ARTICLE

The trouble with girls?

Gina Rippon asks why plastic brains aren't breaking through glass ceilings

> The global gender gap across health, education, economic opportunity and politics has closed by only 4 per cent in the past 10 years, with the economic gap closing by just 3 per cent, suggesting it will take another 118 years to close this gap completely. (World Economic Forum, Global Gender Gap Report 2015)

Despite continued efforts, the under-representation of women in many key areas of global power and influence is evident. This is, of course, not a new issue. Earlier versions of gender gaps associated them with women's biological, social and intellectual inferiority (as an 18th-century given) or with women's 'natural' roles as carers, mothers, 'womanly companions of men' (as in the 19th-century 'complementarity' agenda). 'Blame the brain' was the mantra underpinning these essentialist justifications of the status quo – the biologically determined differences between men's and women's brains were viewed as the cause of these imbalances, and, most significantly, these differences were seen as 'hard wired', fixed and unchangeable.

A key breakthrough in our knowledge of the brain in this century, fuelled by the stunning technological advances in research, is that brain structure and function is *not* fixed and unchangeable, and not the same irrespective of context or culture. It is, in fact, exquisitely plastic, mouldable by experience throughout life. It is also 'permeable', responding to social attitudes and expectations, as is shown by brain-imaging studies of stereotype threat (Wraga et al., 2006).

Additionally, there is a challenge to the very concept of considering males and females as belonging to two separate, often 'opposite' categories. The accepted binary concept of sex needs revisiting. At all levels, biological and behavioural, males and females do not fall into two neat, separable categories, so the quest for differences between them could at best be uninformative and certainly misleading.

You might think that the possibilities offered by these breakthroughs would be seized on as 'game-changers' in the arena of research into sex differences and the brain. The development of powerful and sensitive techniques for studying the brain, paired with a new understanding of how the brain reflects the world in which it develops, *should* be revolutionising the research agenda and galvanising discussion in media outlets. Would that it were so!

My argument in this article is not just that there is a continued emphasis on 'essentialist', brain-based explanations in both public communication of, and research into, many forms of gender imbalance (although the appetite for this and the evident 'confirmation' bias is part

Where populist media and research findings support the notion that gender gaps arise from fixed, brain-based factors, there is greater endorsement of gender stereotypes

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of the problem: see Maney, 2014). The key difficulty is that this essentialist approach remains rooted in the deterministic past, with little or no acknowledgment of the significance that our emerging awareness of brain plasticity *could* and *should* have for the understanding of any differences between the sexes. This problem is magnified by a similar backward focus on historical beliefs in stereotyped sex differences, with little or no acknowledgement that previously accepted differences are being shown to be diminishing or disappearing with time (itself a challenge to a biological determinist perspective), or actually not to be differences at all.

An additional concern is that this sustained emphasis on an old-fashioned biological determinist argument can be a self-fulfilling prophecy. Where populist media and research findings support the notion that gender gaps arise from fixed, brain-based factors, there is greater endorsement of gender stereotypes, increased tolerance of the status quo, and belief in the impossibility of change (Brescoll & La France, 2004). It also reinforces the power of stereotype threat, which can itself change brain function (Wraga et al., 2006) but may also drive educational and occupational choices, thereby maintaining gender gaps, undermining determined initiatives to address them.

Let's look at how those breakthroughs which *should* be contributing to this revolution in our understanding of sex differences are currently limited, for a range of reasons including basic misunderstanding of the technology, poor public communication of research, questionable scientific practice and the 'confirmation bias' that renders entrenched beliefs hard to shift.

Brain-imaging breakthroughs

A key aspect in untangling the arguments about male and female brains is to have reliable and valid ways of providing accurate answers to the questions being asked. We need to move on from merely measuring differences in the size of structures or areas of activation, mapping them on to some kind of neophrenological template, feeding misleading concepts such as 'right-brainedness' or 'brainsex'. We need to understand not differences in brains *per se*, but their role in those behavioural, temperamental, or cognitive differences between men and women that might contribute to imbalances in achievement.

