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Science or belief? Bias in sex differences research

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Abstract

Theories of inherent sex differences for mathematics and scientific abilities have recently re-emerged. In the present paper, it is argued that these theories are problematic for several reasons: their reliance on untested assumptions, methodological and epistemological biases, and poor comprehension of the neurological and genetic underpinnings of development. Finally, some of these theories are proposed by researchers who lack a solid background in neuroscience and genetics. As a consequence, the existence of innate gender differences is often accepted uncritically, without analyzing the equivocal or contradictory data existing in the literature, and without discussing the role of social and experiential factors that can explain such differences when they are present.

Negli ultimi decenni sono emerse diverse teorie scientifiche secondo le quali esisterebbero differenze innate tra i due sessi in termini di abilita' matematiche e scientifiche. In questo lavoro si evidenzia come queste teorie si basino su assunti mai chiaramente dimostrati, su studi empirici metodologicamente viziati, su errori di natura epistemologica, e su una scarsa comprensione dei processi neurali e genetici dello sviluppo. Alcune di queste teorie, inoltre, sono proposte da studiosi che mancano di una solida preparazione nel campo delle neuroscienze o della genetica; di conseguenza, l'esistenza di differenze innate tra i sessi viene spesso postulata ed accettata in modo acritico, senza un'analisi appropriata dei numerosi dati equivoci o contradditori presenti in letteratura, e senza la debita discussione dei molti fattori esperienziali e sociali in grado di spiegare tali differenze quando esse siano presenti.

> "Research on presumed sex differences in cognitive abilities is an area of the natural sciences in need of the drastic revision that feminists effected in the field of primatology. This field is fraught with unexamined or untested assumptions, with inconclusive and contradictory findings and misleading interpretations that become incorporated into belief systems called *theories*, and with the reckless use of language designed to appeal to the news media and a reading public highly susceptible to scientific pronouncements, especially those that confirm common beliefs."
>
> Ruth Bleier (1991, p. 147)

The number of women graduating in science programs and entering the science work force has considerably increased in the last two decades. In Europe, 50% of the undergraduate degrees are now granted to women (European Technology Assessment Network Working Group on Women and Science, 2000). However, a gap still exists between the proportion of women who earn Ph.D.'s and those who are in faculty positions at top universities (Handelsman, et al., 2005). Furthermore, although women receive 50% of Ph.D.'s granted in medicine and biology, their number remains low in the hard sciences (i.e., engineering, mathematics, and physics).

These data have been interpreted in two ways. According to the first interpretation, cultural and structural obstacles have prevented, and in some cases still prevent, women from pursuing or succeeding in academic careers (Bertsch McGrayne, 1998). Prejudices and stereotypes still influence how women scientists are perceived and their performance evaluated, even if at an unconscious level. For example, in a study by Steinpreis, Anders, and Ritzke (1999), academicians were more likely to indicate that they would hire a potential male colleague than an equally qualified female colleague. A study of postdoctoral fellowships awarded in Sweden found that female applicants were given lower scores than equally productive male applicants (Wennerås & Wold, 1997). Furthermore, women are less encouraged than men in their choice of pursuing a scientific career, often do not have the chance to work with women who serve as role models (such as advisors, principal investigators, and lab directors), and must balance responsibilities at work and in the family (Handelsman et al., 2005). Finally, the low number of women in the hard sciences may be due to the fact that women have entered these fields later than fields like medicine and biology. For example, in the last 35 years there has been a 30-fold increase in the proportion of Ph.D.'s granted to women in engineering (Handelsman et al., 2005). Therefore, the gap between the proportion of women in biology and those in engineering may be temporary.

According to the second intepretation, in addition to the above-mentioned obstacles, there exist inherent sex differences in scientific abilities and interests (Baron-Cohen, 2003[1]; Halpern, Wai, & Saw, 1995; Pinker, 2005). Such differences, albeit minimal, are purportedly constant in the population and are reflected in the higher number of men in the hard sciences and among the Nobel Prize winners in science, and in males' better performance in math standardized tests (Baron-Cohen, 2003). Furthermore, sex differences in interests and preferences are purportedly present in newborns (Connellan, Baron-Cohen, Wheelwright, Batki, & Ahluwalia, 2000), when behavior is not influenced by social and cultural expectations or previous experiences. In most cases, these differences are explained in terms of different concentrations of sex hormones *in utero* or during development (Baron-Cohen, 2003; Halpern et al., 2005; Kimura, 2005).

