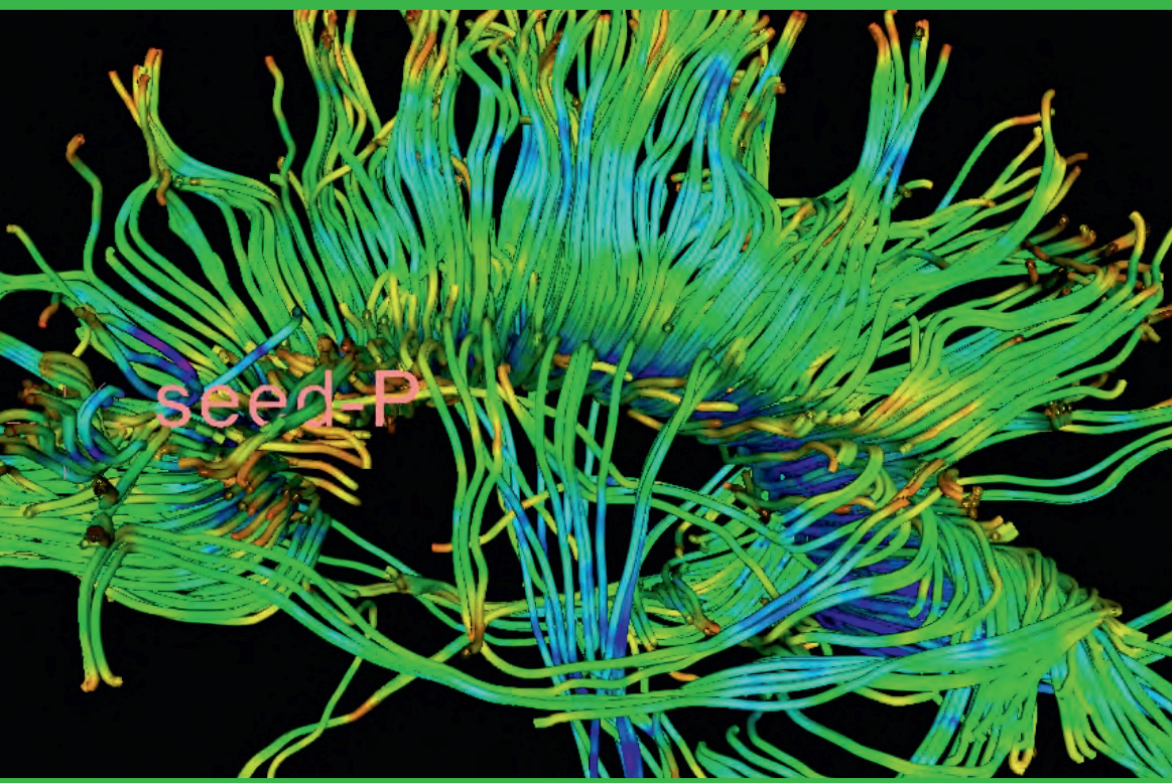


CAMBRIDGE FUNDAMENTALS OF NEUROSCIENCE IN PSYCHOLOGY



# The Neuroscience of Intelligence

RICHARD J. HAIER



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Advance Praise: '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, King's College London

Advance praise: 'An original, thought-provoking review of modern research on human intelligence from one of its pioneers.' Aron K. Barbey, University of Illinois

Advance praise: 'Defly 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, Vrije Universiteit Amsterdam

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Advance praise: '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, Harvard Medical School

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Advance praise: '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, American Enterprise Institute

Advance praise: '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.' Aljoscha Neubauer, University of Graz, Austria

Advance praise: '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, Universidad Autonoma de Madrid

Advance praise: 'Richard Haier's The Neuroscience of Intelligence is an excellent summary 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, University of New Mexico

## The Neuroscience of Intelligence

This book introduces new and provocative neuroscience research that advances our understanding of intelligence and the brain. Compelling evidence shows that genetics plays a more important role than environment as intelligence develops from childhood, and that intelligence test scores correspond strongly to specific features of the brain assessed with neuroimaging. In understandable language, Richard J. Haier explains cutting-edge techniques based on genetics, DNA, and imaging of brain connectivity and function. He dispels common misconceptions – such as the belief that IQ tests are biased or meaningless – and debunks simple interventions alleged to increase intelligence. Readers will learn about the real possibility of dramatically enhancing intelligence based on neuroscience findings 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. Online resources, including additional visuals, animations, questions and links, reinforce the material.

