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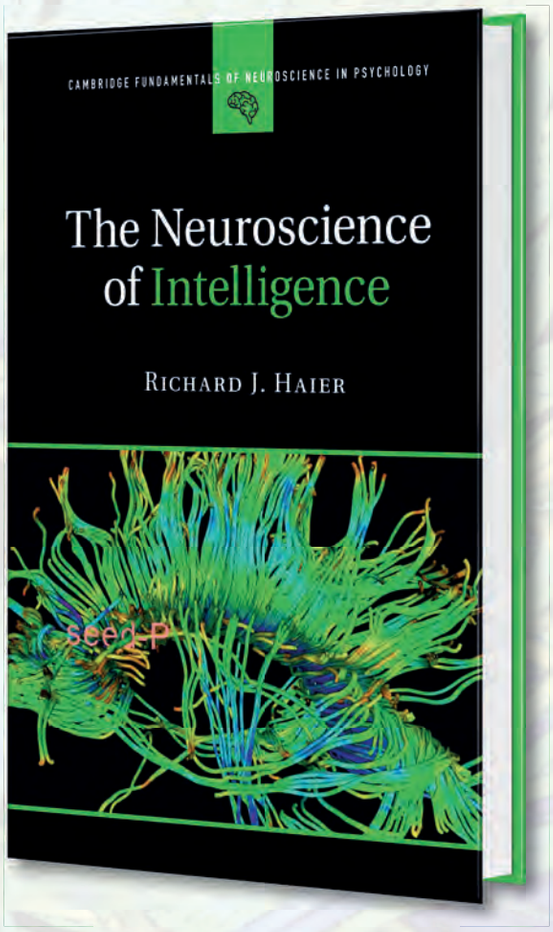
The Neuroscience of Intelligence

RICHARD J. HAIER

University of California, Irvine

Why are some people smarter than others? This book clearly explains what neuroscience tells us about intelligence and the brain, emphasizing genetic and neuroimaging research. It dispels common misconceptions and shows how neuroscientific methods could dramatically enhance intelligence, with surprising implications for education and social policy.

- **Demonstrates that much of the controversy surrounding intelligence has in fact been resolved by modern neuroscience research**
- **Explains advanced concepts in a way that makes them accessible to readers without technical backgrounds**
- **Inspires a new optimism about intelligence and its role in readers' everyday lives**



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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*.

Haier / The Neuroscience of Intelligence

"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, Associate 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, 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 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, 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 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, Department of Neurosurgery, University of New Mexico

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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.

Book excerpts, August 17, 2016
The Neuroscience of Intelligence
Richard J. Haier

Preface

Be advised, if you already believe that intelligence is due all or mostly to the environment, new neuroscience facts might be difficult to accept.

The ultimate purpose of all intelligence research is to enhance intelligence.

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.

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.

If you are an educator, policy maker, parent, or student you need to know what 21st century neuroscience says about intelligence.

Chapter 1: What We Know About Intelligence From the Weight of Studies

No matter how you define intelligence, you know someone who is not as smart as you are. And, in honesty, you know someone who is smarter than you are.

Given their rarity, it is less likely you know a true genius, even if many mothers and fathers say they know at least one.

Many of the controversies about intelligence have their origins in confusion about how we use words like mental abilities, intelligence, the *g*-factor, and IQ.

IQ scores are not absolute measures of a quantity, like pints of water ... *IQ scores are meaningful only relative to other people*.

The best teachers can maximize a student's learning but the intelligence level of the student creates some limitations, although it is fashionable to assert that no student has inherent limitations.

… early childhood education has a number of beneficial effects but increasing intelligence is not one of them.

Most people with high *g* cannot easily imagine what the daily life is like for a person with low *g*.

Life is a long mental test battery.

Chapter 2: Nature More than Nurture: The Impact of Genetics on Intelligence

It would be unlikely if genetics influenced all manner of human physiological differences but had no impact on the brain or the brain mechanisms that underlie intelligence.

All of the twin and adoption studies of intelligence that demonstrate an important role for genes also are consistent in showing that genes do not account for 100% of the variance.