Theories of innate sex differences in cognitive abilities have become extremely popular, as demonstrated by the recent comments of the ex-president of Harvard University, Larry Summers (Summers, 2005). The goal of this paper is to examine some of the problems that taint the field of sex difference research. Some of these problems have already been discussed elsewhere (Barres, 2006; Bleier, 1984, 1991; Caplan & Caplan, 2005; Fausto-Sterling, 1985; Nash & Grossi, in press; Spelke, 2005). The present discussion will therefore focus on the following aspects: 1. Reliance on undemonstrated assumptions; 2. Lack of methodological rigor; 3. Lack of epistemological rigor; and 4. Simplifications and inaccuracies in scientific and popular scientific literature.

1. Undemonstrated assumptions

One of the most often cited data to support the existence of inherent sex differences for scientific abilities concern the male advantage in standardized mathematical tests (Halpern et al., 2005; Pinker, 2005). The most popular quantitative standardized tests employed in the United States are the SAT[2], required for college admission, and the Graduate Record Examination (GRE), required for admission to graduate school. According to recent data (Halpern et al., 2005), the male advantage in these tests is considerable, especially among talented students, and, for the SAT, has remained constant in the last 25 years.

However, studies that have employed different mathematical tests have failed to report differences between girls and boys or have observed differences in the opposite direction (Pajares, 1996). Moreover, tests used in international assessments have revealed that the male advantage, although present in several countries, is certainly not ubiquitous. For example, in the 2003 Programme for International Student Assessment (PISA) assessment of 250,000 students (Organization for Economic Cooperation and Development, OECD, 2004), boys scored higher than girls in mathematical tests in 27 countries out of 40. In Iceland, not only did girls scored much higher than boys on the same tests; they scored higher than American boys. Finally, data on scholastic achievement show that girls outperform boys in any field and discipline, even in advanced math courses (Kimball, 1989).

Some have suggested that the difference between results on standardized tests and school achievement is due to the use of different cognitive strategies: girls are better than boys in retrieving previously learned information and applying conventional solutions to problems (hence their better performance in school assignments and exams), whereas boys are better than girls in manipulating information in working memory and solving problems by employing less conventional solutions (hence their better performance in standardized tests; Gallagher & DeLisi, 1994; Halpern et al., 2005). Gallagher and DeLisi (1994) also suggested that these differences are probably due to both biological and experiential factors (p. 210), a comment not followed by the discussion of pertinent empirical evidence. Indeed, as Caplan & Caplan (2005) pointed out, in the Gallagher and DeLisi study most participants, regardless of their sex, adopted conventional solutions. Therefore, there is no reason to believe that these cognitive strategies are fixed and associated with biological sex.

Standardized tests are considered a more adequate measure of mathematics abilities than school achievement for two reasons: first, they allow us to examine how one's mathematical knowledge is applied to new problems; second, girls are more diligent than boys in school and such diligence might conceal differences in underlying abilities (Pinker, 2005). In reality, it is unclear what standardized tests measure, given that their construction follows psychometric criteria and is not based on detailed models of the cognitive processes that they intend to measure (Gallagher & Kaufman, 2005). Moreover, gender differences in these tests do not emerge until the late adolescence (Spelke, 2005), at an age when, in many countries, girls and boys start taking different classes. For example, in the Unites States many more boys than girls take advanced courses of calculus, chemistry, physics, and computer science (U.S. Census Bureau, 2004-2005). Therefore, gender differences in these tests could simply reflect differences in curricula.

Finally, performance in standardized tests is notoriously influenced by social and psychological factors. For example, individuals of a stereotyped group underperform when tested in a situation in which their performance could confirm a negative stereotype about the group to which they belong. This psychological pressure, known as "stereotype threat" (Aronson, Lustina, Good, & Keough, 1999), has been described in several stereotyped groups, including women (Inzlicht & Ben-Zeev, 2000; Spencer, Steele, & Quinn, 1999). In these experiments, the stereotype is primed by simply asking participants to indicate their gender or ethnic group before the administration of the test, or by explicitly informing them that other social groups score higher in the test at hand. Importantly, gender differences are reduced or eliminated when the stereotype threat is minimized or removed. For example, differences on the GRE in college students were eliminated when female students were informed that females and males obtain similar scores in the test (Spencer et al., 1999) or when they were informed of the negative effects associated with the stereotype threat (Johns, Schmader, & Martens, 2005). Furthermore, Inzlicht & Ben-Zeev (2000) have shown a negative correlation between GRE scores of female students and number of male students present during the test. In this case, the mere presence of a male student is sufficient to activate the negative stereotype that associates women to lower performance in mathematics.

