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Is the Brain the Key to a Better Understanding of Gender Differences in the Classroom?

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ABSTRACT
Gender differences are clearly noticeable in education in both performance and preferences. Neuroscience offers a promising method for exploring these differences. In the popular media, the idea of completely distinct male and female brains is often advocated. However, in reality the issue of gender differences in the brain is more complicated. Moreover, the use of neuroscientific findings in education has proven to be a thorny endeavour. In this article, we will critically discuss several issues arising from the research on gender in the brain in relation to education. First, what is actually known about sex differences in the brain will be discussed. Second, several difficulties associated with the interpretation of neuroscientific research on these differences will be pointed out. Third, we will discuss why caution is needed in the implementation of neuroscientific findings in education. Finally, possible future directions for the field of brain, gender and education will be described.

KEYWORDS
Neuroscience; neuroeducation; gender; sex; brain

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INTRODUCTION

Students differ substantially in their educational achievements and trajectories and gender is an important predicting factor. For example, in most Western countries more girls than boys graduate from high school, while male students strongly outnumber female students in mathematics and technology related courses (Barone, 2011; Buchmann & DiPrete, 2006; Halpern et al., 2007; Snyder & Dillow, 2012). It is likely that these gender differences in education are the result of cultural norms and stereotypes (e.g. Ceci, Williams, & Barnett, 2009; Gunderson, Ramirez, Levine, & Beilock, 2012) but also of individual differences in interests (e.g. Croson & Gneezy, 2009; Su, Rounds, & Armstrong, 2009) and, arguably, perceived or actual differences in abilities (e.g. Else-Quest, Hyde, & Linn, 2010; Hyde, Lindberg, Linn, Ellis, & Williams, 2008; Mullis, Martin, Kennedy, & Foy, 2007).

Over the last three decades, the literature on psychological differences between the sexes has been complemented by studies elucidating the basis of these differences in the brain. These studies have generated important evidence for structural and functional differences between the sexes, which potentially may reveal the neural mechanisms underlying these differences. However, the interpretation of the brain findings is far from straightforward. First, the relationship of brain differences to overt behaviour is not always clear. Second, just like differences in cognition and emotion, gender differences in the brain result from an intricate interplay between biological and social factors (e.g. Beltz, Blakemore, & Berenbaum, 2013; McCarthy & Arnold, 2011). Yet, in the popular media, gender differences are often simplified, generalized and exaggerated, sometimes favouring a strictly biological account of gender differences as hard-wired in the brain (e.g. Hurst, 2013), but in other sources emphasizing a highly plastic brain, that we can easily manipulate ourselves (e.g. Kennedy, 2013).

While the risk of simplified interpretations and misapplications of scientific findings is clearly not restricted to neuroscience, the popularity of brain research - as reflected in the number of brain-related newspaper articles, books and even games (e.g. Griffiths, 2013; Hurley, 2012; Welham, 2013) - calls for increased caution in communicating neuroscientific results (Racine, Bar-Ilan, & Illes, 2005). Education is one area in which neuroscientific findings have been received with enthusiasm, and sometimes unfounded claims have been made as to the implementation of these findings (Howard-Jones, 2009; Lindell & Kidd, 2011; Pasquinelli, 2012). One of these claims is that distinct male and female brains exist, and therefore boys and girls should receive specialized education (e.g. Sax, 2006). Other popular claims are unrelated to gender, and for example, propose that we use only 10% of our brain, and that people can be distinguished as "left and right brainers" (Dekker, Lee, Howard-Jones, & Jolles, 2012). In contrast, the enthusiasm for brain-based accounts of learning has also led to thoughtful discussions on how to bridge the gap between education and neuroscience (Ansari, Coch, & De Smedt, 2011). Clearly, the neuroscientific approach is of great value in understanding the origins of gender differences, given that nature and nurture are both represented in brain structure and function, and these insights may eventually inform educational practice. However gross misinterpretations or exaggerations (e.g. Frean, 2008; Hurst, 2013) of findings do not do justice to the sophisticated work of neuroscientists, and may introduce wrong practices in education (Geake, 2008). It would be highly unfortunate if the emergence of neuromyths and flawed brain based educational programmes eventually discredit the potential of neuroscience for education.

