular biology research that could identify salient mechanisms that underlie the cognitive processes necessary for intelligence. It is this kind of research that I believe could someday result in ways to dramatically enhance intelligence for individuals. I still believe that is the ultimate and noble goal of intelligence research.

There are also new sections on neuroimaging and connectivity analyses to identify specific brain networks and circuits relevant to intelligence and to individual differences. This kind of research similarly has potential to identify ways to manipulate network information flow within and across brain areas to enhance intelligence. Related to these advances, many cognitive neuroscientists previously focused on learning and memory have broadened their interests to specifically study intelligence and individual differences. It's not just about psychometrics anymore, but meaningful collaborations still require psychometric sophistication.

The chapters in this edition have been updated with new research findings and references. There were many to choose from and I could not include them all. Mostly, their findings are consistent with those discussed in the first edition. This may be the result of my unconscious

cherry-picking or it may reflect the robustness of the underlying phe-
nomena. Time will tell and I will be the first to change my mind if the
weight of evidence changes. But, as always in science, new data typically
make the explanatory picture more complex, not less. We see this in the
stunning images from the James Webb telescope and their impact on
cosmology theories. There is poetry and a bit of magic in these images.
As neuroscience approaches go deeper and deeper into smaller and
smaller brain structures and faster and faster functions, the complexity
is both beautifully grand and nightmarishly challenging. That dynamic
is the excitement of intelligence research that I hope to convey on every
page. The poetry and magic are up to you.

## Acknowledgments (First Edition)

Because my academic appointments have been in medical schools, I have never had psychology graduate students working with me on research so I have none to thank. I have had fabulous collaborators over the years and they have made all the difference. Most of my neuro-imaging studies of intelligence are co-authored by friends Rex Jung, Roberto Colom, Kevin Head, Sherif Karama, and Michael Alkire. Many others, too numerous to name, contributed time, effort, and ideas over the last 40 years. I am indebted to all of them. I am especially grateful to Matthew Bennett at Cambridge University Press for inviting me to contribute to their Neuroscience series. It is the first time intelligence has been included. Drafts of this book were read all or in part by Rosalind Arden, Roberto Colom, Doug Detterman, George Goodfellow, Earl Hunt, Rex Jung, Sherif Karama, Marty Nemko, Aljoscha Neubauer, Yulia Kovas, and Lars Penke. Their corrections and insights were invaluable; any remaining errors are mine. Although I have included a substantial number of citations to relevant work, I could not possibly include everything I would have liked to. In fact, the field is moving so quickly, I added newly published papers right up to the last days before my deadline. I apologize to anyone who feels his or her work was left out. Some topics, explanations, and illustrations in this book were included in a set of my video lectures, *The Intelligence Brain* (copyright 2013 The Teaching Company. LLC. www.thegreatcourses.com). Most of all, my wife protected my work time against all intrusions, and that is why this book exists.

## Acknowledgments (Second Edition)

Many people reviewed parts of this edition and I thank them all. Of course, any errors are mine alone. I also thank David Repetto and Rowan Groat at Cambridge University Press for bringing this edition to fruition. And, I thank all the readers of the first edition who commented publicly or privately both on the exposition and the content. They made me eager to write this second edition. It turned out to be a harder job than I had imagined because there are so many new interesting papers to consider. I am grateful to have had the time and resources to focus on writing, especially with the unconditional support of my wife, who makes everything possible.