High heritability is a primary reason that neuroscience research on intelligence is expanding so quickly.

No one ever believed that understanding intelligence on the molecular level would be simple, but the studies and their complex analyses summarized here, show that the challenge is not impossible.

On one hand China has substantial investment in this hunt [for intelligence genes], and on the other hand, a majority of members currently in the United States Congress apparently do not believe in evolution. Seriously.

Chapter 3: Peeking Inside the Living Brain: Neuroimaging Is a Game Changer For Intelligence Research

A surprising early finding was an inverse correlation between intelligence test scores and brain activity determined by glucose metabolic rate, suggesting a hypothesis that efficient information flow was an element of higher intelligence.

… this counter-intuitive result suggested to us that it's not how hard your brain works that makes you smart; it's how efficiently it works.

How the brains in the high SAT-Math women were working to solve the problems could not be determined, even though they were solving the same problems as the men equally well. And, the men showed the opposite of what we expected. And, that is how research often goes.

PET scan differences between men and women solving problems, and PET differences between high and average intelligence watchers of videos, indicate that not all brains work the same way.

All these early MRI studies of gray and white matter structure were exciting because they found correlations between various psychometric test scores of intelligence and quantifiable brain characteristics both in specific locations and in the connections among them.

The salient brain areas [related to intelligence] we identified were distributed throughout the brain but mostly were in parietal and frontal areas. We called our model, The Parieto-Frontal Integration Theory (PFIT) of Intelligence.

Chapter 4: 50 Shades of Gray Matter: A Brain Image of Intelligence Is Worth a Thousand Words

In other words, there may be multiple, even redundant, neuro-pathways to the *g*-factor just like there are multiple routes driving from New York City to Los Angeles.

Imagine if colleges and universities gave applicants for admission a choice between submitting either SAT scores or a brain image.

Conceptually, predicting IQ or any intelligence factor from neuroimaging is straightforward.

We do not know if twice the gray matter in a particular part of the cortex, for example, makes one twice as smart.

So can intelligence be predicted from neuroimaging? The short answer is, no. The longer answer is, not yet.

It is my speculation, however, that should a cross-validated method become available to predict IQ or SAT scores accurately from brain images, many parents of high school students will be eager to use it and lobby institutions of higher education to do so as well. Imagine that.

Stop imagining! Just as I was finishing the final draft of this book, a remarkable new study reports that the pattern of connectivity among brain areas based on fMRI is stable within a person and unique enough to identify that person like a fingerprint. And, these brain fingerprints predict intelligence.

It is not unusual to find that books in the field of cognitive psychology and cognitive neuroscience do not include “intelligence” in the index. Language counts. No one is fooled by substituting “reasoning” for “intelligence”, although some granting agencies may think so.

… gray and white matter in specific brain areas had a common genetic basis with IQ.

Here’s the short story. Genes influence brain networks and intelligence. Until specific genes and their expression are identified, we cannot distinguish directly whether genes influence brain morphometry, which then influences intelligence or whether genes influence intelligence, which then influences brain morphometry. It is also possible that many genes influence both brain morphometry and intelligence (pleiotropy) and only some of them are common to both.

We are light years past earlier controversies about whether there is a role for genetics for understanding individual differences in intelligence.

if replicated, identifying genes related to intelligence and how they function can point to potential mechanisms for enhancing intellectual performance if the cascade of genetic influences on functional molecular events can be manipulated at the right stage of brain development.

There is now a context for thinking about how brain parameters might be used to predict or even define intelligence. There is also a developing empirical context for thinking about how brain mechanisms might be manipulated to enhance intelligence …

The combination of molecular genetics and neuroimaging has identified specific genes and related brain mechanisms that may influence individual differences in intelligence.

Chapter 5: The Holy Grail: Can Neuroscience Boost Intelligence?

This chapter is about sense and nonsense regarding the possibility of increasing intelligence. The good news is that neuroscience may someday offer the possibility of increasing intelligence based on an understanding of the brain mechanisms involved, including mechanisms that can be influenced by a variety of means. The bad news is that the claims that we already know how to do this are naïve, wrong, or misrepresentations.