Contemporary techniques do allow a much more detailed characterisation of what is going on in the brain, including tracking of structural pathways or connections, and identifying the comings and goings of networked patterns of activity in millisecond timescales (Sporns et al., 2005). Access to pooled datasets from many labs means there are participant cohorts of many hundreds if not thousands (Poldrack & Gorgolewski, 2014). Together with more complex approaches to modelling patterns of brain activity, these advances *should* allow detailed examination of the claims and counter claims in cognitive neuroscience research, increasing our understanding of the true nature of links between brain and behaviour, and possibly also dispelling many brain-based myths (Jarrett, 2014).

However, the public representation of findings from such techniques is not always accurate. 'Neurotrash' is a light-hearted term applied to the sometimes bizarre representations (or misrepresentations) of brain-imaging findings that can be found in the popular press. They mainly arise from a journalistic lack of awareness of the complexities and the limitations of brain-imaging techniques, famously characterised in the 'dead salmon' study (Bennett et al., 2011), and from a tendency to succumb to the 'seductive allure' of the brain images themselves

Meet the author

'Alongside my work on the more basic aspects of brain imaging, I have always been interested in what used to be called "biological politics" and has now morphed into "critical neuroscience". A key focus was critiquing research into sex differences and social inequality and psychology's contributions (positive and negative) to that debate. My main interests were in women's mental health, and at that stage I was influenced by researchers such as Janet Sayers and Stephanie Shields.

'In 2010 I was asked to review the contribution of newly emerging brain-imaging techniques to the concept of the male and the female brain. Exchanging ideas with colleagues such as Cordelia Fine and Rebecca Jordan-Young, it became clear that there were major problems in this field. There were too many examples of the sort of irresponsible reporting that characterises the neurotrash and neurononsense I'm writing about here. 21st-century gender stereotypes about what females and males can and can't do seem to be more rigid and prescriptive than ever before, much enhanced by the power of many forms of media. Misunderstanding and misrepresentation of brain imaging findings feed into the kind of "blame the brain" beliefs that underpin many such stereotypes and stop people from achieving their potential (or even trying in the first place). Hopefully, this article will alert readers to some of the myths and misconceptions in the area and help them fight back against such negative thinking.'

Gina Rippon
is Chair of Cognitive Neuroimaging at Aston University
g.rippon@aston.ac.uk

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(McCabe & Castel, 2008; Rhodes et al., 2014). The impression given that imaging techniques offer instantaneous, real-time access to our brains that can be 'read back' by researchers leads to over-hyped claims about the links between brains and just about anything from being a Republican to designing a kitchen. Such 'neuroflapdoodle' pieces are often cleverly critiqued within neuroscience circles (e.g. tinyurl.com/9lboz24), but the wider public sense is that imaging insights are continuing to offer support for existing beliefs about the causal links between brain and behaviour.

One of the areas where this problem manifests itself most powerfully is in the reporting of neuroimaging studies of sex differences. There appears to be an insatiable appetite for 'at last, the truth will out' stories: research has finally solved the centuries old conundrum of why 'women can't read maps and men can't cry' (Maney, 2014, 2016). For example, *Daily Mail* coverage of a recent report on sex differences in brain connectivity (Ingalhalikar et al., 2014) had the headline 'Men's and women's brains: The truth' and claimed that researchers had shown that 'differences between the sexes are profound'. 'Men generally have more connections within each hemisphere (which) means men are more logical and better at coordination', the newspaper announced, concluding that 'the differences between the genders were so profound that men and women might almost be separate species'. As has subsequently been widely reported, there were problems with the research paper itself, including failures to report the (very small) effect sizes in the comparisons they made, but in a detailed science communication case study, tracking reports of this study through press releases, online comments and blogs, it is clear that the take-home message from coverage of the study was of strong support for a biologically determinist perspective (O'Connor & Joffe, 2014).

