Research Article

Can Open Science be a Tool to Dismantle Claims of Hardwired Brain Sex Differences? Opportunities and Challenges for Feminist Researchers

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Abstract

Feminist scholars have long been concerned with claims of hardwired brain sex differences emanating from neuroscience and evolutionary psychology. Past criticisms of these claims have rightfully questioned the impact of this research on gender equality, pointing out how findings can be used to vindicate gender stereotypes. In this article, we appraise the brain sex differences literature through the lens of open science, a movement aimed at improving the robustness and reliability of science. In this discussion, we offer a feminist evaluation of the strategies (e.g., pre-registration, data sharing, and accountability) provided by open science, and we question whether these may be the novel and disruptive tools needed to dismantle claims about hardwired brain sex differences. We suggest that open science strategies can be useful in challenging some of these claims, and we note that promising initiatives are already being developed in neuroscience and allied fields. We end by acknowledging the distinct challenges that feminist researchers wishing to engage in open science face, particularly in the context of limited diversity. We conclude that open science presents considerable opportunity for feminist researchers, and that it will be crucial for feminists to be involved in shaping the future of this movement.

Keywords

neurosexism, hardwired brain sex differences, feminism, open science, reproducibility, research methods

Traditional research methods have long been regarded as unaligned with feminist objectives (Eagly & Riger, 2014; Westmarland & Bows, 2018). While this view is shifting, contemporary scientific methods still exist in the context of patriarchal values (D'Ignazio & Klein, 2020). