Brains, Bias, and Biology

In, Why Aren't More Women in Science? Edited by Ceci & Williams, APA Books 2007

Chapter 8

Brains, Bias, and Biology: Follow the Data

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Considerable evidence, reviewed in this volume, indicates that men and women show some differences in their respective patterns of cognitive strengths and weaknesses. Any such group differences are statistical in nature and never predict anything about a specific person's abilities. Most of the differences are rather small and may have no practical consequences. Nonetheless, the nature of these group differences may provide some insights into the origin of rather substantial cognitive differences among individuals. Some of my research addresses whether such differences reflect, at least in part, biological differences (genetic or not) in brain structure and function.

I was drawn recently into commenting on the subject of male versus female differences in cognition. Our most recent research study concerning sex differences in brain structure as related to intelligence was published about the same time that Lawrence Summers, president of Harvard University, made controversial remarks about difficulties faced by women in science careers. From reading a transcript of his remarks, I believe he summarized the current situation reasonably well. As he noted, women face serious sex discrimination and child-rearing or family pressures. He also wondered whether women could be underrepresented at the very highest end of talent in science, especially fields that require advanced mathematics like engineering and physics, not only because of cultural bias, workplace discrimination, and unequal family pressures, but also because of possible biological or genetic reasons. This last remark caused consternation and bitter recriminations on the part of those who inferred he was proposing the biological or genetic inferiority of women.

For most researchers, this was an unfair inference, but not an uncommon one. Biological and genetic variables influence behavior, cognition, and the brain. No controversy exists about the importance of understanding how these influences work for Alzheimer's disease, schizophrenia, mental retardation, and a host of other serious problems. Controversy is more apt to arise when biology and genetics are studied as they influence behavior and cognition in the absence of neurological problems, as they surely do. In the case of Summers's remarks, the scientific controversy is whether the brain parameters necessary for the most advanced mathematical reasoning may be unequally distributed between men and women, and if so, why. There are no definitive answers yet to either part of this straightforward question, but there are interesting scientific data to consider. None of the data are correctly interpreted as showing the superiority or inferiority of one group or another.

Many studies show male versus female differences in cognitive abilities. Many other studies show male versus female differences in brain structure and function. Do such brain differences have connection to cognitive differences or anything else? So what if one group, on average, has a bigger brain, or more gray matter, or more white matter, or more connections between right and left hemispheres? Do any of these brain differences correlate to differences in general intelligence, to specific cognitive abilities, to vulnerability to dementia, or to other neurological diseases? Do any brain differences predict which individual will respond to a psychotropic drug or which stroke victim will have a full recovery? These are important and serious questions worth researching. They have little to do with popular psychology questions like why men allegedly do not ever ask for or read directions.

Earlier research conducted by my colleagues and I used functional brain imaging with positron emission tomography (PET) to investigate whether men and women, matched for SAT–Mathematics (SAT-M) scores, activated the same or different brain areas during a test of mathematical reasoning (see Haier & Benbow, 1995). There were 22 men and 22 women of college age; half of each group were admitted to college with scores over 700 on SAT-M (a perfect score is 800), the other half scored in the average range with a score about 500. Each person completed a new SAT-M test while undergoing the PET scan procedure. The results showed that the harder the temporal lobes were working in the men, the better their score. This relationship between temporal lobe activation and performance on the math reasoning test was not found in the women, nor was activity in any other brain area related to the women's SAT-M score. Here was a clear sex difference in brain function, although it was unsatisfying that no regional activity related to math performance in the women. How such highly able women did the math reasoning without activating (or deactivating) specific brain areas was a mystery.

Our recent research used magnetic resonance imaging (MRI) and asked whether brain structure, especially the amount of gray and white matter in different brain areas, was related to general intelligence, as determined by standard IQ tests in normal volunteers ($N = 47$). Apparently, it is (see Haier, Jung, Yeo, Head, & Alkire, 2004). There are structures distributed throughout the brain where the amount of gray matter or white matter predicts IQ score. Specific areas associated with language in the frontal and parietal lobes seem especially important. Other researchers have shown that the volume of these same brain areas appears to be under genetic control.

Because general intelligence does not differ between men and women, we had no reason to expect sex differences in the brain structures related to IQ. However, we were wrong. When we reanalyzed our MRI data separately for men and women, we found completely different brain areas correlated to IQ (the men and women in these samples were matched on IQ). The amount of gray and white matter in the frontal areas seems more important in the women; the gray matter in the parietal areas seems more important in the men (Haier, Jung, Yeo, Head, & Alkire, 2005). This apparent sex difference is the finding that received significant public attention following

Summers's remarks. If this difference proves to be correct after independent replication, it could be concluded that men and women achieve the same general cognitive capability using different brain architectures.