The media may also 'insert' such a perspective where none exists. A recent survey of gender differences in various cognitive skills over different times and places showed some evidence of increased gender differences favouring women in some cognitive functions (like episodic memory) and decreases or elimination of gender differences in other cognitive abilities (Weber et al., 2014). This is what the authors focused on: 'Our results suggest that these changes take place as a result of women gaining more than men from societal improvements over time, thereby increasing their general cognitive ability more than men.' There was also evidence of a sustained but diminishing gender gap in favour of males in numeracy. It was the existence of *this* gap (and not its diminution) that the *Daily Mail* focused on. The headline read: 'Female brains really ARE different to male minds with women possessing better recall and men excelling at maths'. Assuming that their readers might not make it back to the original study, they helpfully interpreted this particular finding: 'It is thought the differing strengths can be explained by differences in the biology of the brain as well as in the way the sexes are treated by society.' A quick scan of the original text reveals that neither the word 'brain' nor the word 'biology' appears.

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Such claims are associated with populist literature that harnesses neuroscience findings to 'prove' genuine differences between men and women and hand out associated advice (e.g. Gray, 1992; Maney, 2016). And they also continue to support the 'blame the brain' culture by failing to correct misplaced or outdated beliefs about male and female brains.

Neurosexism

But this is just the *Daily Mail*, right? We can just sigh and move on, patting ourselves on the back at our own enlightened ways. No: 'neurosexism' is an even more serious problem. Cordelia Fine (2010, 2013, and *The Psychologist*, November 2010: see tinyurl.com/hpto3bu) draws attention to specific practices within the neuroimaging research community itself that serve to create

Philosophical Transactions of the Royal Society B. doi:10.1098/rstb.2015.0119.
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'a literature biased toward the presentation of sex differences in the brain as extensive, functionally significant, and fixed – and therefore implicitly supportive of a gender essentialist perspective' (Fine, 2013, p.369). As discussed above, findings from neuroimaging studies are proving to be attractive sources of support for deterministic belief, so it is important not only that the design and analysis of such studies are reflective of contemporary developments in the area, but also that researchers are sensitive to the potential public interpretation of what they are reporting.

If the purpose of the study is to link the data on sex differences in brain characteristics with sex differences in some aspect of human behaviour, then one would assume that some care would be taken to ensure the reliability of such behavioural differences, with an appropriate choice of task to demonstrate these. However, there are instances of brain-imaging studies where the neuroimaging data are interpreted in terms of behaviour that was not actually measured in the scanner (Ingalhalikar et al., 2014) or at all (Tomasi & Volkow, 2012). In the latter study, for example, findings of some sex differences in resting state connectivity were interpreted thus: '…we hypothesize that the men's lower brain connectivity might reflect optimization of functions that require specialized processing, such as spatial orienting, whereas the women's higher brain connectivity may optimize functions that require integration and synchronization across large cortical networks such as those supporting language' (p.7). It does not appear that any measures of spatial orienting or language were obtained from these participants.

Similarly, where the focus is so firmly on proving the existence of brain-based differences as the bases for explaining gender inequalities, it is important to quantify the size of these differences and the extent to which they are meaningful, (i.e. of sufficient size and stability to reliably differentiate the two groups). In a research sphere where the differences being studied are extremely small and the distributions of measured variables almost always closely overlapping, then measures of effect size must be reported (Cohen, 1988). One of the criticisms of the Ingalhalikar et al. paper discussed above was that the 'profound' differences reported were actually rather small. No effect sizes were reported by the authors themselves, but subsequent analysis revealed that the largest effect size was small to moderate (0.482). It could also be revealing to report the proportion of possible comparisons in the data that were not significant to provide some sort of context. Jarrett (2015) pointed out that in another recent study on sex differences in functional connectivity, only 178 out of 34,716 measures of a particular aspect of connectivity were significantly different between males and females (effect size 0.32). Yet the authors refer to 'prominent' sex differences in their abstract (Satterthwaite et al., 2014).

So we do have the techniques that could allow us to resolve some of the arguments in this arena and really illustrate where any differences, if any, lie, and what these differences might mean. But misunderstanding of what these techniques can do, misuse in a research context and miscommunication of the associated findings currently serve to undermine their potential power to challenge stereotypical beliefs.

Brain plasticity

> Our brains renew themselves throughout life to an extent previously thought not possible. (Michael S. Gazzaniga)

One key breakthrough in our understanding of brain structure and function in the last 40 years or so is the concept of *neuroplasticity* – our brains can and do change, and this remains true throughout our lives. Where the 'biology is destiny'-type arguments have stood in the way of progress towards understanding if and why male brains are different from female brains, new insights offered by an understanding of how plastic brains are *should* bring about greater attention to the factors in addition to biology which might determine a brain's characteristics.

It has been known for some time that specific events and exposure to specific types of learning experiences, such as taxi-driving, juggling or playing Tetris, can change both structure and function in the human brain (May, 2011; Shors, 2016). In addition, there is accumulating evidence that more intangible experiences – including exposure to social attitudes and expectations such as 'stereotype threat' or self-perceptions of status – can change brain structure and function. A study by Wraga and colleagues (2006) demonstrated that carrying out a spatial cognition task under either negative or positive stereotype threat conditions resulted in differences not only in performance but also in brain-activation patterns. The association between objectively measured socio-economic status and brain structure has been demonstrated (Hackman & Farah, 2009), but it has also been shown that *perceived* socio-economic status, or where you think you are in the pecking order, can affect brain structure, independently of other possible variables, such as ethnicity or psychological health. (Gianaros et al., 2007).

> "our brains can and do change, and this remains true throughout our lives"

The significance of these findings is that they provide powerful evidence of how 'entangled' our brains are with the world (Fausto-Sterling, 2000; Rippon et al., 2014). It can take us beyond the old nature vs. nurture debate and illustrate the truly interactive nature by which our brain characteristics are formed (and can be changed), and how these characteristics then proceed to affect how we interact with the world. Acknowledgment of plasticity has changed thinking in many spheres of behavioural biology but has been strangely slow to feed through into questions of sex differences in the brain, the very research arena where the effect could be powerfully demonstrated (Fine et al., 2013).

With respect to the study of sex differences in the brain, acknowledging

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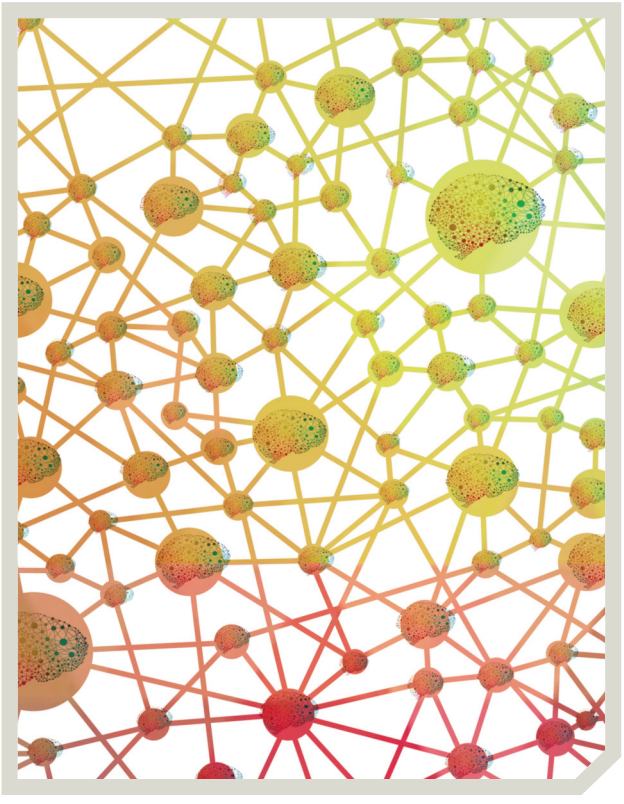
neuroplasticity should have significant consequences for research design and interpretation. The understanding of the potent 'brain-changing' effects of social and cultural influences means that a much wider range of factors should be accounted for when researching into this area or when offering explanations for differences. Educational experience, occupation and socio-economic status will need to be measured, or at least acknowledged as a potential source of variance. This will, for example, be important when it comes to looking for differences in the large neuroimaging datasets that are becoming available. If there is only minimal attention paid to the range of possibly relevant independent variables (e.g. just sex and age) in any interrogation of these data, then misleading conclusions could be reached. Currently, examination of many neuroimaging papers reporting evidence of sex differences in the brain shows that little, if any, attempt has been made to take account of the potential effects of neuroplasticity (Biswal et al., 2010; Rippon et al., 2014). This means that reports of alleged sex differences in the brain could continue to contribute to the canon of beliefs about the source of any kind of imbalance between the sexes.

