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Cognition and the Brain: Sex Matters

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Research to determine the nature of cognition has a long and honorable history. Scientific programs to understand the basic processes of cognition—attention, learning, and memory—generally are well-supported and without much public controversy. Cognition is based in the brain, and many researchers around the world are engaged in identifying precisely how the brain manages it. A special urgency is associated with understanding how cognition is disrupted when the brain is attacked by Alzheimer's disease, schizophrenia, stress, aging, and a host of other diseases and insults. Often, researchers interested in dissecting normal cognition find funding only by invoking the promise of their research to elucidate some aspect of abnormal cognition and disease.

It is fair to characterize most research on cognition as normative—that is, its goal is to establish the general principles that underlie basic cognitive processes like learning and memory. Normative research generally focuses on what is common among subjects, whether rats, mice, or humans. If, for example, a drug given to a group of laboratory rats disrupts their subsequent average performance, compared to placebo and control conditions, on a problem-solving task previously memorized, this is evidence that the drug affects the aspect of memory in question.

Researchers who focus on individual differences in cognition, on the other hand, try to address such questions as whether each rat receiving the drug shows the same magnitude of effect on memory. What does it mean if some rats have a very strong effect and others show a weak or zero effect, especially if all the rats are of the same genetic strain and were raised in similar environments? Here is where controversy begins in this exceedingly complex and important work. After a hundred years of laboratory experiments on learning and memory, we still question whether experimental findings can be generalized to answer why some children learn faster or memorize more than others, or why some people reason better than others.

Research on individual differences in cognition has a controversial history. This is to be expected somewhat because of the focus on how we differ from each other, rather than on what we have in common. In fact, research on intelligence has one of the most controversial histories in science, even though intelligence, as commonly understood, refers to little more than individual differences in basic cognitive processes, especially learning and memory. Along with the usual and necessary scientific skepticism and debate about various findings have come emotional and political criticisms, not unlike those targeted against stem cell research. The combination of the study of genetics and/or biology (the basis for modern neuroscience) with research investigations examining the sources of variance for individual differences can be incendiary. In 2005, for example, the president of Harvard University, Lawrence Summers, suggested that, in addition to discrimination and other sociocultural factors, there might also be biological reasons for fewer women than men having careers in science and math. The response to his remarks, especially in academia, was a vociferous and acrimonious outcry and the sudden, compelling desire of the president of Harvard to spend more time with his family. As late as September of 2007, Dr. Summers was abruptly disinvited to speak at a dinner of the University of California (UC) Regents because of some faculty complaints concerning his remarks two years previously.[1]

Uncertainty in the Field

The furor over Summers's remarks also resulted in renewed interest and debate among scientists about what the data on sex differences and cognition actually show and what they mean. One group of prominent researchers recently reviewed the data from several perspectives.[2] They reached a consensus that there are some sex differences in cognitive ability, and that many factors, both social and biological, contribute to career choices in science and math professions. Their summary of the data and the issues, including definitions of key concepts and terms, is succinct and demonstrates why simple conclusions are not yet possible. Another comprehensive and balanced presentation of the data and their interpretation by many experts on this issue can be found in a collection of papers published in 2007 by the American Psychological Association, entitled, *Why Aren't More Women in Science?*[3] In its concluding chapter, the editors summarize several key issues, focusing on areas where the same data are interpreted differently by researchers. Among them are the following four:

- *The right tail of the distribution.* On average, males and females are essentially equivalent on most measures of cognitive performance, although some differences in specific abilities are consistently found. An important question is whether there are more males at the very highest end of the distribution of science and math ability. This argument centers not on superior ability in the top 5 percent or even the top 1 percent, where sex differences are not large and may have no practical implication for professional success. Rather, the question is about extraordinary ability in the top one-tenth of 1 percent. Some of the best evidence about this rarified group (that is, about 1 of 10,000 individuals) comes from longitudinal studies of mathematically precocious youth begun at Johns Hopkins University more than thirty years ago. Based largely on the results of the SAT-M test, this research shows more boys than girls in the extraordinary range. There is no definitive explanation for why more boys than girls score in the top one-tenth of 1 percent, but some think that the use of the SAT-M for this categorization may not provide an accurate reflection of underlying aptitude, as opposed to manifest performance. Others argue that performance tests always assess aptitude, at least to some degree. Experts also disagree as to whether the magnitude of the performance difference (three to one in recent data, down from thirteen to one in the early 1970s data) suggests a biological basis.[4]

