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# From Scanner to Sound Bite: Issues in Interpreting and Reporting Sex Differences in the Brain

**Cordelia Fine**

Centre for Agency, Values and Ethics, Macquarie University, and Department of Psychological Sciences, University of Melbourne

**Abstract**

Neuroimaging research is yielding reports of sex differences in the brain. Yet the likelihood of spurious findings of sex differences, the teething problems of new technology, the obscurity of the relation between brain structure and psychological function, and difficulties inferring mental states from neuroimaging data all require us to be considerably cautious in interpreting such results. Unfortunately, these issues are often overlooked in popular accounts. Together with a tendency for people to regard neuroscientific information as more scientific than behavioral data, and as indicative of male and female "nature," these issues point to the worrisome possibility of public misunderstanding of what contemporary neuroscience tells us about gender.

**Keywords**

neuroimaging, gender, science communication, neuroethics

For as long as there has been brain science there has been both scientific and popular interest in male–female differences and their psychological consequences. For example, 19th-century scientific opinion held that women's intellectual inferiority could be attributed to their smaller and lighter brains—a fact that was widely known among the Victorian public as the "missing five ounces" of female brain (see Russett, 1989). Today, the weighing scales and other crude methodologies of the Victorian brain scientists have been supplanted by sophisticated neuroimaging techniques that give unprecedented access to structural details of the brain and patterns of neural activity. Yet there remains cause for skepticism regarding neuroscientific claims about sex differences and concern over the way such information is reported to, and interpreted by, the public. In this article, I lay out four scientific issues arising from the production and interpretation of "facts" about sex differences in the brain, then discuss how these issues are overlooked and exacerbated when neuroscience findings are disseminated in the popular media and digested by the public.

To illustrate these points, I use as an example a long-standing and influential claim about male–female brain difference. The greater male lateralization (GML) hypothesis proposes that males, compared with females, are more strongly left hemisphere dominant for language processing and right hemisphere dominant for visuospatial processing. Females, by contrast, tend to engage both hemispheres for these tasks and, in keeping with the female brain's supposedly more interhemispheric functioning, are claimed to have a relatively larger corpus callosum (the bundle of neurons that connects the two hemispheres). In both academic and especially popular work, these structural differences are proposed to have psychological implications.

## Production: The Problem of Spurious Results

When neuroscientists, in a single experiment, establish a "significant difference" between the sexes, does this reflect a real and reliable sex difference? Because sex is a primary and ubiquitous social category, classifying participants by sex is obvious, easy, and may be done by default (Kaiser, Haller, Schmitz, & Nitsch, 2009). However, since by convention researchers declare a difference to be "significant" if there is no more than a one in 20 probability that it occurred by chance, if 20 researchers routinely test for sex differences, then even if there is no real difference between the populations, one

**Corresponding Author:**
Cordelia Fine, Department of Psychological Sciences, University of Melbourne, Victoria 3010, Australia
E-mail: cfine@unimelb.edu.au

researcher will find a statistically significant difference. The concern is that, given that the publication process is geared toward emphasizing difference rather than similarity, this 1-in-20 finding of difference will be reported while the 19 failures to find a difference will not. Indeed, Kaiser et al. provide examples of how, in language research, even marginal sex differences in the brain are given prominence in the published paper.

The problem of spurious results for all sex-differences research has been long-noted. However, the inevitable teething problems of the new neuroimaging technologies may exacerbate the situation. Nuisance variables like breathing rate and caffeine intake can influence the imaging signal and give rise to spurious results; this is particularly the case when sample sizes are small, as they often are in the studies that have reported sex differences (Wallentin, 2009). Researchers have found that sex differences in language lateralization fail to generalize to a distinct but similar task within a second group of men and women and that identical analyses of the same participants can also "discover" brain-activation differences between randomly created groups matched on sex, performance, and obvious demographic characteristics (Ihnen, Church, Petersen, & Schlaggar, 2009). As controversies over statistical procedures are resolved, researchers may turn out to have used inadequate or inappropriate techniques: It has recently been argued that some reported sex differences in language lateralization have not been put to adequate statistical test or that they can come and go depending on how the analysis is done (Kaiser et al., 2009). There is also an as-yet-unresolved controversy regarding how—or even whether—neuroscientists should control for the sex difference in average brain size when attempting to establish whether the sexes differ in the volumes of particular brain regions (see, for example, Fausto-Sterling, 2000). A change in methodology can transform what appears to be a sex difference into a difference between people with smaller and larger brains (e.g., Im et al., 2008).