The aim of the current article is therefore to discuss the research on gender differences in the brain, focusing specifically on the interpretation and implications of the results. First, we will summarize the evidence for differences in the brain between males and females. It is beyond the scope of this article to cover all research on gender differences in the brain, therefore main findings will be presented, referring to other reviews where applicable. Second, we will discuss the interpretation of the observed gender differences, pointing out the complexities in the interpretation of brain imaging results and focusing on the different causes of brain gender differences. Third, we will discuss the implementation of neuroscientific findings about gender for education, emphasizing that caution is necessary.

THE EVIDENCE

Gender differences in the brain pertain to both structure and function. Regarding structural differences, there is clear evidence from both post mortem studies and structural Magnetic Resonance Imaging (MRI) studies for a difference in total brain volume between men and women. In line with general gender differences in height and weight, the average adult male brain is about 9-12% larger than the average female brain (Beltz et al., 2013; Giedd & Rapoport, 2010; Lenroot & Giedd, 2010). This basic difference in brain size makes it somewhat difficult to study more specific issues, such as differences in gray matter (where the cell bodies of neurons are located) and white matter (where the axons which transmit signals between different brain regions are located). When controlling for brain volume, women have a higher percentage of gray matter and men have a higher percentage of white matter, although the evidence for the latter difference is less consistent (Beltz et al., 2013; Cosgrove, Mazure, & Staley, 2007). There is no clear consensus on the significance or interpretation of these gender differences.

In addition, longitudinal data shows that boys have a larger brain volume than girls throughout development. However, the peak volume of the brain is reached at a younger age in girls (10.5 years) than in boys (14.5 years), suggesting that brain maturational processes occur earlier in girls (Giedd & Rapoport, 2010; Giedd, Raznahan, Mills, & Lenroot, 2012; Lenroot et al., 2007). The white matter volume increases linearly throughout development in both genders, but the volume of gray matter peaks in pre-adolescence, again a few years earlier in girls than in boys (Giedd et al., 2012; Lenroot et al., 2007).

Differences between the sexes have also been studied in specific brain structures. There is evidence that on average men have a larger amygdala and hypothalamus; structures which are often related to emotional processing and sexual behaviour.

The caudate and hippocampus, structures generally related to the learning and memory system, are larger in women (Beltz et al., 2013; Cosgrove et al., 2007; Lenroot & Giedd, 2010). Apart from these key structures, several studies have shown gender differences in other brain regions. However, these findings are less consistent, with differences in areas that were not always a priori hypothesized and/or could not be replicated in other studies (Cosgrove et al., 2007).

Functional differences are differences in brain activation during rest or during the execution of specific tasks, often measured using functional Magnetic Resonance Imaging (fMRI). Gender differences in fMRI activation have been found in a wide range of behavioural tasks (see Beltz et al., 2013), such as emotion processing (e.g. McRae, Ochsner, Mauss, Gabrieli, & Gross, 2008; Schienle, Schäfer, Stark, Walter, & Vaitl, 2005), executive functioning (e.g. Boghi et al., 2006; van den Bos, Homberg, & de Visser, 2013) and spatial processing (e.g. Clements-Stephens, Rimrodt, & Cutting, 2009; Grön, Wunderlich, Spitzer, Tomczak, & Riepe, 2000). In general, there is evidence that women more often use both hemispheres when performing a task while men are more likely to use just one hemisphere (Beltz et al., 2013).

The evidence for sex differences in the brain goes well beyond the evidence presented here and is described in more detail in several review papers (e.g. Beltz et al., 2013; Cosgrove et al., 2007; Giedd et al., 2012). Although a large number of recent studies have together yielded robust evidence for gender differences in functional brain activation, the findings have not always been consistent. This is mainly the result of differences in research design and the use of small sample sizes (Beltz et al., 2013). Still, there is clear evidence for average gender differences in the brain, ranging from overall size to differences in specific brain regions. However, it is equally clear that the notion of distinct male and female brains, as sometimes suggested in the popular press, is not supported. In the end, gender differences in the brain are not large enough to categorize men and women. To illustrate this, Giedd and Rapoport (2010) point out that the effect sizes of most gender differences in neuroimaging studies are only half as large as gender differences in height. And although men are on average taller than women, height alone is not an effective way of determining someone's sex. In the next paragraph we turn to the interpretation of the observed brain gender differences.