- *Real-world demands.* Gender-related real-world demands are a subject of much interest with respect to explaining why there are fewer women in certain fields. Whereas experts generally agree that the most successful professional achievement requires the dedication to it of over sixty hours a week, data indicate that women work fewer hours in their professions because of competing cultural roles demanding more of them for childrearing and family responsibilities. Some data also suggest that women who work fewer hours end up being more satisfied. As is often the case, especially when using survey data, conflicting interpretations are frequent.[5]

- *Differing preferences.* Some data indicate that differing career interests may account for fewer women than men choosing certain professions, suggesting that, on average, women prefer people-oriented professions (such as medicine and law) while men prefer object-oriented ones (such as engineering and physics). Interpretations of these data also differ. At best, the factors shaping any such differences in career interests are not well established empirically.[6]
- *Interaction of biology and environment.* A small biological advantage for some attribute may lead a person to seek out environments in which the advantage comes to flourish. Disentangling such effects is difficult. They may contribute to fewer women being in certain professions, but this is not determined.[7]

These examples underscore the uncertainty among researchers regarding the existence and importance of sex differences in cognition as they may relate to professional choices and success. Ceci and Williams wonder how this research can even proceed when some interpretations of data, especially those suggesting some biological basis for some sex differences, are offensive to many people. They conclude that "all legitimate views need to be aired openly for science to flourish and for policies to be well informed by scientific findings."[8]

Certainty at the NAS

A committee of the National Academy of Sciences (NAS) has taken a different position. Their report on women in science, Beyond Bias and Barriers: *Fulfilling the Potential of Women in Academic Science and Engineering,*[9] includes specific recommendations to address the paucity of women in the physical sciences and engineering. While summarizing essentially the same research literature covered by Ceci and William's book and the review by Halpern and colleagues, the NAS report finds far less nuance and uncertainty in the data. It asserts that sex differences in cognition, if they exist at all, do not have any bearing on why fewer women are in physical and engineering professions, and reasons that if there are no sex differences in cognition, there is no need to argue over their cause. The report endorses support for additional research on social and cultural factors to address the gender imbalance in certain professions; there is no endorsement for more biological or neuroscience research.

Here is the committee's logic, as expressed in the opening summary of chapter 2 of the report, entitled, "Learning and Performance":

> 1. Most research studies of sex differences in cognition find more overlap than differences and any differences tend to be small. 2. When average differences are found, the differences are on measures designed to predict high school and college success; and since there is no longer any academic performance difference between male and female students, there is no gender gap to explain. 3. The observation that there are more males than females in the very top tier of performance on tests of mathematical reasoning is based on tests (e.g. the SAT-M) designed to predict high school and college success, not success in science careers. 4. Thus, we can not look to cognitive sex differences to explain the differential success of men and women scientists and engineers.[10]

The data interpretations given to justify this logic are not compelling. Virtually all researchers in this field agree with point 1, but questions remain open with respect to aspects of spatial ability and their relationship to mathematical reasoning, a key component of science and engineering. Point 2 also is widely accepted for most cognitive abilities, but the same questions about spatial ability remain, especially about the top one-tenth of 1 percent of students. Point 3 is based on a frequently used ploy to blame the test when results are controversial; more importantly, the SAT-M specifically has been shown to predict professional success.[11] As to point 4, despite the NAS committee's assertion, research questions about sex differences in cognition that may have bearing on the imbalance of women in certain professions remain unresolved.[12]

The NAS report also all but eliminates the possibility that any biological factors may be relevant to understanding the complexities of professional success. The report does acknowledge anatomical and functional differences between the brains of males and females, but asserts that "studies of brain structure and function . . . have not revealed biological differences between men and women in performing science and mathematics that can account for the lower representation of women in these fields."[13] The wording of this assertion is overly precise—what, exactly, would such brain studies look like? Have any studies, positive or negative, been directed at this exact wording of the problem?