Higher intelligence is better than lower intelligence; no one seriously disagrees.

There may be some people who do not care to be smarter, but I do not know any of them.

There is a long history of trying to increase intelligence. I cannot document it, but I suspect this was a subject of interest to the alchemists, ancient builders, and even earlier mystics. So far as modern scientific efforts, there is no appreciable success when success is defined by independent replication of empirical research results that last over time based on sophisticated assessments of intelligence in well-designed studies.

… apparently undaunted by past failures and inherent measurement problems, or ignorant of them, there are newer reports in the scientific literature that claim to raise IQ scores dramatically in children and adults.

We will examine three of these specific claims [about increasing IQ] under the implied heading, “Don’t let this happen to you.” These claims are based on the use of classical music, memory training, and computer games to raise IQ. By showing how such claims should be evaluated skeptically I hope to inoculate you against future declarations of alleged breakthrough or landmark results.

Enumerable high school science fair projects investigated various aspects of the Mozart Effect, tested mostly on friends and family. In fairness, these were hardly terrible consequences of a wrong idea. Possibly with the exception of a few accordion lessons, no one was harmed but no one’s IQ increased either.

The title of this meta-analysis paper said it all, Mozart effect-Shmozart effect.

Whatever the many rich benefits of music exposure and training are, increased intelligence, general or spatial, is not one of them. The Mozart Effect should be a cautionary tale for any researcher who claims dramatic increases in IQ after an intervention.

Eight years after the initial PNAS report, the weight of evidence from independent studies finds essentially no transfer effects from memory training to intelligence scores that are truly independent of the training method.

Based on the history of similar claims in the past, I suspect memory-training research will become less directed at improving intelligence and more directed at other cognitive and education variables.

Neuro-education and brain-based learning are attractive concepts for educators but, in my view, there is not yet a compelling weight of evidence of successful applications so considerable caution is required. Potential buyers of such programs, especially those claiming increases in intelligence, are advised to keep three words in mind before signing a contract or making a purchase: independent replication required.

Drugs influence brain mechanisms more directly than memory training, for instance, so drugs may have greater intelligence boosting potential.

In short, there is no compelling scientific evidence yet for an IQ pill. As we learn more about brain mechanisms and intelligence, however, there is every reason to believe that it will be possible to enhance the relevant brain mechanisms with drugs, perhaps existing ones or new ones.

If such drugs become available to enhance learning and memory in patients with Alzheimer's disease, surely the effect of those drugs will be studied in non-patients to boost cognition.

Because there is a paucity of empirical evidence for raising intelligence, and because psychoactive drugs often have serious side effects, especially when a physician does not monitor their use, no list of drugs claimed to increase intelligence appears in this book. In my view, there are none to list. The potential for drugs to boost intelligence, however, is directly correlated to the extent to which the biological bases of intelligence are revealed, and as described in previous chapters, the pace of discovery is increasing.

We now turn to what may sound like science fiction efforts to enhance intelligence and related cognition. They are not fiction and they are mind blowing, almost literally.

There are reports of homemade "brain shock" devices used by gamers and others looking for enhanced cognition. Some commercial companies sell such devices for a range of self-uses. Independent replication research supporting their claims, if any, would be important to evaluate. Applying homemade or commercial electrical devices to your brain might have unintended consequences. Please do not compete for a Darwin Award by trying this at home.

Could constant Deep Brain Stimulation in multiple areas enhance the *g*-factor, especially in individuals with low IQ, or could on-demand DBS in a specific area enhance specific mental abilities in any of us?

Moreover, my assertion that enhancement is an important goal is not universally recognized. If it were, considerably more federal and foundation funding would be

directed toward achieving it and not just for disadvantaged children. After all, many national challenges from technological and economic innovation to cyber crime and cyber warfare pit the smartest against the smartest. This is serious business. Silly magazine tips are not helpful.

If I had to bet, the most likely path toward enhancing intelligence would be a genetic one.

Even if hundreds of intelligence relevant genes are discovered, each with a small influence, the best case for enhancement would be if many of the genes worked on the same neurobiological system. In other words, many genes may exert their influence through a final common neurobiological pathway. That pathway would be the target for enhancement efforts.