**Richard J. Haier** earned his PhD from the Johns Hopkins University and is Professor Emeritus at the University of California, Irvine. 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*.

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# The Neuroscience of Intelligence

**Richard J. Haier**

*University of California, Irvine*



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## Preface

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% 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. Because 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 USA).

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.

## The Neuroscience of Intelligence

Richard J. Haier

### FAQ for website

#### 1. Are you saying intelligence test scores are the most important thing about a person?

*No. No person can be reduced meaningfully to a test score. I am saying that, like it or not, the differences among people in their general ability to solve problems and learn complex material are important aspects of life success. Intelligence test scores estimate this general ability and the scores predict many things. But test scores are not perfect predictors because there are many things that influence any measure of success. The predictions made by a test are best thought about as probabilities. Intelligence by itself is one of many attributes that contribute to the way a person navigates through life. Intelligence without judgment or character, of course, may not serve a person well. Intelligence does not guarantee happiness, health or likeability. Nonetheless, intelligence is a key to being human and we should understand where it comes from and how it develops. Intelligence tests are necessary tools for researching these questions.*

#### 2. What does an IQ point measure?

*IQ points and scores on all intelligence tests are indirect estimates of reasoning ability. There is no direct measure of intelligence like the direct measures of distance or weight. Four feet is twice the distance of two feet and 10 pounds is twice the weight of five pounds. A person with an IQ score of 140 is not twice as "smart" as a person with a score of 70. This inherent measurement problem is a limitation for intelligence research but test scores do have meaning relative to other people. That's why test scores typically are referenced as percentiles. An IQ score of 130, for example, puts a person statistically in the top 2% of people. Ranking people on IQ scores is what predicts things like academic success or income. For example, the top percentiles of people on IQ test scores are also in the top percentiles of income. There are many individual exceptions, but generally there is a relationship between intelligence and income. This should not be surprising since jobs and professions that pay more often require more complex thinking. Intelligence correlations with other variables like longevity are perhaps more surprising but the message is that intelligence test scores are meaningful despite measurement issues.*

#### 3. Aren't IQ tests biased against some groups?

*There is no research evidence that standard intelligence tests developed with sophisticated statistical methods (called psychometrics) are biased for or against any group. If there was bias against a group, individuals with low scores might consistently get excellent school grades; or persons with high scores might consistently get bad grades. Both these combinations happen in individual cases so we all can think of such examples. Nonetheless, these generally are exceptions---that's why IQ scores are not perfect predictors in any individual case. The data show that IQ scores predict academic*

*success, for example, equally well for all groups indicating that the tests themselves are not biased. Note that a difference in an average measurement between two groups does not necessarily mean the measure is biased. For example, on average men are taller than women; no one would conclude this result comes from a bias in tape measures against women. However, since we do not have the equivalent of a tape measure for intelligence, the anti-bias argument is not so obvious.*

4. Are computers that beat humans playing chess, Go, or Jeopardy smarter than people?

*As machine software becomes capable of learning from mistakes and improving performance, it becomes more difficult to answer this question, especially with respect to general intelligence that is used across many situations outside of games with prescribed rules. The answer to this question will become even more complex as computer hardware can be designed based on the way the brain actually works. At some point “artificial” intelligence in machines might be replaced by “real” intelligence.*

5. If intelligence differences among people are mostly genetic, should we waste time trying to increase intelligence?

*Like test scores, genes are best thought of as probabilistic rather than deterministic. Genetic influences on complex characteristics like intelligence are themselves quite complex. Some genes are deterministic meaning that if you have the “bad” gene, you get the characteristic. This is the case with some diseases and in the 21<sup>st</sup> century, such examples are also examples of hope for discovering ways to correct the “bad” genes. But for intelligence, the data indicate many genes are involved and until we identify specific genes in this large set we won’t know which genes are sensitive to environmental influences and what combinations of genes are most important. Once these things are understood, there likely will be methods to manipulate the salient genes to increase general intelligence and, perhaps, even specific mental abilities like music or math. Meanwhile, there is nothing wrong with trying to maximize the use of a person’s intelligence through education and supportive environments. In my view, neuroscience doesn’t yet have much to help parents and educators accomplish this worthy goal. However, the more intelligence is influenced by genes, the more likely it is that someday we will know how to manipulate those genes to increase intelligence, perhaps dramatically.*