Some Relevant Brain Data

It would be odd to assume that cognition had nothing to do with the biology of the brain, and it would be even odder to assume that individual differences in brain biology were not related to individual differences in cognition. Tools to study the brain directly have only become available to cognition researchers relatively recently. Neuroimaging techniques are especially powerful, and many researchers are now engaged in determining how brain structure and function are related to cognition. Thousands of these studies are published; most are directed at normative processes and do not investigate individual difference, and most do not address any male/female differences.

There are exceptions in which male/female differences are specifically investigated; some of these studies are even cited in the NAS report.[14] Haier and Benbow first addressed the question in 1995, when we used functional brain imaging with positron emission tomography (PET) to examine the brain areas used for mathematical reasoning.[15] We studied twenty-two male and twenty-two female college students. Half of each group was selected for having had college entrance SAT-M scores over 700, and the other half for having had average scores. All subjects were scanned while they performed a new SAT-M test. Brain activity in specific parts of the temporal lobe was correlated to SAT-M score in the men, but not in the women. This was a clear difference. Note that even though the key research design element in this study was selecting male and female subjects matched for mathematical reasoning ability, the data still showed a strong sex difference in the brain. This methodology took the investigation of biological factors and sex differences in cognition in a new direction by investigating whether different brain architectures or designs produced equal cognitive performance.

Recently, we reported a similar finding using structural magnetic resonance imaging (MRI) to assess gray and white matter throughout the brain and correlating the amount of tissue with IQ scores from the Wechsler Adult Intelligence Scale (WAIS). We found significant correlations for several brain areas,[16] but the areas differed for men and for women matched on IQ scores and controlling for brain size.[17] In men, more gray matter was related to IQ; in women, white matter was more important. These results suggested that the brain might have more than one organization designed for intelligence.[18] Interestingly, one of the areas which appeared to be more important for intelligence in men than in women was in the parietal lobe, an area important for visual-spatial ability; it is an area where Albert Einstein's brain, at autopsy, showed greater volume than control brains.[19]

Based on a review of thirty-seven neuroimaging studies of intelligence published since 1988, a specific network of brain areas has been proposed as a neural basis for intelligence,[20] but there are not yet enough studies to tell us if the same network details apply to both males and females. The study of brain structure and function in individuals selected for extraordinary ability in a specific cognitive domain may be particularly informative. More than one brain design or architecture may be identified, and each may be related to high cognitive performance. Research to determine the frequency of these hypothesized brain designs in males and females, matched for extraordinary ability, may be important in understanding the depth of the career disparity problem. Even matching males and females for average performance at the fiftieth percentile may yield different brain architectures. Such studies done in children surely would elucidate important developmental factors.[21] Even a passing familiarity with neuroimaging studies like these demonstrates that there is so much we do not know and so much yet to discover about brain biology and sex differences, and perhaps even career choices.

Offense and Myth

The NAS committee's discussion of biology concludes, "Because men and women do not differ in their average abilities and because they have now achieved equal academic success in science through the college level, there is no sex performance difference for the biological studies and theories to explain."[22] This logic is not compelling for such a definitive closure. What about the observed fact of fewer women in science and engineering professions after college? Could brain differences between men and women emerge in later life when some brain-related genes turn on or off? Are there any biological factors at all which could have even a little to do with the disparity? Given the sophistication of neuroimaging technology and other neuroscience techniques, would it not be appropriate for the NAS committee to call for more research rather than for none? Whatever social and cultural factors help explain gender differences in science professions, and there surely are important ones, why must the possibility that any biological factors contribute even a little to the disparity be excluded so definitively? It is likely that, as Ceci and Williams acknowledged, some people are offended by the possibility that biological factors, genetic or not, may be involved. Such offense is often based on misunderstanding or myth about what it means if something is biological.

There is no need for such offense. Suppose a human attribute "X" is the result of biological processes. This does not mean that X is destined to be fixed in stone, even if there is a genetic component to the biological process (not every biological phenomena is genetic, but anything genetic always works through biology, whether through interaction with the environment or not). Moreover, the possibility that X may actually change is not the basis for a logical argument that X cannot be biological or even genetic. Biology can be changed, as is apparent every time you see your doctor and ask for broken biology to be fixed. If X has a genetic component, it may not be expressed equally in all populations, and the frequency of genes may differ; that is why there are more blue-eyed people in some countries than others. Inferences that X confers inferior or superior status on a person or a group are judgmental and inappropriate, whether X has a biological basis or not. When it comes to X, interactions between brain and environment are two-way streets (this used to be called the nature/nurture debate). More knowledge of how the interactions work in both directions is always better than less.

