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The Sexed Brain: Between Science and Ideology

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Abstract Despite tremendous advances in neuroscience, the topic “brain, sex and gender” remains a matter of misleading interpretations, that go well beyond the bounds of science. In the 19th century, the difference in brain sizes was a major argument to explain the hierarchy between men and women, and was supposed to reflect innate differences in mental capacity. Nowadays, our understanding of the human brain has progressed dramatically with the demonstration of cerebral plasticity. The new brain imaging techniques have revealed the role of the environment in continually re-shaping our brain all along our lifetimes as it goes through new experiences and acquires new knowledge. However, the idea that biology is a major determining factor for cognition and behavioral gender differentiation, is still very much alive. The media are far from being the only guilty party. Some scientific circles actively promote the idea of an innate origin of a gender difference in mental capacities. Experimental data from brain imaging, cognitive tests or genetics are often distorted to serve deterministic ideas. Such abuse of “scientific discourses” have to be counteracted by effective communication of clear and unbiased information to

the citizens. This paper presents a critical analysis of selected examples which emphasize sex differences in three fields e.g. skills in language and mathematics, testosterone and financial risk-taking behavior, moral cognition. To shed light on the data and the methods used in some papers, we can now—with today’s knowledge on cerebral plasticity—challenge even more strongly, many false interpretations. Our goal here is double: we want to provide evidence against archaic beliefs about the biological determinism of sex differences but also promote a positive image of scientific research.

Keywords Sex · Gender · Brain · Biological determinism · Cerebral plasticity

Introduction

Despite tremendous advances in neuroscience, the topic “brain, sex and gender” remains a matter of misleading interpretations that go well beyond the bounds of science. The idea that biology is a major determining factor for cognition and behavioral gender differentiation is still very much alive. This concept is rooted in the ideology of biological determinism typified by the extrapolations of evolution theory, currently designated as sociobiology and evolutionary psychology [1, 2]. Accordingly, the human condition, individual and social, is being “explained” by genetic laws rather by sociology,

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economics or psychology. Biological evolution is thus accounting for many, if not all, aspects of human life, from social inequalities of race, gender and class, to individual propensities such as sexual orientation, use of drugs, psychological distress...[for critical reviews see 3, 4].

Biodeterminism goes along with a reductionist conception of the human person, which reduces mind to brain, brain to molecules and molecules to the products of genes [5, 6]. In the contemporary booming of genetics and neuroscience, the brain has become the focal point to depict individuality and subjectivity. Brain imaging technology, in particular functional Magnetic Resonance Imaging (fMRI) is now a key method to investigate the neural correlates of previously invisible features of psychology such as consciousness, morality, social empathy etc [7–9]. The brain is becoming the commonly accepted metaphor of thinking about what it is to be human [10–13]. In this context, it is hardly surprising to find in the scientific community, a number of researchers supporting the view that the primary causes of gender differences lay in the brain, over any other type of explanation. Experimental data from brain imaging, cognitive tests or genetics are often distorted to strengthen this deterministic argument.

This paper presents a critical analysis of selected examples which emphasize deterministic explanations to sex differences in cognition and behavior. To shed light on the data and the methods used in some papers, we can now—with today's knowledge on cerebral plasticity—challenge more strongly than ever before, many false interpretations. Our goal here is double: we want to provide evidence against archaic beliefs about the biological determinism of sex differences but also promote a positive image of scientific research.

The Topic of Brain, Sex and Gender is not a Neutral Matter

In the 19th century, the size of the brain was used to justify a hierarchy between men and women, races and social classes. The French scientist Gustave Le Bon pointed out that women's brains are smaller than men's and said that this explained the "*fickleness, inconstancy, absence of thoughts and logic and incapacity to reason*" in women. The famous anatomo-

mist Paul Broca stated: "*One wonders whether the smaller size of women's brains is due to the small size of their bodies. But let's keep in mind that women are, on average, slightly less intelligent than men. Therefore one can conclude that the smaller brain of women is explained by their inferiority in both size and intelligence*" [14]. Yet at that time it was known that brain volume is not necessarily linked to body size nor to intellectual capacities. For instance the brain of Anatole France weighed 1 kg while Turgeniev's brain weighed 2kg! But for Broca and his colleagues, ideology was stronger than scientific objectivity: "*On average, the brain mass is larger in men than in women, in clever men than in ordinary ones, and in superior races than in inferior ones [...]* *There is an obvious relationship between intelligence and brain volume*".