If you think the hunt for intelligence genes is slow and complex, the hunt for the functional expression of those genes is a nightmare. Nonetheless, we are getting better at investigations at the molecular functional level and I am optimistic that, sooner or later, this kind of research applied to intelligence will pay off with actionable enhancement possibilities. The nightmares of neuroscientists are the driving forces of progress.

Chapter 6: As Neuroscience Advances, What's Next for Intelligence Research?

Paradoxically, in any area of scientific inquiry, the more we learn, the more we do not understand.

It is nearly impossible to imagine, but what if a country ignored space exploration and announced its major scientific goal was to achieve the capability to increase every citizens' *g*-factor by a standard deviation? By the end of this chapter, you might not think this is so impossible.

Advances in the intelligence field likely will come from the integration of findings from basic research on clinical brain disorders, aging, and normal cognitive processes like learning, memory, and attention from both animal and human studies that expose events smaller and smaller, faster and faster, and deeper and deeper in the brain.

On one side of the equation that links genetic and neuroimaging data to intelligence, we have the most up-to-date multimillion-dollar equipment and teams of specialists to collect and analyze complex data sets. On the other side of the equation, we have a psychometric test score, often from a single test that costs a few dollars. This is quite a mismatch, or more accurately a chasm.

Another illuminating example is the use of fluorescent proteins that literally light up neurons and synapses.

Neuroimaging methods described in chapters 3 and 4 give researchers a view of the brain like the view of a city from a high-flying airplane, a unique and informative view not possible before the invention of the airplane. These new neuroscience techniques give researchers experimental control over individual neurons. This is like an aerial view that

allows seeing individual cars on a city street and possibly who is in the car and how fast their heart is beating.

There is breathtaking potential for elucidating intelligence brain circuits if these techniques are applied to animal models of intelligence … If such methods are available in humans, the potential for neuroscience/intelligence research staggers the imagination. Ready to change your major or thesis topic?

But, an even more ambitious goal is to create intelligent machines with algorithms based on how neurons communicate in actual brain circuits explicated by basic neuroscience researchers. This is "real" intelligence.

Hopefully, at some point someone with access to a simulated brain will wonder about just how smart the virtual brain may be.

… if there are common circuits between consciousness and intelligence, we might speculate that new drugs that work in opposite ways than anesthetic drugs may produce hyper-consciousness or hyper-awareness, possible aspects of higher intelligence.

Or as we say privately, we really don't know how intelligence and creativity are related to genius on the brain level.

How intelligence may be related to creativity and consciousness on a neural level is an intriguing question that raises opportunities for imaginative research designs and innovative neuroscientists. Students, that means you.

PLEASE NOTE THAT SECTION 6.6 BELOW IS LIKELY TO BE THE MOST CONTROVERSIAL PART OF THE BOOK. I AM PASTING IT IN ITS ENTIRETY BELOW WITH SOME KEY SENTENCES HIGHLIGHTED.

6.6 N**euro-poverty and Neuro-Social Economic Status (SES): implications for public policy based on the neuroscience of intelligence**

The confounding of SES with intelligence was introduced in Chapter 2.1. Now we consider it further because it remains an important problem that often results in misleading conclusions from research studies. Here is a common train of thought about the importance of SES: *Higher income allows upward mobility, especially the ability to move from poor environments to better ones. Better neighborhoods typically include better schools and more resources to foster children's development so that children now have many advantages. If the children have high intelligence and greater academic and economic success, it could be concluded that higher SES was the key factor driving this chain of events.* Here is an alternative train-of-thought: *Generally, people with higher intelligence get jobs that require more of the g-factor and these jobs tend to pay more money. There are many factors involved, but empirical research shows g is the single strongest predictive factor for obtaining high paying jobs that require complex thinking. Higher income allows upward mobility, especially the ability to move from poor environments to better ones. This often includes better schools and more resources to foster children's development so that children now have many advantages. If the children have high intelligence and greater academic and economic success, it could be*

concluded that higher parental intelligence was the key factor driving this chain of events, due in large part to the strong genetic influences on intelligence.