6. Are you saying that family and early environment don’t influence IQ?

*One of the most surprising findings from behavioral genetic studies of intelligence is that the influences of family and other environments are relatively small compared to genetic influences. All environmental influences on intelligence are stronger in children but almost disappear by teen years. This is not a popular finding but it might make sense from an evolutionary perspective given that the environments of early humans were mostly harsh and unpredictable. However, since genetic potential unfolds within an environment, research on gene/environment interactions (epigenetics) is an important but nascent focus in human neuroscience studies. Ironically, progress on understanding environmental influences may accelerate once specific genes for intelligence are identified.*

7. Are you actually suggesting that poverty and economic disadvantages are brain or genetic problems?

*It's hardly popular to suggest that some individuals have limited potential for education and economic success due to genetic influences on intelligence. To the extent that intelligence is a major factor of education and economic success and not the other way around, it's time to consider that some persistent social problems result, in part, because many individuals lack the requisite mental abilities to succeed on their own even modestly in the modern world. 51 million Americans have IQ scores below 85. To the extent that intelligence has major genetic inputs, we are faced with the uncomfortable possibility that some part of poverty and low SES (social-economic-status) are driven indirectly by genetics. I call this piece of the problem "neuro-poverty." It's a hard-edged concept and the natural reaction among many fair-minded people is to reject it in favor of more obvious and possibly more malleable environmental drivers. My interpretation of the data may be incorrect, but I stand by the need to examine the concept of "neuro-poverty" and its implications. For me, the implications lead directly to a strong role for government programs that support people in need, through no fault of their own, both materially and with dignity. I am optimistic that in the long run, an understanding of the neuroscience basis of intelligence might alleviate some aspects of persistent social problems.*

8. What is the relationship between intelligence and education?

*The pace of learning complex material and the amount of material learned are related to general intelligence. Bright students typically learn more material and learn it faster. It would be quite surprising if intelligence and learning were unrelated. Given this basic relationship, here's a mystery: why is the word "intelligence" absent from virtually every issue discussed about education? Every teacher knows that each student comes to class with a unique combination of mental ability strengths and weaknesses. Educators try to maximize how each student applies these abilities. Shouldn't what we know about intelligence be part of the discussion about how best to maximize learning for individual students? Many of the problems with the Common Core program could have been avoided by paying attention to robust findings from intelligence research. For example, holding all children to a college-ready standard is not realistic and results in poorer performance overall.*

9. If intelligence is so important for success, why do smart people do dumb things?

*Humans don't rely solely on intelligence for making decisions. Remember Star Trek's mega-rational Mr. Spock is fictional (and half alien), and arguably not a fun guy. Emotions usually play at least some role, even if unconscious (intuition). Neuroimaging suggests largely separate neural networks for emotion and intelligence. Perhaps there is more or less overlap in these networks in individuals or perhaps emotion decisions have some priority in many situations based on our evolutionary history---better to run immediately when afraid rather than think about what might be causing the fear. The fact that smart people do dumb things does not negate the important role of intelligence in everyday life but it also underscores that intelligence is not the only important thing. If*



*stupidity was regarded as a disease, we might have a National Stupidity Institute to find a cure by funding neuroscience studies of intelligence to address this question.*

10. Isn't there anything I can do to increase intelligence for my children or me?

*In my opinion, the weight-of-evidence doesn't support any claims about increasing intelligence by any means. If there were a way, I'd be the first in line. I believe that dramatic increases may be possible once we understand the basic neuroscience of intelligence. This is a formidable goal but imagine what it would be like learn more, learn faster, and see complex relationships more clearly. Not everyone may dream about this possibility but having the ability to increase intelligence really would change everything.*