It is surprising and unfortunate that myths and misunderstandings surrounding such issues are well represented in chapter 2 of the NAS report.[23] Efforts of neuroscience to understand the biology of how the brain works, both in general and in individuals, face serious and important questions whose resolution requires unprejudiced scientific approaches to understanding sex differences. We may find, for instance, that men and women of equal cognitive ability use different brain mechanisms to achieve the same performance. If so, we have learned something potentially important for cognitive rehabilitation following brain injury, and for minimizing the effects of normal aging or brain disease. We may also learn that one brain mechanism is more common than another in either sex. This could have a bearing on different rates of career choices and success. Diane Halpern, a leading researcher on cognitive differences between men and women, is quoted in the NAS report:

> Some researchers object to the study of sex differences because they fear that it promotes false stereotypes and prejudice. There is nothing inherently sexist in a list of cognitive sex differences; prejudice is not intrinsic in data, but can be seen in the way people misuse data to promote a particular viewpoint or agenda. Prejudice also exists in the absence of data. Research is the only way to separate myth from empirically supported findings.[24]

It is disappointing that the NAS report apparently ignores this sentiment when it comes to the exciting potential of neuroscience investigations for understanding more about sex differences.

Conclusion

We just do not have simple answers about the observed disparity in the presence of men and women in science and engineering professions because there are compelling data that suggest several interacting factors, some cultural and social, others biological. Objective readers will understand that no one study or perspective will provide a satisfactory understanding of the complexities of career choice and professional success. Many may conclude that the data are not sufficiently clear to inform public policy discussions concerned with the number of women in science and other professions, let alone provide a basis for specific public policies. It is entirely possible that the data will never be clear, given the inherent limitations of scientific methods applied to complex human activities. It is also possible that compelling data will point in directions politically or socially uncomfortable.

The NAS recommendations can be debated on their social and political merits alone. Scientific justifications typically are not required in matters of public policy, and scientific data often do not influence policymakers in how social goals are set or achieved. But, if scientific findings are introduced as part of the debate, all the relevant data need to be considered fairly. The scientific study of sex differences in cognition will continue on many fronts, including biology, genetics, and neuroimaging, whether these approaches are endorsed by a particular NAS committee or not. Progress in neuroscience is globally competitive and inexorable. The rate of progress is tied to funding availability, and we need to ensure that funding sources are unbiased, especially when scientific questions are directed at controversial and emotional social issues like the disparities between men and women as they choose and work in various professions.

In *Why Aren't There More Women in Science?* editors Ceci and Williams concluded their summary discussion of the "knotty problem" with a quote from one chapter, "Brains, Bias, and Biology: Follow the Data."[25] It is repeated here with optimism:

> 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.[26]

Notes

1. Dr. Summers, despite this controversy, now holds a senior position in the Obama administration.
2. Halpern et al. 2007.
3. Ceci and Williams 2006.
4. Ibid., 214–17.
5. Ibid., 217–20.
6. Ibid., 220–22.
7. Ibid., 230–32.
8. Ibid., 233.
9. National Academy of Sciences et al. 2006.
10. Ibid., 2.
11. See the review of the long-running Study of Mathematically Precocious Youth in Lubinski and Benbow 2006, and the discussion of it in chapter 9, below.
12. Ceci and Williams 2006; Halpern et al. 2007.
13. National Academy of Sciences et al. 2006, section 2-3.
14. Ceci and Williams 2006; Halpern et al. 2007.
15. Haier and Benbow 1995.
16. Haier et al. 2004.
17. Haier et al. 2005.
18. Please note this is not the same as "intelligent design"!
19. Witelson et al. 1999.
20. Jung and Haier 2007.
21. Schmithorst and Holland 2006 and 2007.
22. National Academy of Sciences 2006 et al., 2–16.
23. Ibid., 2.
24. Ibid., 2–5.
25. Haier 2006, 113–19.
26. Ibid., 233–34.

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