The latter train-of-thought is hardly new. It was made clear more than 40 years ago in a controversial book mentioned earlier in Chapters 1 and 2, IQ in the Meritocracy (Herrnstein, 1973). The argument was reduced to its simplest form in a syllogism: "(1) If differences in mental abilities are inherited, and (2) if success requires those abilities, and (3) if earnings and prestige depend on success, (4) then social standing (which reflects earnings and prestige) will be based *to some extent* on inherited differences among people" (pages 197-198, italics added). When this was published in 1973, the evidence for a genetic role in intelligence was strong but not overwhelming and there was room for skepticism; today the evidence is overwhelming and compelling (see Chapters 2.5, 2.6, 4.5 and 4.6).

Dr. David Lubinski has written a comprehensive review of the SES/intelligence confounding issue (Lubinski, 2009). Although the context for his paper is Cognitive Epidemiology, the argument applies to all research using SES as a variable. Essentially, if a study incorporates measures of both SES and intelligence, statistical methods can help disentangle their respective effects. The interpretation of results from any study of SES cannot disentangle which factor is driving the result unless a measure of intelligence is included in the study. Studies of intelligence without considering SES are also problematic. When both variables are included in multivariate studies in large samples, the results typically show that general cognitive ability measures correlate with a particular variable of interest even after the effects of SES are statistically removed. For example, in a study of 641 Brazilian school children, SES did not predict scholastic achievement but intelligence test scores did (Colom and Flores-Mendoza, 2007). An even larger classic study had data on 155,191 students from 41 American colleges and universities. Their analyses showed that SAT scores predicted academic performance about the same even after SES was controlled; that is, SES added no additional predictive power (Sackett et al., 2009). Another study of 3233 adolescents in Portugal found that parents' level of education predicted intelligence in the children regardless of family income (Lemos et al., 2011). These researchers stated their conclusion straightforwardly: *"Adolescents from more affluent families tend to be brighter because their parents are brighter, not because they enjoy better family environments"*.

Studies with equally large samples showing SES effects remain after removing effects of intelligence are less frequent although one meta-analysis suggested that SES independently predicts economic success about as well as intelligence (Strenze, 2007). An illustrative example of using both SES and IQ is a study of 110 disadvantaged middle school children. It included maternal IQ along with composite measures of parental nurturance and environmental stimulation (Farah et al., 2008). In the main analysis, parental nurturance was related to memory and environmental stimulation was related to language, after any effects of maternal IQ were statistically removed. The range of maternal IQ, however, was restricted to the lower end of the normal distribution (mean = 83, standard deviation = 9), possibly explaining the lack of an IQ finding, but this study does illustrate why it is important to include IQ measures when investigating specific SES factors. Replication in another sample of disadvantaged children would be important

along with obtaining father's IQ. Replication in a sample of children in higher SES levels would also be informative, as would studies of children at different ages since the effects of SES on the heritability of intelligence may vary with age (Hanscombe et al., 2012). It is particularly interesting that there is emerging evidence that the SES itself has a strong genetic component (Trzaskowski et al., 2014). Obviously, there are many questions to pursue for establishing a weight of evidence regarding how SES and IQ relate to each other.

One common view in cognitive psychology is that SES/cognitive relationships are mediated by how SES variables influence brain development during early childhood. Other researchers see such relationships as more related to neuroscience, especially when trying to relate such findings to education (Sigman et al., 2014). As you might imagine, the line between cognitive psychology and neurobiology is permeable (Hackman et al., 2010, Neville et al., 2013). The term "cognitive neuroscience" refers to both. Nothing about a major genetic component to intelligence and related neurobiological mechanisms negates or minimizes the importance of SES influences on cognitive psychology variables. Surely, SES is a consequence of many factors but let's consider just the portion of SES that is confounded with the genetic portion of intelligence. I designate this portion by the term "neuro-SES" and in my view it should be recognized as a matter for research and discussion.