Even nowadays, the idea of linking intelligence and brain size is still alive. In 1992 the question of the link between IQ and brain size was once again debated in a paper submitted to the scientific journal *Nature*. This study was built on data gathered from American army archives and was based on the size of helmets and uniforms. The study reported that the skull size was larger in men than in women, in whites than in blacks and in officers compared to privates. Considering that the study was not 'politically correct', *Nature* refused to publish it [15]. Nevertheless the author managed to get it published in another international journal.

From Original Publication to Press Release

In 2010 a French research team published an original paper showing in newborn mice the implication of a specific gene in sucking activity [16]. The work also outlined the role of the hormone oxytocine to counteract feeding deficiency in these mutant mice. In the conclusion, the authors proposed that oxytocine supply might constitute a promising avenue for the treatment of feeding difficulties in human newborns with impaired feeding onset. Interestingly the press release of the paper by the French National Committee for Scientific Research (CNRS) added to the initial conclusions: "*this demonstration is important because in humans oxytocine plays a key role in behavior, especially in social interactions which are altered in autism. Also in women oxytocine plays a role in*

parturition, lactation and mother-baby bonding". None of these notions were present in the original paper. Yet the role of oxytocin on the human brain has not been demonstrated contrary to the evidence obtained in animals [16, 17]. This is one of the many examples of distortion of scientific data aimed at seducing the public with simplistic ideas of an innate origin of the maternal instinct which is claimed to result from the action of hormones in women's brain just as in female mice. Such assumptions contribute to maintain archaic prejudices in the general public about traditional roles of women in families and in society.

Sex Differences and the Concept of Cerebral Plasticity

At the beginning of the 21st century what answer can be given to the question : does the brain have a sex/gender? The scientific response is paradoxically yes and no. Yes because the brain controls the reproductive functions. Male and female brains are not identical, in every species, including our own, because sexual reproduction involves different hormone systems and sexual behaviors, which are controlled by the brain [18]. In women, a particular brain area (the hypothalamus) shows a cyclic activity to induce ovulation, which is not the case in the men's brain.

But when we consider the cognitive functions (memory, attention, reasoning etc.), the answer is no, because the diversity between brains is predominant, independently of the sexes [19]. Indeed, for thought to emerge, the brain needs to be stimulated by the environment. The human brain is made up of 100 billion neurons and 1 million billion synapses which are the junctions between neurons, while there are only 6000 genes involved in the nervous system. This means that there are not enough genes to control the building of our billions of synapses. In the course of embryonic development the genes play a key role in designing the basic architecture of the brain. At birth, however, the brain is by no means 'hard-wired'. Only 10% of the 100 billions neurons are already inter-connected. The 90% of the remaining synapses will then be progressively constructed in ways which are influenced by family, education, culture and society. This ability of the brain to shape

itself according to life experience is called "cerebral plasticity".

The new brain imaging tools like MRI clearly demonstrate this. For instance, the brains of professional pianists show higher thickness of the gray matter of the neocortex in the regions controlling finger movements and audition [20]. This thickening is likely due to the building of additional synapses and, importantly, it is proportional to the time spent in piano training during infancy. The same process happens in adulthood. In taxi drivers, there is a thickening the brain regions which control spatial orientation and memory, this process being proportional to the number of years of taxi-driving experience [21]. Moreover the changes in cortical thickness can be reversible. In subjects learning how to juggle three balls, MRI performed after 3 months of training shows a thickening of the brain areas which control hand movements and vision. Then, when the subjects stopped practicing, the brain images revealed a shrinking of those regions which had been thicker [22].