THE INTERPRETATION

Neuroimaging research primarily provides insight into neural mechanisms. Yet, its potential for understanding behaviour is tremendously appealing, the popularity of brain research with the general public being a clear expression of this. Unfortunately, this is also an area with perils and pitfalls, which are rarely discussed in these popular accounts. Differences in brain volume, either overall or in specific structures, cannot readily be linked to differences in function. The same holds for differences in functional activation: less activation does not necessarily mean that the brain areas in question are less efficient or function on a lower level. In addition, neuroanatomical differences may be associated with functional activation patterns. Thus, in the absence of clear behavioural indicators, interpretation of brain research in terms of the behavioural implications is a thorny issue. If, on the other hand, significant performance differences are found, the question arises to what extent neural differences reflect task-specific factors, or non-specific factors such as lack of motivation (Kaiser, Haller, Schmitz, & Nitsch, 2009; Poldrack, 2008).

In the area of gender differences, many studies have reported differences in brain activity in the absence of differences in behaviour. For example, some fMRI studies have found gender differences in neural networks involved in language processing (e.g. Baxter et al., 2003; Chen et al., 2007; Clements et al., 2006) but no differences at the behavioural level. Such findings suggest that sometimes activity in different brain structures in men and women underlies similar behaviour, which is possibly indicative of different strategies. Yet, the interpretation of these strategies relies on how well the function of the brain areas involved is understood, as the behaviour has to be inferred from the brain. This reverse inference is to some extent problematic, because brain areas may have multiple functions (Poldrack, 2006). Additionally, it is possible that gender differences in the brain may *prevent* rather than cause differences in behaviour. In animal research, male and female brain structures have been found to be different to ensure similar behaviour under different circumstances, such as sex-specific hormonal influences (de Vries & Södersten, 2009).

Similar complexities arise when neuroimaging research is used to elucidate the possible causes of behaviour. A linear model of genetic differences leading to hormonal differences leading to brain differences is appealing, but much too simple (Beltz et al., 2013; Berenbaum, Blakemore, & Beltz, 2011; McCarthy & Arnold, 2011). Factors in the social and cultural environments are able to shape the development of both structural and functional aspects of the brain and may even trigger epigenetic changes (e.g. McGowan et al., 2009). This way, the social environment may influence long-term abilities and preferences. For example, if boys spend more time playing ball sports or playing with construction toys (such as building blocks) this may enhance the development of their brain areas for spatial reasoning (e.g. Draganski et al., 2004). And if the cultural stereotype holds that girls are less able to do exact sciences, this may well affect their performance accordingly, and establish a behavioural preference for other topics, even at the level of the neural signalling of reward (e.g. Mitchell, Ames, Jenkins, & Banaji, 2009). The area of gender differences may thus offer an exciting opportunity to investigate how genetic, hormonal and social influences may act in concert to produce differences in brain structure and function. But equally, this complexity requires a careful and nuanced communication of research findings to the general public. Issues around the implementation of neuroimaging research on gender differences in the brain are discussed in the next section.

THE IMPLEMENTATION

Unfortunately, while the complexity of the origin of gender differences is increasingly being recognized, leading to calls to join forces in research (Beltz et al., 2013; Berenbaum et al., 2011), this is not yet reflected in increased caution in translating research findings to the classroom. Popular misconceptions about male and female brains are finding their way to the educational world. Policy makers, school principals and teachers, looking for ways to improve education, may be drawn to brain explanations of gender differences based on the authority that comes along with neuroscience. For instance, in an interview in The Times, psychologist Leonard Sax argues that "boys and girls should be educated in separate classes because their brains are hard-wired to learn in different ways" (Frean, 2008). While many people would argue that more evidence is needed before engaging in such high-impact educational reforms, the risks associated with the current popularity of brain research may also be much more subtle. Brain research may form a new source to fuel gender-specific educational expectations, and there is ample evidence that such expectations influence educational attainment, at the level of parents and teachers (Gunderson et al., 2012) and society (Nosek et al., 2009), even when they are implicit. Thus, when gender differences are incorrectly or preliminary considered to be inherited, this can easily lead to the conclusion that gender differences are insurmountable, leading to gender specific expectations which may impact on educational outcome, thereby reinforcing the differences.