To repeat the main point, studies that make claims about SES variables without including measures of intelligence are difficult to interpret and need to at least acknowledge the confound problem before concluding or implying that SES has a causal role. This was a primary point made two decades ago in The Bell Curve. Nonetheless, bias toward SES-only explanations remains prevalent. Two recent high profile examples illustrate the issue. Both studies use neuroimaging with structural MRI. The first paper is from MIT, reported by Dr. Mackey and colleagues (Mackey et al., 2015) (Dr. Mackey also reported a 10 point IQ increase in disadvantaged children following brief computer game playing in school; see Chapter 5.3). These researchers set out to study neuroanatomical correlates of the academic achievement gap between higher and lower income students (n= 35 and 23, respectively). The higher group average yearly family income was $145,465 (95% confidence interval between $122,461 to $$168,470. The lower group family average was $46,353 (95% confidence interval between $22,665 to $70,041). It is arguable whether family incomes of over $50,000 constitute a disadvantaged household, but the key finding is still of interest. Structural MRIs showed greater cortical thickness in several areas for the high-income group, although other brain measures did not (e.g. cortical surface area, cortical white matter volume). Cortical thickness differences between the groups in some areas were related to standard test score differences. The authors concluded, *"Future studies will show how effective educational practices support academic gains and whether these practices alter cortical anatomy."* This is fair enough and certainly supports a commonly held view. However, without assessing cognitive ability of the parents, we cannot be sure whether the cortical thickness difference is related to family income or to the genetics of intelligence. The results from this study would be far more compelling had some estimate or measure of parental intelligence been included to help disentangle SES effects from intelligence effects.

The second paper is a multi-center collaboration reported in *Nature Neuroscience* by Dr. Noble and colleagues (Noble et al., 2015). This MRI study had a large sample of 1,099 children and adolescents. Data included family income, parental education, and genetic ancestry. Income was related to brain surface area even after controlling for parental education. Parental education related to other structural brain characteristics even after controlling for income. These associations were found irrespective of genetic ancestry. The authors state that, *"…in our correlational, non-experimental results, it is unclear what is driving the links between SES and brain structure. Such associations could stem from ongoing disparities in postnatal experience or exposures, such as family stress, cognitive stimulation, environmental toxins or nutrition, or from corresponding differences in the prenatal environment. If this correlational evidence reflects a possible underlying causal relationship, then policies targeting families at the low end of the income distribution may be most likely to lead to observable differences in children's brain and cognitive development."* This is not an unreasonable statement but one implication of this train-of-thought might be an experiment that provided modest or large monthly payments to low income families to improve everyday life with the expectation that the resulting life changes might have subsequent effects on their children's brain and cognitive development. Some recognition and discussion of the neuroscience aspects of intelligence and its intertwining with SES would be important considerations if such an experiment was undertaken. Intelligence was not mentioned in the discussion of these MRI results.

The Blank Slate belief, discussed in Chapter 2, promotes SES and other social/cultural influences as critical to intelligence and its development. As noted throughout this book, the weight of evidence does not support the primacy of this view over a genetic one. There is also growing recognition that this view has failed to invigorate successful public policies aimed at closing widely acknowledged gaps in education achievement and cognitive skills shown by many disadvantaged children. A main implication of this book is that the empirical evidence overwhelmingly supports paying more attention to neurobiology as a foundation for changing the status quo. As argued in previous chapters, neurobiology can be modified, even if there are strong genetic components involved. This simple fact combined with advances in neuroscience research like the ones discussed in this Chapter, provide new optimism for addressing serious problems that have persisted for decades.

What are possible policy implications of introducing neurobiology perspectives to research on these problems? Not all individuals have a pattern of cognitive strengths that allow barely minimum success in modern, complex society. This is evident with respect to *g* and other factors of intelligence. To the extent that different patterns of cognitive strengths and weaknesses are rooted more in neurobiology and genetics than in childhood experience, it is incorrect to blame lack of economic or educational success entirely on poor motivation, poor education, or other social factors. All these things matter but with respect to intelligence, they do not appear to matter that much, as the weight of evidence indicates.