These difficulties point to the importance of not placing too much confidence in any single functional or structural neuroimaging study that seems to demonstrate a sex difference. The wisdom of such caution is demonstrated by meta-analyses of tests of the GML hypothesis. A recent meta-analysis of 26 functional neuroimaging studies of language lateralization found no significant sex difference (Sommer, Aleman, Somers, Boks, & Kahn, 2008). Similarly, a meta-analysis of 49 postmortem and structural neuroimaging studies of the corpus callosum found no support for the hypothesis that this structure is larger in females, even allowing for their relatively smaller brains (Bishop & Wahlsten, 1997).

The failure of meta-analyses to support predictions of the GML hypothesis, to which much research attention has been devoted, highlights the importance of remaining skeptical about other reported sex differences. Clearly, isolated reports of sex differences in brain activation or regional brain volume require replication and generalization before they can be assumed to be reliable.

## Interpretation: The Obscurity of Structure–Function Relations

Further difficulties arise when it comes to understanding what, if anything, brain differences might imply for psychological function. Despite the extraordinary progress made in neuroscience, we still have minimal understanding of how neural structures contribute to complex psychological phenomena. Again, the GML hypothesis is an instructive example: There is no a priori reason to think that a more lateralized brain would be advantageous for visuospatial processing but disadvantageous for language function. (Nor, to my knowledge, have any such relations been demonstrated.) Bishop and Wahlsten (1997) questioned the assumption that a modest size difference in a structure as complex and massively interconnected as the corpus callosum would have tangible implications for a specific psychological construct.

Nonetheless, functional speculations arising from the GML hypothesis have recently taken new form in suggestions that a male brain skewed toward more lateralized, intrahemispheric processing may be advantageous for scientific disciplines that supposedly require focused scrutiny of details rather than integration of information (Baron-Cohen, Knickmeyer, & Belmonte, 2005; Gur & Gur, 2007), and that a female brain skewed toward more long-range processing may be advantageous for empathizing (Baron-Cohen et al., 2005).

While speculation is an important part of the scientific process, as Fausto-Sterling (2000, p. 118) has observed, the problem is that "despite the many recent insights of brain research, this organ remains a vast unknown, a perfect medium on which to project, even unwittingly, assumptions about gender." As noted earlier, it was once readily assumed that brain weight correlated with intelligence, thus explaining women's supposed intellectual inferiority. With that history in mind, we should be wary of suggestions that the typical female brain is suboptimally designed for currently male-dominated pursuits like science—suggestions made in the absence of adequate knowledge of how the brain enables scientific thinking and practice. There is no neuroscientific reason, for example, to think that the shorter circuits of an intrahemispheric brain will enable narrower focus in the mind.

Inferring a mental process from significant activation in a particular brain region (for example, inferring that the amygdala was activated, therefore participants were anxious) is known as reverse inference and is also fraught with difficulty. The statistical procedures of functional neuroimaging identify regions that are differentially activated by the experimental task, compared with a control task. However, while brain function involves specialization—the entire brain is not involved in all of its functions—there is no simple one-to-one mapping between brain regions and psychological processes. Mental processes arise from the complex interaction of multiple areas, and any one region will be involved in any number of mental processes. The anterior cingulate, for example, is activated by so many tasks that one cognitive neuroscientist known to the author refers to this region as "the on button" (Geoffrey Boynton, personal communication).

Moreover, the psychological implications of significant differences in the *amount* of brain activity in particular regions are ambiguous. "More" activity does not necessarily imply psychologically "more" or 'better," or even that that region is critically involved in that particular task (Poldrack, 2008). Furthermore, data acquisition in functional magnetic resonance imaging (fMRI) is slow: At its most sensitive, it averages over a few seconds the activity of millions of neurons that can fire up to one hundred impulses a second. (Positron emission tomography, PET, is even slower.) This massively limits the interpretations that can be made about brief psychological events.

Thus it becomes clear that observing, say, significantly greater female anterior cingulate activity over the time course of the performance of a complex task is unlikely to indicate what mental process, if any, differs between males or females, or in what direction that difference lies. It has been argued that reverse inferences can be valuable when the underlying processes involved in the participants' task are well known, and when they are used to generate hypotheses that drive further experimental work rather than to interpret neuroimaging results (Poldrack, 2008). However, so far these conditions are rarely, if ever, met in neuroimaging studies of sex differences. These obstacles to valid reverse inference severely constrain the possibilities for making inferences about psychological differences between males and females from brain activation differences, even supposing these differences reported in studies are statistically valid and reliable.

## Popular Dissemination

While neuroscientists may routinely test for sex differences in the brain and emphasize those they find, or engage in post hoc speculations about such differences' functional implications, they are presumably aware of the issues outlined previously and are engaging with peers who share this knowledge. The public, however, rarely gain its knowledge from neuroscientists or the neuroscientific literature. Instead, information is presented to the public by popular writers. That such writers are either not aware of the critical issues of production and interpretation I have outlined or think them unimportant may be inferred from the fact that their books confidently purport to offer practical applications for life, love, and learning on the basis of sex differences in the brain.