Sex redefined

Another more fundamental way of challenging the arguments about male and female brains is to stop searching for differences between two groups that actually turn out not to be separate groups at all.

There is emerging evidence that describing sex as a dichotomous and internally consistent category is flawed. Just thinking in terms of either male or female, XX or XY, 'Mars or Venus' is simplistic and not representative of the wider spectrum. This is claimed to be true even at the most fundamental biological level (Ainsworth, 2015) and, most recently, at the level of the brain itself. In a study based on the first whole-brain analyses of 'male/female' characteristics in structures and connections, based on over 1400 brains, it is claimed that there is no such thing as a 'male' or a 'female' brain. All brains, regardless of the biological sex of their owner, are a 'mosaic' of different characteristics (Joel et al., 2015) arising from a range of 'brain altering' experiences (Joel & Fausto-Sterling, 2016). Looking for differences between brains solely based on the sex of their owners will mask the true sources of variability.

This parallels a long-standing message of previous psychological research demonstrating that there is much greater *similarity* between the sexes, with greatly overlapping data distributions and tiny effect sizes, challenging long-standing certainties about 'reliable' differences between the sexes (Hyde, 2014). More particularly, it has been shown that in many categories of behaviour, cognition, personality and aptitudes that have been assumed to unfailingly distinguish men from women, there really are very few consistent differences *between* the sexes and that the patterns of such characteristics are more accurately grouped along a single dimension (Carothers & Reis, 2013; Reis & Carothers, 2014). This includes measures such as masculinity/femininity, empathy and science inclination. To paraphrase the title of an excellent paper on this very theme, we are none of us from Mars or Venus, we are all from Earth.



Stop searching for differences between two groups that actually turn out not to be separate groups at all

The claims and counter-claims about differences between two groups divided according to their biological sex could thus be dismissed as founded on a fundamental misconception about the very basis of the division. Understanding differences (a) where they genuinely exist and (b) where the differences appear to have negative consequences is clearly important; it is just that we might need to be more open-minded about where those differences came from and not focus solely on biological sex as their source.

A powerful position

Gender inequality remains a matter of global concern, in both developed and emerging economies. In order to make full use of our human capital, we need a better understanding of why there are still individual differences in achievement and what we might do to address them. Social cognitive neuroscience now offers potential game-changers to alter our understanding of the role of the brain in any kind of imbalance between groups – in normal or abnormal behaviour, ability, aptitude or achievement. Stunning advances in brain-imaging techniques offer much more detailed and accurate understanding of the role that brain characteristics might play in generating and sustaining inequalities. But the techniques need to be responsibly harnessed and their findings reliably communicated if they are going to provide any kind of genuine insights. When comparing brains, we need to know more than just the sex of their owners, we need to know what kind of brain-altering experiences these owners have been through. And, most radical of all, cognitive neuroscientists have suggested that the very concept of differences between the sexes is not representative of the true state of affairs. Basing research efforts and social policy initiatives on two neat, distinct categories may well be misguided.

We are in a powerful position to challenge beliefs (spoken or unspoken) about the 'essential' unchangeability of the human brain and its role in determining gender inequality. It's time to counter self-fulfilling prophecies of underperformance, to harness the plasticity of all brains and ensure they can break through glass ceilings.