Here is my political bias. I believe government has a proper role, and a moral imperative, to provide resources for people who lack the cognitive capabilities required for education,

jobs and other opportunities that lead to economic success and increased SES. This goes beyond providing economic opportunities that might be unrealistic for individuals lacking the requisite mental abilities. It goes beyond demanding more complex thinking and higher expectations for every student irrespective of their capabilities (a demand that is likely to accentuate cognitive gaps). It even goes beyond supporting programs for early childhood education, jobs training, affordable childcare, food assistance, and access to higher education. There is no compelling evidence that any of these things increase intelligence but I support all these efforts because they will help many people advance in other ways and because they are the right thing to do. But, even if this support becomes widely available, there will be many people at the lower end of the *g*-distribution who do not benefit very much, despite best efforts. Recall from Chapter 1, that the normal distribution of IQ scores with a mean of 100 and a standard deviation of 15 estimates that 16% of people will score below an IQ of 85 (the minimum for military service in the US). In the United States, about 51 million people have IQs lower than 85 through no fault of their own. There are many useful, affirming jobs available for these individuals, usually at low wages, but generally they are not strong candidates for college or for technical training in many vocational areas. Sometimes they are referred to as a permanent underclass, although this term is hardly ever explicitly defined by low intelligence. *Poverty and near-poverty for them is a condition that may have some roots in the neurobiology of intelligence beyond anyone's control.*

The sentence you just read is the most provocative sentence in this book. It may be a profoundly inconvenient truth or profoundly wrong. But if scientific data support the concept, is that not a jarring reason to fund supportive programs that do not stigmatize people as lazy or unworthy? Is that not a reason to prioritize neuroscience research on intelligence and how to enhance it? The term "neuro-poverty" is meant to focus on those aspects of poverty that result mostly from the genetic aspects of intelligence. The term may overstate the case. It is a hard and uncomfortable concept but I hope it gets your attention. This book argues that intelligence is strongly rooted in neurobiology. To the extent that intelligence is a major contributing factor for managing daily life and increasing the probability of life success, neuro-poverty is a concept to consider when thinking about how to ameliorate the serious problems associated with tangible cognitive limitations that characterize many individuals through no fault of their own.

Public policy and social justice debates might be more informed if what we know about intelligence, especially with respect to genetics, is part of the conversation. In the past, attempts to do this were met mostly with acrimony, as evidenced by the fierce criticisms of Arthur Jensen (Jensen, 1969, Snyderman and Rothman, 1988), Richard Herrnstein (Herrnstein, 1973), and Charles Murray (Herrnstein and Murray, 1994, Murray, 1995). After Jensen's 1969 article, both IQ in the Meritocracy and The Bell Curve raised this prospect in considerable detail. Advances in neuroscience research on intelligence now offer a different starting point for discussion. Given that approaches devoid of neuroscience input have failed for 50 years to minimize the root causes of poverty and the problems that go with it, is it not time to consider another perspective?

Here is the second most provocative sentence in this book: *The uncomfortable concept of "treating" neuro-poverty by enhancing intelligence based on neurobiology, in my view,*

affords an alternative, optimistic concept for positive change as neuroscience research advances. This is in contrast to the view that programs that target only social/culture influences on intelligence can diminish cognitive gaps and overcome biological/genetic influences. The weight of evidence suggests a neuroscience approach might be even more effective as we learn more about the roots of intelligence. I am not arguing that neurobiology alone is the only approach but it should not be ignored any longer in favor of SES-only approaches. What works best is an empirical question although political context cannot be ignored. On the political level, the idea of treating neuro-poverty like it is a neurological disorder is supremely naïve. This might change in the long run if neuroscience research ever leads to ways to enhance intelligence, as I believe it will. For now, epigenetics is one concept that might bridge both neuroscience and social science approaches. Nothing will advance epigenetic research faster than identifying specific genes related to intelligence so that the ways environmental factors influence those genes can be determined. There is common ground to discuss and that includes what we know about the neuroscience of intelligence from the weight of empirical evidence. It is time to bring "intelligence" back from a 45-year exile and into reasonable discussions about education and social policies without acrimony.