These results show how performance on standardized tests is influenced by psychological and social factors that are not associated to the abilities that these tests purport to measure. Therefore, the assumption that gender differences in such tests reflect inherent differences in abilities remains undemonstrated.

<u>2. Lack of methodological rigor</u>

One of the elements that characterize methodological rigor in science is the attempt to exclude the role of confounding factors in the explanation of a particular phenomenon, attained through a rigorous experimental control. Furthermore, the interpretation of empirical evidence must be justified based on both methodological and logical considerations. In most works on gender differences in mathematics, standardized math tests are administered to female and male students. Because the two groups of participants differ in terms of experiences and socio-cultural backgrounds, it is difficult to interpret differences in scores when they are present. Nevertheless, some scholars have interpreted them as reflecting a biological male advantage for visuo-spatial abilities (Geary, 1996; Nuttall, Casey, & Pezaris, 2005) or for the ability to analyze and comprehend systems (Baron-Cohen, 2003).

According to Baron-Cohen (2003), "The female brain is predominantly hard-wired for empathy. The male brain is predominantly hard-wired for understanding and building systems." (p. 1). The development of such hardwiring is based on the action of fetal testosterone, as hypothesized by a theory proposed at the beginning of the 1980s by Geschwind, Behan, and Galaburda (Geschwind & Behan, 1982; Geschwind & Galaburda, 1987), which will be discussed later. According to Baron-Cohen (2003), girls and boys behave differently and manifest different interests and preferences from birth (Connellan et al., 2000). These differences are later evident in play activities and personal relationships. Specifically, girls are better than boys in emotionally relating to others, judging emotion, sustaining a conversation, maintaining eye contact and communicating with others. Boys are better than girls in understanding systems, regardless of their nature (e.g., abstract, natural, technical, social), attending to details, analyzing visuo-spatial information, evaluating objects' qualities in terms of space and speed, and classifying and organizing systems. These abilities allow boys to develop an expertise and dominate in a particular discipline. Expertise and competence in math and science are therefore seen by Baron-Cohen as an expression of the male brain (2003, p. 123).

The evidence provided by Baron-Cohen (2003) is generally anecdotal and often not supported by any citations or empirical evidence. His conclusions are also invalidated by the presence of alternative explanations. For example, the author cites a 1999 *Times Higher* article according to which only three of the 170 living Nobel prize winners in sciences are women, a disadvantage interpreted as reflecting gender differences in abilities and interests (p. 71). However, there is ample documentation of the overt discrimination that women in science have suffered for decades (Bertsch McGrayne, 1998) and still suffer, even if such discrimination is perpetrated more subtly or unconsciously (Steinpreis et al., 1999; Valian, 1998; Wennerås & Wold, 1997). Finally, there is no evidence that females and males show different cognitive abilities or interests at birth. The only work documenting cognitive differences in newborns (Connellan et al., 2000) has been criticized for its numerous methodological flaws (Nash & Grossi, in press; Spelke, 2005); moreover, it has never been replicated.

The idea that interests and abilities develop in a social vacuum under the direction of biological mechanisms that proceed blindly, solely controlled by some unspecified internal clock and without interacting with the environment, is simplistic, unrealistic, and incorrect. Mathematics and science are learned in a period of time that spans across several years; passion and application need to be constantly nurtured and encouraged. It is well-known that from birth onwards, girls and boys are exposed to different social and cultural expectations and are treated differently by both peers and adults (see Nash & Grossi, in press, for a more in-depth discussion). Over the course of childhood, they are exposed to different physical environments and toys (Nash & Krawcyzk, 1994) some of which, for example building blocks and videogames, usually given to boys, are known to enhance spatial skills (Baenninger & Newcombe, 1989; Dorval & Pepin, 1986; Subrahmanyam & Greenfield, 1994).

Based on these data, it is both methodologically and logically unjustified to interpret gender differences in standardized tests or the under-representation of women in scientific fields in terms of inherent sex differences. The role of socio-cultural factors (e.g., differential experiences and backgrounds), although mentioned, is never convincingly excluded. Interestingly, theories of biological sex differences often allude to the role of experiential factors in the development of cognitive (i.e., spatial, math) abilities and cortical development (e.g., Halpern et al., 2005); but the contribution of these factors is rarely extensively discussed or accompanied by the relevant scientific literature. At the end, behavioral and cognitive gender differences are mainly explained in terms of differences in sex hormones (e.g., Baron-Cohen, 2003). This position is also unjustified in the light of recent studies in neural plasticity demonstrating both micro- and macrostructural changes in cortical organization following certain types of experiences (Draganski, et al., 2004; Maguire, et al., 1997; Recanzone, Schreiner, & Merzenich, 1993).