Why is the notion of differential brain architecture important? It would mean that not all brains work the same way to achieve the same result, negating a principal assumption of traditional cognitive psychology. It would put the concept of individual differences in the center of human brain research and refocus attention on questions like why do some individuals learn, memorize, and reason better than others; it also may help explain why some pain drugs work better in women than in men. It also could have important clinical implications for understanding individual and group differences in the impact of brain damage and for cognitive rehabilitation strategies. For example, given our MRI and intelligence findings, a stroke or tumor in the frontal lobe may have different cognitive consequences for women than for men. For another example, Alzheimer's disease reaches the frontal lobes later than other areas, so it may be possible that women have the disease longer before any cognitive symptoms are apparent. This could lead to women receiving the diagnosis later in the disease process, delaying efficacious treatment with drugs now under development.

Questions about group differences often raise difficult social issues because they focus on how people differ rather than on how all humans are the same. It is still fashionable to ascribe behavioral and cognitive differences among people entirely to cultural and environmental differences, especially in childhood. This remains true even through many twin or sibling studies in behavioral genetics consistently show zero contribution of shared environment to variance in psychological variables like personality and intelligence. Because such variables do show moderate to high heritability, we know there is a genetic component of importance. Because genes always work through biology, there must be some biological basis for intelligence and personality. We also know that genes and their expression must be influenced by non-genetic factors. For example, identical twins are not nearly 100% concordant for schizophrenia (i.e., if one twin is schizophrenic, the other has only a 50% chance although both are genetically identical). Even more striking is the relatively recent revelation from the Human Genome Project that there are fewer than 25,000 human genes, a fraction of the number originally predicted. Because there are over 2 million gene products, this means each gene can express itself in a thousand different ways. The mechanisms that lead a gene to one expression or to any of a thousand others are not understood (Silverman, 2004). Whatever these mechanisms turn out to be, some of them are likely to be influenced, at least in part, by non-genetic factors including social and cultural ones.

What does all this have to do with women in science? Was the president of Harvard correct to wonder whether there are more men than women with advanced mathematical reasoning ability because of biological or genetic reasons? It is a question I have wondered about since my first year of graduate school in psychology at Johns Hopkins University in 1971. Professor Julian Stanley was conducting the first search for mathematically talented junior high school students (a project still under way). I helped with the SAT-M testing of about 450 Baltimore area students recommended by their math or science teachers. The students were mostly 12 to 14 years old. Twenty-three scored over 650 on the SAT-M, a score at the 94th percentile for college-bound seniors. Forty-three boys scored higher than the highest scoring girl (her score was 600; Stanley, Keating, & Fox, 1974).

Long-term studies with hundreds of thousands of students do show more mathematically gifted males than females, and many possible explanatory variables have been examined (see

Lubinski and Benbow, chap. 6; Camilla Benbow was also a graduate student with Professor Stanley). The ratio of boys to girls from the original Hopkins testing is not constant over time nor is it constant across countries. The sample sizes at 0.1% are very small so inconsistencies are to be expected. Nonetheless, it must be noted that any inconsistency in itself does not argue against a possible genetic component. There are more blue-eyed people in Iceland than in Tibet, but it would be wrong to conclude from this fact that blue eye color is not genetic. At this stage of research, it is not certain that genes play a role either in mathematical talent among individuals or in any sex differences in the size of the talent pool at this level of ability, but it is a fair and important question.

A role for genes is strongly suspected in rare cases of mathematical genius, especially those in which environmental and cultural variables discouraged achievement. For example, Srinivasa Ramanujan is regarded as one of the great math geniuses of all time (Kanigel, 1991). He was born in poverty in India in 1887. In school, he was mostly self-taught in mathematics from outdated books, but he created profoundly original proofs and conjectures, which came to the attention of the best mathematicians at Cambridge University. As a young man, Srinivasa was bought to Cambridge, where he produced one astounding theorem after another until he died at age 32. Emilie de Breteuil, Marquise du Chatelet, however, was born into French aristocracy in 1706 (Osen, 1974). She had excellent tutors and a fine education. She led a life of wealth and privilege, spending much time with Voltaire and other intellectuals. She also showed an early genius for mathematics. It is reported that she could divide a nine-digit number by another nine-digit number in her head. Emilie conducted scientific experiments on motion and speed and published research works despite intense cultural bias against women pursuing such intellectual activities. Before she died at age 43, she demonstrated mathematically that velocity squared was the appropriate measure of kinetic energy; this is regarded as a major contribution and an important basis for Albert Einstein's most famous equation more than 150 years later.

Of course, two cases of exceptional genius tell us nothing about the size of the pool of mathematical talent let alone any differences in the pool between men and woman. They do suggest, however, that despite environmental deprivations or cultural limitations, genius can emerge. Did these two individuals share similar, but rare, neurotransmitter activity, brain structure connections, unusually large brain areas in the frontal and parietal regions, or other cerebral anomalies that resulted in their mathematical genius? To what extent did unknown genetic factors contribute to these brains?