A recent book explores this possibility. Authored by two behavioral genetics researchers, the starting point is acknowledgement that all students enter the education system with different genetic propensities for learning reading, writing and arithmetic (Asbury and Plomin, 2014). The authors propose policy ideas for tailoring the education environment to help each student learn core material in a way that is likely best suited to that student's genetic endowment. This is a long way from the incorrect assumption that genes are deterministic; actually genes are starting points. As the authors note, genetic research findings are uniquely excluded from discussions about education while at the same time genetic research has transformed aspects of medicine, public health, agriculture, energy, and the law. Individualized education is a longtime goal for educators and genetic research supports that goal. Asbury and Plomin conclude, *"We aim to treat all children with equal respect and provide them with equal opportunities, but we do not believe that all our pupils are the same. Children come in all shapes and sizes, with all sorts of talents and personalities. It's time to use the lessons of behavioral genetics to create a school system that celebrates and encourages this wonderful diversity (page 187)."*

This view is strikingly similar to Jensen's conclusion more than 45 years ago (Jensen, 1969), *"Diversity rather than uniformity of approaches and aims would seem to be the key to making education rewarding for children of different patterns of ability. The reality of individual differences thus need not mean educational rewards for some children and frustration and defeat for others (page 117)."* Both views are common among neuroscientists who study intelligence and understand the probabilistic nature of genes. Nonetheless, failure to acknowledge the conclusive findings about the role of genetics for individual differences in intelligence and other cognitive abilities perpetuates the ineffective "one size fits all" approach to education reform. It is easy to see how ignoring what we know about intelligence has led, and will continue to lead, to frustration and failure for addressing any issue where intelligence matters (Gottfredson, 2005). Nonetheless, intelligence remains missing from public conversations.

In the United States, for example, considerable rancor pervades discussions about education reform even without any reference what-so-ever to intelligence differences among students. The idea that every high school student be held to a graduation standard of four year college-ready, irrespective of mental ability, is naïve and grossly unfair to those students for whom this expectation is unrealistic. Remember, statistically half of the high school student population has an IQ score of 100 or lower making college work considerably difficult even in highly motivated individuals. It is similarly naïve and unfair to evaluate teachers by student test score changes when many tests are largely *de facto* measures of general intelligence rather than of the amount of course material learned over a short time period. Perhaps the greatest disservice to students will come from purposefully increasing the difficulty of evaluation tests by requiring more complex thinking to get the right answers. The odds are that this change alone will *increase* performance gaps because the tests are now more *g*-loaded. [The last sentence was drafted months before the Los Angeles Times reported a front-page story with the headline: "New scores show wider ethnic gap" (9/12/15)].

In principle, there is nothing wrong with evaluation testing or having high expectations and standards. These examples, however, illustrate the consequences of ignoring what we know about intelligence from empirical studies when crafting well-intentioned policies for education, especially those policies that assume thinking skills can be taught to the same degree to all students, or that buying ipads for everyone in the education system will increase school achievement. As most teachers recognize, maximizing a student's cognitive strengths, whatever they may be, is a worthy goal. Everything we know from the research literature on intelligence supports this view, including why the *g*-factor is important, how the brain develops, and the major role genetics plays in explaining intelligence differences among individuals. In the future, the potential for enhancing intelligence based on neuroscience research just might make this goal more achievable for all students and result in greater school and life achievement. As the 21st century progresses, we all need to be aware of neuroscience research findings on intelligence and what they could mean for our lives.

Section 6.7: Final thoughts

I also believe that neuroscience perspectives on intelligence offer the best hope to resolve pressing issues about education and public policy that have not yet been resolved or ameliorated after 50 years of attempts based on blank slate assumptions about individual differences in intelligence and where they come from. Neuroscience has the potential to change the status quo in ways that other approaches have yet to accomplish. You may not agree, but if you are now thinking about intelligence differently than when you started reading this book, my primary goal is met.

If you are thinking about whether to have a career studying intelligence and the brain, here is a statement that will always be true: Get started---science is a never ending story--whenever you begin will be the most exciting time to work on the puzzles that define the neuroscience of intelligence.

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 21st 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 it's 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.