Training also impacts the structure of the white matter fiber tracts which connect brain regions to each other [23]. Long-term trained professional GO game players develop larger regions of white matter in brain areas involving attention, working memory and executive functions [24]. It has also been shown that only 2 months training of a memory task induces an increase in white matter signal which is correlated to the improvement of memory capacity [25]. Another substrate of plasticity in the adult human brain might be the production of new neurons (neurogenesis). Recent evidence suggests that the act of learning may be able to recruit new neurons from the pool of cells with neurogenic potential, particularly in the hippocampus [26]. These are a few among the many empirical studies which illustrate the impact of physical and mental training and practice on brain structure and function [27, 28].

The plasticity concept offers a perspective on biology that transcends neurogenetic determinism which implies that structure precedes function. We know now that brain function might as well precede brain structure. Plasticity challenges the old dichotomies of nature and nurture by showing that the phenomena of human existence and experience are simultaneously biological and social [6]. Specifically, it allows new insight to the question of the origin of

brain differences between the sexes. Experience in the sociocultural context involves gender learning processes which interact with the biological processes [29, 30].

Despite such evidence, the neuroscientific interpretation of sex/gender differences which highlights biological determinism rather than brain plasticity is still widespread [18, 19, 29, 31]. In the following sections we critically examine a selection of research works exemplifying essentialist explanations to sex differences. The confrontation of these interpretations to current evidence of brain plasticity brings some cues to analyze and challenge the ideology and scientific claims of biological determinism.

Skills in Language, Spatial Cognition and Math's

The media regularly echoes scientific studies claiming that cerebral specialization differs between men and women. The theories on the hemispheric differences between the sexes concerning language, spatial cognition and math's appeared over 30 years ago. They continue to survive and inspire the public despite their lack of validation by contemporary studies.

Language and Brain Lateralization The idea that sex differences in language lateralization accounts for better language skills in women is a source of particular controversy [32]. In 1995 a MRI study revealed that women used both brain hemispheres when performing a language task, while men used only the left hemisphere. Only 19 male and 19 female subjects took part in the experiment. Later meta-analysis of 24 such experiments conducted on 700 subjects between 1995 and 2004 found no statistical difference between the sexes in the hemispheric distribution of language zones [32, 33]. Thus when a large sample of subjects is analyzed the sex differences disappear. This is explained by the fact that the location of language zones varies considerably from one individual to the next. The differences between individuals of one and the same gender are so great that they outweigh any differences between the sexes. It appears that each individual has his own way of performing a language task, reflecting his or her personal experience and the plasticity of his or her brain.

Spatial Cognition and Mathematical Skills Another current view is that the perception of space and consequently geometric reasoning are better performed by men than by women. This idea is supported by the under representation of women in physical sciences, mathematics and engineering. One argument that is frequently put forward to explain unequal performances in mathematics is that men succeed better in three-dimensional geometric-type tasks. Experimental psychology does indeed show that men often perform better on tests of mental rotation of 3D objects [34]. The extent to which biology and environment can affect mental rotation performance is a matter of controversy [35–38]. MRI studies aimed to correlate performance to brain structure and function have yielded inconclusive data. These studies have used small samples of subjects that preclude the determination whether female and male brain fundamentally differ in processing visuo-spatial information. Moreover, MRI images of sex differences in neuronal activation during a spatial task do not provide any information about the origin of the differences. The supposed biological advantage for men may be due to educational and social environment which thereby impacts on neuronal circuits and cognitive performances.

An additional factor influencing performance process is the situational context in which tests are administered. Stereotype threats have a strong impact on performance [39]. For instance, if before carrying out the 3D rotation test in a classroom, pupils are told that this is a geometry exercise, the boys will generally get better results. But if the same group is told that this is a drawing test, the girls will perform as well as the boys [40]. These findings clearly show that self-esteem and internalization of gender stereotypes, and not biology, play a decisive role in spatial performance.