Over time, modern societies seek to minimize cultural and environmental disadvantages and overt discrimination as best as they can to promote a level playing field for everyone. As these social goals are achieved, the differences that remain among people, especially at the highest levels of talent, will be attributed more and more to genetic factors. It is commonly believed that anything genetic is fixed in stone and cannot be easily altered, at least not as easily as any environmental variable. In the 21st century, just the opposite may be true. As we learn more about genetic engineering and the mechanisms for multiple gene expressions, there may be ways to influence brain development, growth, and function as they relate to specific and to general mental abilities.

So now we come to speculation beyond the current scientific findings but well within the imagination of scientists and writers of science fiction. Brain imaging research on intelligence is identifying the specific areas important for reasoning ability (Jung & Haier, 2007). These include frontal areas and parietal areas, especially Brodmann area (BA) 39 in the left parietal lobe (Brodmann areas are a standard numerical nomenclature for regions of the cortex). Compared with normal control subjects, BA39 was 15% bigger in Einstein's brain studied after his death. Gray matter volumes in the frontal and parietal lobes also appear to be under genetic control. If mathematical and scientific thinking is best accomplished in individuals with bigger BA39s and more connections between BA39 and the frontal lobes, what do we need to know before we can increase the volume of BA39 and its connections in any person who wishes to do so? Is it just a matter of finding the right brain growth factors, biological or non-biological? With the right tweaking of the brain, can an average math student become gifted? Can a gifted student become a math genius? If such factors exist, are they the same in men and women? How could such factors be stimulated and controlled? What would be the best techniques—brain surgery, drugs, diet, listening to Mozart?

This is an important direction in neuroscience research, and the results likely will be as controversial as any issue involving the application of new biological or neuroscience knowledge, perhaps more so because the brain is involved. It will build on current work on drugs being developed for Alzheimer's disease by trying such medications in non-impaired people to increase their memory ability from normal to extra-normal. It will build on research implanting electrical stimulators, or stem cells, into specific brain areas to alleviate the symptoms of Parkinson's disease and other brain disorders. Can such electrical or stem cell stimulation to other brain areas improve cognition even in people who do not have any impairment or disorder? If any of this comes to pass, such techniques may work better in men or in women, depending on any differences in the salient brain architectures underlying cognition. If there is a disparity in any cognitive ability like talent for mathematical reasoning, which likely is based in part on biological and genetic aspects of the brain, neuroscience research someday may help minimize the disparity. Is this any less desirable or any more controversial than minimizing cognitive disparities by applying any social or cultural research results?

The hardest part of science is going wherever the data take you. Nature is the way it is, no matter how we think it should be. Yet, once empirical facts become known through scientific inquiry, there is always the possibility of changing Nature. This is certainly true in biology. Every time you visit a physician, it is with the expectation that broken biology can be fixed, even if there is a genetic basis for the problem, and even if the fix involves changes in diet or exercise rather than medication. For any scientific question, especially about the brain and differences in cognitive performance, the data may point in uncomfortable directions, but gathering data from all potentially relevant sources is required for understanding the depth of the problem.

Research often takes unexpected turns not foretold by *a priori* hypotheses or by popular expectations. Given the pressures of funding, publication, and peer acceptance, such turns can be unwanted intrusions, or they can be thought-provoking opportunities that lead to original discoveries and controversial applications. The challenge is to follow where the data lead, always cognizant of Orwellian fears and prejudiced misuse of knowledge balanced by the prospects of alleviating suffering from disorders and enhancing the quality of life for everyone. Along the way, controversy can only escalate as we constantly test new knowledge against old and comfortable ideas. This is the way science works and the way our culture evolves.

References

Haier, R. J., & Benbow, C. P. (1995). Sex differences and lateralization in temporal lobe glucose metabolism during mathematical reasoning. *Developmental Neuropsychology, 11,* 405–414.

Haier, R. J., Jung, R. E., Yeo, R. A., Head, K., & Alkire, M. T. (2004). Structural brain variation and general intelligence. *NeuroImage, 23,* 425–433.

Haier, R. J., Jung, R. E., Yeo, R. A., Head, K., & Alkire, M. T. (2005). The neuroanatomy of general intelligence: Sex matters. *NeuroImage, 25,* 320–327.

Jung, R. E., & Haier, R. J. (2007). The Parieto-Frontal Integration Theory (P-FIT) of Intelligence: Converging neuro-imaging evidence. *Behavioral & Brain Sciences,* 30, 135-187.

Kanigel, R. (1991). *The man who knew infinity: A life of the genius, Ramanujan.* New York: Scribner's.

Osen, L. M. (1974). *Women in mathematics.* Cambridge, MA: MIT Press.

Silverman, P. H. (2004). Rethinking genetic determinism. *The Scientist, 18*(10)*,* 32–33.

Stanley, J., Keating, D. P., & Fox L. H. (1974). *Mathematical talent: Discovery, description, and development.* Baltimore: Johns Hopkins University Press.