3. Lack of epistemological rigor

As already mentioned, the Geschwind-Behan-Galaburda theory (Geschwind & Behan, 1982; Geschwind & Galaburda, 1987) is usually cited to explain gender differences in mathematical abilities (e.g., Halpern et al., 2005). According to a simplified version of this theory, high levels of fetal testosterone, usually present in males, slow down the growth of the left hemisphere and enhance the development of the right hemisphere in terms of both size and functions. Therefore, the theory predicts the existence of hemispheric differences related to biological sex and spatial and mathematics abilities (which are seen as mainly supported by the right hemisphere).

The role of fetal testosterone on cortical and cognitive development is well documented in rats (Lewis & Diamond, 1995), but its contribution in humans, in relationship to spatial abilities, is uncertain. The two studies addressing the relationship between fetal testosterone and spatial abilities in children (Grimshaw, Sitarenios, & Finegan, 1995; Jacklin, Wilcox, and Maccoby, 1988) have provided contradictory results. Furthermore, there is no evidence that fetal testosterone is somehow related to mathematics or scientific abilities, or to success in these disciplines. When structural differences are considered, post-mortem studies (Witelson, Beresh, and Kigal, 2005) and neuroimaging studies on living individuals (Allen, Damasio, Grabowski, Bruss, & Zhang, 2003; Barta & Dazzan, 2003) have failed to report any hemisferic differences associated to sex or spatial abilities. When differences are present, it is difficult to establish if they are present at birth or if they reflect different life experiences (Draganski et al., 2004; Maguire et al., 1997).

Despite the lack of empirical support for many of its predictions (Bryden, McManus, & Bulman-Fleming, 1994), the Geschwind theory is still cited to illustrate the role of testosterone on cognitive development in humans, especially in relation to spatial and linguistic skills (Baron-Cohen, 2003; Halpern et al., 2005). Crucially, the theory itself is cited as experimental evidence for the existence of inherent sex differences for cognitive abilities. For example, Lutchamaya et al. (2002) discuss how fetal testosterone influences the degree of hemispheric lateralization, in turn associated to cognitive functions, and cite four types of evidence, among which is Geschwind's theory (p. 327-328). The same theory is cited by Halpern and colleagues (2005, p. 54-55) to describe the role of sex hormones on cognitive development.

Baron-Cohen (2003) makes a similar epistemological error. While discussing the role of gender role beliefs on sex differences, he cites David Geary's theory, according to which sex differences in behavior, emotion, interests, and skills arose due to evolutionary pressures. In particular, "… more males are agentive because males depend for their reproductive success on a drive to establish social dominance. " (p. 93). Baron-Cohen continues: "… For the gender-role theory to work, it would have to disprove such Darwinian factors. This has not yet been done." (p. 93). This reasoning reveals a fundamental epistemological problem: Darwinian factors and gender role beliefs are treated as mutually exclusive explanations; however, both factors can influence behavior. Therefore, from a logical point of view, disproving the role of one factor does not automatically provide support for the other factor. Furthermore, in science as in jurisprudence, the burder of proof is on those who make a positive assertion. In other words, evidence must be provided to support the existence of Darwinian influences. This is not the case: the existence of the factors hypothesized by Geary has never been confirmed by empirical research. Rather than using data to support his theory, Baron-Cohen uses Geary's speculation as supporting evidence. As Bleier (1991) has argued, the use of theories as evidence, unjustified from a logical point of view and revealing epistemological superficiality, creates the illusion of a structure characterized by weight, consistency, conviction, and reason (p. 149).

4. Simplifications and inaccuracies in scientific and popular scientific literature

Theories purporting the existence of sex differences in mathematics and scientific abilities are characterized by both methodological and epistemological problems. Yet, these theories are appealing to both the reading public and the scientific community. The casual use of expressions such as "hard-wired" (Baron-Cohen, 2003) and "inherent gender differences" (Summers, 2005), along with the continual references to sex hormones, evoke images of stability and unchangeability: women and men behave differently because their brains are structured differently. Although the term "hard-wired" has a very specific connotation in computer science (i.e., fixedness), its meaning is much more opaque in neuroscience: any type of behavior, even if learned, is hard-wired, that is, supported by neuronal activity spread across thousands of synaptic connections. However, this neuronal activity is never "fixed" and changes continuously with experience, as studies on neural plasticity and learning have shown (Draganski et al., 2004; Maguire et al., 1997; Recanzone et al., 1993).