A further risk is associated with the tendency to describe the brain as an independent personal identity that is to some extent out of the control of the person herself, also referred to as "brainism" (Racine et al., 2005). Teachers or students may read an article or book about "how the brain learns" (e.g. Sousa, 2005) and perceive the brain as an independent learning device. This is conceptually incorrect (the brain does not learn, only a person can learn), and may again lead to an underestimation of the extent to which learning is influenced by the students themselves, their teachers, parents and environment.

To prevent misapplication of brain gender research in the classroom, it is important to consider this field as part of the emerging field of neuroscience and education. In this field, neuroscientists work together with both educational scientists and educational professionals to investigate how knowledge on brain development can be integrated with knowledge about learning and teaching, to eventually improve education. A good example of the application of science is the impact of research on adolescent development on the juvenile justice system. In this field, practitioners, policymakers, health care professionals and scientists from different disciplines are collaborating to improve public policy (Steinberg, 2009). There is growing consensus that the field of educational neuroscience can only advance by investing in an interdisciplinary, bidirectional, reciprocal collaboration between the disciplines of neuroscience and educational science (Ansari et al., 2011). Neuroscience is relatively new to the area of education, and should therefore benefit from other sciences with a long history of studying and understanding persons in educational contexts. For example, research showing different developmental trajectories in the brains of adolescent boys and girls can help to understand gender differences in school attitude and performance. However, in itself this knowledge is not sufficient to set up gender-specific educational programs. Therefore, (among other things) behavioural research is needed on the development of related functions, such as planning, motivation, self-control, educational research on effective approaches to children with different attitudes and performance, and theoretical research on the aims and ideals education entails or strives to achieve. Similarly, the question of whether children should be schooled in single-sex classes cannot just be answered by neuroscience, not even if research on gender differences in the brain would have led to a complete understanding of their origins and meaning. Such claims can only be justified in combination with educational, psychological and philosophical arguments.

CONCLUSION

The evidence for gender differences in brain structure and function is impressive but not yet conclusive and consistent. The interpretation of the findings on a behavioural level is often still speculative. Therefore, direct implementation is much too preliminary. Well-meaning educators and policy makers may do more harm than good in their efforts to implement state-of-the-art science. Just as well-meaning neuroscientists may not realize the impact of their complex neural explanations and appealing brain images on the educational reality.

Misinterpretation and misapplication of science is a problem for all areas of science. However, the problem may be even more pressing for neuroscience because of the authority that comes along with the field. As an illustration, the presence of brain images in a paper on cognitive processes led to higher rating of scientific merit of the reported research (McCabe & Castel, 2008). Similarly, it is likely that teachers are more easily impressed and persuaded by an article explaining gender differences using brain scans than by an article using more conventional psychological measurements (see Weisberg, Keil, Goodstein, Rawson, & Gray, 2008). Along with this authority comes the responsibility to inform practitioners on the limitations of neuroscience and to temper their expectations. Neuroscientists should keep in mind the possible impact of their research once it makes its way to the general public (Beck, 2010; O'Connor, Rees, & Joffe, 2012).

Neuroscience is a promising field that potentially could be of great value to education. Brain research may tell us more about the fundamentals of learning. It could help to disentangle the conditions under which children and adolescents are best able to study. Gender differences can also be better understood by exploring their neural basis and this could lead to a better adjustment of education to boys and girls. However, this can only be achieved in an interdisciplinary collaboration that aims to integrate knowledge from neuroscience, developmental psychology and educational science into the new field of educational neuroscience (Ansari et al., 2011; Coch & Ansari, 2012; Fischer, Goswami, & Geake, 2010; Samuels, 2009). This field should be inherently bidirectional, with neuroscience informing education about the neural mechanisms relevant to learning and teaching, and educational science and philosophers of education informing neuroscience about what works in the classroom, as well as the meaning of education. Evidently, gender differences in the brain and the classroom could be an important aspect of research on education and neuroscience. Only by carefully integrating these fields of research and the experiences of practitioners in education can neuroscientific research findings be validly implemented in the classroom.

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