Another popular idea is that the male brain is more suited to abstract reasoning, in particular in the field of mathematics [2, 41, 42]. This conception is drawn on claims that boys are predisposed from birth to develop skills required by maths and science [43]. It is also argued that men exhibit more variability than women in intellectual performance and therefore predominate at the highest reaches of math talent [44]. Research in cognitive psychology in human infants, children and adults fails to support these claims [45–47]. There is behavioral and brain imaging

evidence that mathematic reasoning develops from a set of biologically based cognitive capacities that male and females share (for review see [48]). This is illustrated by recent studies published in 2008 in the journal *Science* [49, 50]. A previous survey launched in 1990 in the United States and involving a sample of 10 million pupils showed that, statistically, boys did better than girls in math's tests. Certain people interpreted this result as a sign of the inaptitude of the female brain in math's. The same investigation, commissioned in 2008, this time showed girls scoring as well as boys [49]. It's hard to imagine that in less than two decades a genetic mutation has increased women's aptitude in mathematics ! In fact, these results were due to the development of the teaching of science and the growing gender mix in scientific fields. Another study carried out in 2008 on 300 000 adolescents in 40 countries has clearly shown that wherever the socio-cultural environment is more favorable to male–female equality, the girls score better in math's tests [50]. In Norway and Sweden the results are comparable. In Iceland, the girls beat the boys, while the boys outperform the girls in Turkey and Korea.

Yet, despite the evidence that social and cultural factors account for the persistent scarcity of women in fields like science and technology, the prejudice in favor of biological determinism persists. This view was expressed in January 2005 by the former president of Harvard University Lawrence Summers, who asked “*whether innate differences between men and women might be one reason fewer women succeed in science and math careers*” (Boston Globe, January 17, 2005), leading to a wide controversy and eventually to his resignation from presidency in 2006.

Testosterone and Financial Risk-Taking Behavior

Whether or not sex hormones, particularly testosterone, act on the brain to mould personality characteristics is being widely debated today [51–54]. According to the “brain organization theory” launched in the 1960s, traits related to competition, aggression or risk-seeking behavior result from a masculinization of the brain due to prenatal exposure to testosterone and subsequent specific sensitivity to the male hormone in adult life [55, 56]. This theory,

originally based on animal research, has been extensively criticized when applied to humans [18, 29, 30]. First of all, since we cannot experimentally manipulate testosterone levels for obvious ethical reasons, empirical data are indirect and do not allow cause-and-effect statements. Another weakness of this theory is that it claims that the action of testosterone at an early stage and for a short period of time during the pregnancy, produces persisting hard-wiring of neuronal circuits. This notion is contradictory with the evidence of brain plasticity during the development of children and in adulthood. Despite the poor credibility of the theory, it continues to survive and even inspire some researchers.

In a 2008 publication, J.M. Coates and J. Herbert from Cambridge University, conducted a study about the relationship between testosterone and economic behavior [57]. The experiment measured the level of testosterone in a group of 17 male traders in the City of London and correlated it with day's profitability. The results showed a significant correlation between high testosterone, financial risk-taking and economic return. The authors concluded that “*acutely elevated steroids may shift risk preference and even affect a trader's ability to engage in rational choice [...] This effect, even if confined to a small number of people, could cause financial markets to deviate from the prediction of rational choice theory.*”

In the current context of the economic crisis, this paper has been largely echoed in the media, and particularly in the financial world. The idea spread that if Lehman Brothers had been Lehman Sisters, their financial performance would have been better. Even the French Minister of Economy, Christine Lagarde, declared that “*libido and testosterone level influence some operators of the financial market*” (Le Monde, October 13, 2010).

However, such an interpretation of the original publication is a definite distortion from experimental data. First of all, the paper does not demonstrate that an action of testosterone in the trader's brains might influence his or her behavior. Testosterone was just measured in saliva samples, which do not predict the actual testosterone concentration in the brain. The “evidence” of the relationship between testosterone and economic behavior is merely correlative and does not imply causal inference. Also, the data obtained in only 17 subjects is not statistically representative of the population of traders.

In a paper published in 2009, Swedish researchers addressed the same question with a much more rigorous methodology [58]. To investigate whether there is a causal relationship between sex hormones and risk taking behavior they studied 200 postmenopausal women treated with estrogen, testosterone or a placebo. Blood samples were collected to measure unbound bioactive testosterone, which is a more reliable method than salivary measures. After a one month treatment, the subjects participated in economic experiments with real monetary payoffs to measure financial risk taking, reciprocal fairness and trust. The results did not show any significant effect of testosterone or estrogen on the tested behaviors. This study of effective statistical power offers no support for the hypothesis that sex hormones affect economic behavior. It was ignored by the media....