Simplification, inaccuracies, and imprecision in reviewing existing literature, the omission of contradictory results, and the use of theories as evidence for one's model, contribute to the consolidation of the myth of sex differences. For example, as discussed by Nash & Grossi (in press), Baron-Cohen misrepresent the results from the Connellan et al. (2000) paper on newborns and the Grimshaw et al. (1995) paper on fetal testosterone in several occasions. The impression conveyed by his summaries is that differences in preferences at birth are reliable and that fetal testosterone is responsible for the male advantage in spatial tasks. A careful analysis of the two works reveals that these conclusions are actually inaccurate.

The inevitability of cognitive sex differences and their biological origin is taken for granted in college textbooks (Bee, 2000; Gazzaniga et al., 2002), in popular science books (Baron-Cohen, 2003), and even by researchers who work in field of gender differences. For example, in a paper on the effects of socio-economical status on the development of spatial skills, Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher (2005), discuss two exceptions to the widespread male advantage in spatial abilities: a study by Berry (1966) on Canadian Eskimo populations, where no gender differences were found, and the advantage of Icelandic girls on standardized mathematical tests in the 2003 PISA assessment. The authors write, "Because both of these populations are relatively isolated, these patterns may reflect genetic rather than experiential factors." (p. 841). Levine and colleagues borrowed the genetic/geographical isolation hypothesis from McGee (1979, p. 900), whom they cited. Interestingly, they did not cite the results from the 2000 PISA assessment, where no differences were found between Icelandic girls and boys on mathematical tests (National Center for Education Statistics, 2002). This result raises serious doubts on the genetic hypothesis. Remarkably, although the 2000 PISA data were available and easily accessible, Levine et al. (2005) did not consult them or report them. It seems that the genetic argument regarding gender differences is so rooted in our belief system that the search for alternative explanations and the need to justify one's position or hypotheses, which constitute fundamental steps in scientific inquiry, become unnecessary.

As a consequence, the idea of the inevitability of these differences, not balanced by an in-depth discussion on the effects of the environment on cognitive and brain development and not supported by convincing empirical evidence, has the potential to penetrate, indisputed, into the belief system of a culture and shape it in terms of expectations and sexual roles. The impression is that science today is confirming intuitions and beliefs about gender differences. On the contrary, in the absence of methodological and epistemological rigor, beliefs and stereotypes have crept into the research process and undermined its validity, transforming hypotheses (i.e., mere speculations), often without empirical support, in facts.

Conclusions

Twenty years after the publication of Ruth Bleier's edited book (the first edition of *Feminist Approaches to Science* was published in 1986), the field of gender difference research still lacks the methodological and epistemological rigor required in other scientific disciplines. The field is still fraught with problems, ranging from the uncritical acceptance of untested assumptions to methodological and epistemological biases. The approach has changed in the last two decades and many have adopted interactive models where cognitive and neural development interacts with experiential and social factors in a complex pattern of reciprocal influences. Nevertheless, gender differences, when present, are still interpreted by many scholars as mainly determined by some form of biological or genetic predisposition that favors males. Such intepretation, labeled as 'scientific', is used to justify inequities (e.g., Summers, 2005) that are more likely due to a subtle, sometime invisible, system of assumptions and prejudices that affect the growth and development of girls and young women and limit their professional opportunities.

It is important to bring scientific rigor and the discussion of the complexity of the human mind into schools, scientific journals, and popular science publications. It is equally important that this awareness be followed by the implementation of social, structural, and educational changes. Mechanisms need to be implemented to protect women scientists from biases that even today associate scientific competence to the male figure (e.g., by ensuring an equal number of women and men on committees for the assignment of research fundings; by adopting rigorous procedures in hiring, tenure, and promotion decisions; by providing students interested in cognitive development with an adequate background in both the social and biological sciences). The hope is that knowledge, awareness, and social change would lead to a true culture of equal opportunities.

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Notes

1. Baron-Cohen's book *The essential difference. The truth about the male and female brain* (2003) has been published in Italian in 2004 with the title *Questione di cervello. La differenza essenziale tra uomini e donne* (Mondadori).
2. Once known as "Scholastic Aptitude Test", "SAT" is not considered an acronym anymore and does not stand for anything (PrepMe© 2001-2005).

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