Consider, for example, how the GML is presented in the popular literature. It is not only regularly asserted as fact rather than a hypothesis (a poorly supported one, as noted) but is used as a springboard for scientifically unwarranted claims about men's and women's different psychological abilities. Thus one author (working from an implicit metaphor of the brain as pinball machine) explains how men's language lateralization impairs their ability to talk about their feelings, describing how the "signal" of an emotional feeling, having made it to the right hemisphere, "may well get stopped, disappearing into neural oblivion because the signal found no access to a receptor in a language center in the left side of the brain" (Gurian, 2004, p. 88). Similarly, the corpus callosum is regularly claimed to be (as much as 25%) larger in females, furnishing them not just with superior language skills but also greater multitasking ability, a more intuitive leadership style, better emotion processing, and even greater capacity to remember to buy milk (see Fine, 2010).

Even books written by apparently authoritative and well-credentialed authors are rife with invalid structure–function claims and reverse inferences, as well as factual errors, that go well beyond the GML hypothesis. To cite just a few examples from a multitude, functional neuroimaging findings may be used as evidence of sex differences in intrinsic interest in mathematics, in "hard-wired" ability to talk about feelings, or in capacity to empathize with the feelings of others. As I have discussed elsewhere (Fine, 2010), these particular claims were made in part on the basis of studies that, respectively, didn't involve mathematics, didn't involve talking about feelings, and didn't involve male participants. Furthermore, it should by now be clear that currently *no* neuroimaging data could be cited as compelling support for such claims.

## Popular Digestion

In addition to overinterpretation, misinterpretation, and misrepresentation, a number of characteristics of neuroscientific information and the way it is often communicated may further contribute to public misunderstanding. With its expensive, complex machinery, the data yielded by neuroscience may seem somehow more scientific and real than data collected in less high-tech fashion. A consequence of this "neuro-realism" (Racine, Bar-Ilan, & Illes, 2005) is that substantial behavioral evidence of gender similarity may be overshadowed by a single finding of a sex difference in the brain. There may also be a tendency to equate "in the brain" with "innate." Although the effects of gender socialization must manifest in the brain (where else?), some popular authors promote the idea that brain differences constitute evidence that the sexes are "hard-wired" to be different. Lastly, neuroscientific data have been shown to have a "seductive allure": For instance, people find circular explanations of psychological phenomena more satisfying when accompanied by information about brain responses (Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). Thus, popular neuroscience is well placed to entice people to overlook psychological and sociological data showing that gender difference is contingent on historical period, ethnicity, socioeconomic group, and social context and to instead conclude that gender differences are immutable, inevitable, and the product of fixed differences between the "male brain" and the "female brain."

## Conclusion

While neuroimaging has potential to contribute in novel ways to our understanding of gender, scientists, popular commentators, and the public need to be alert to the problem of premature speculation about sex differences. The possibility of neuroimaging "facts" about male and female brains—that may be spurious, overinterpreted, misinterpreted, or even fabricated—influencing public attitudes about gender raises ethical concerns. The imaginative reader will not have too much difficulty envisaging how, by reinforcing stereotypes, such claims may affect people's social attitudes in ways that oppose progress toward greater gender equality, just as such claims did in the past. The task now is to open a dialogue between the producers, communicators, and consumers of knowledge about sex differences in the brain and to take seriously the issues that arise from scanner to sound bite.

## Recommended Reading

Fine, C. (2010). (See References). An accessible book that covers all the issues in more detail than the current article.

Lehrer, J. (2008, August 17). Of course I love you, and I have the brain scan to prove it – We're looking for too much in brain scans. *Boston Globe*, K1. An accessible account of general interpretative issues in fMRI research.

Miller, G. (2008). Growing Pains for fMRI. *Science*, *320*, 1412–1414. A useful and accessible overview of issues, controversies, and potential solutions in the interpretation of fMRI data that provides concrete examples.

Russett, C. E. (1989). (See References). A historical account of Victorian brain science and its reactionary role in social attitudes toward female suffrage and higher education—surprisingly helpful for illuminating current biases in neuroscientific interpretation.

Weisberg, D. S. (2008). Caveat lector: The presentation of neuroscience information in the popular media. *The Scientific Review of Mental Health Practice*, *6*, 51–56. A readable overview outlining the limited insight into psychological processes offered by fMRI, the potential danger of the overinterpretation of neuroimaging data in popular media, and the role of scientists in alleviating this problem.

## Declaration of Conflicting Interests

The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

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