Moral Cognition

A growing number of research papers are now devoted to the study of the neuronal basis of moral cognition. Functional magnetic resonance imaging (fMRI) is the favorite method to investigate the brain regions involved in moral judgment [7–9]. A recent paper has addressed for the first time the question of sex/gender differences in moral sensitivity [59]. The neural correlates of moral sensitivity was tested in 14 females and 14 males. They were scanned using fMRI while viewing a series of pictures, half of which depicted moral violations e.g. a man threatening a women with a knife. In each trial, a picture was first displayed for 6 s, during which the participant determined whether the picture represented a moral violation. Next, a scale bar was shown and the subject was asked to rate the severity of the moral violation on a scale from 1 (none) to 5 (severe).

The results showed that brain activity during picture viewing did not differ between men and women. However differences in brain activation levels were observed when the subjects rated the degree of the moral violation. Women showed increased activity in brain areas associated with emotions (posterior and anterior cingulate, anterior insula) while men showed increased activity in regions involved in cognitive processing (superior temporal sulcus). The authors concluded that their data are consistent with the current view that women

are believed to approach moral dilemmas with a care-based orientation whereas men are would tend to adopt justice-based moral evaluations: “*Males may have used executive resources to evaluate multiple contextual aspects of pictures in evaluating violation severity, whereas females may have focused more on the perception of individuals in distress, e.g. the target of a moral transgression*”. Such declarations when conveyed to a lay public prompts people to believe that men would be more reliable than women in moral judgment because they have a more rational brain, or “so says science”....

To challenge this interpretation, it is crucial to shed light upon methods and basic procedures employed in experiments using fMRI. Three main points have to be considered:

- Brain differences observed in a few dozen participants are not statistically meaningful. Evidence has accumulated that whenever a large number of subjects are analyzed the differences between sexes most often disappears, due certainly to the high inter-individual variability in brain functioning (e.g. in language areas as described above).
- Findings have been obtained in the artificial context of a laboratory, which cannot be extrapolated to real life experiences of moral judgement.
- The visualisation of fMRI data provides only a snapshot image of the current state of an individual’s brain [60]. It does not give direct evidence about the biological factors or the sociocultural processes that have influenced that state. Seeing sex differences in brain structure or function does not imply that the differences existed at birth nor that they will stay engraved in the brain.

The Challenges for Research on the Differences between Men’s and Women’s Brains

A central debate concerns the continued strength of archaic prejudices correlated to the persistence of traditional man-woman division of roles in families and in society. The challenge is not to deny that there are brain differences between the sexes, but to find out their origin and to assess their significance in real-life situations. One major advance of neurobiological

research has been the revelation of the dynamism of brain plasticity. From now on, it is no longer tenable to invoke biological reasons to explain the differences between men and women in society. But this “biologising” vision continues to satisfy people by providing a sort of scientific explanation for the existence of manifest inequalities. Research works dealing with sex differences in the brain are easily picked up by the media. Publishers of scientific journals, including the most prestigious ones, are unfortunately sensitive to this. It is unfortunate that studies of doubtful scientific value continue to be so widely echoed.

The emergence of the field of neuroethics is symptomatic of such a situation [61–63]. There is an increasing awareness on the epistemological reduction of self to brain and its impact on ethical and social aspects [5, 10–13]. One major preoccupation is the use of fMRI studies for understanding human personhood reduced to colored brain images. Such reification of thought, the possibility to compare neuroimaging data between men, women or ethnic groups encourage a hierarchical classification [8]. The shaping of public opinion by the media through the power of brain visual imagery is a particular threat [8, 9, 12, 64]. Racine et al. [64] use the term of *neuro-realism* to describe how the media coverage of fMRI investigations can make a phenomenon “indubitably” real in the eyes of the public.

It is imperative to encourage ethical thinking on the societal implications of neuroscientific findings on sex/gender, as well as to promote effective communication to the public about the advances of research in light of the current knowledge on brain plasticity.

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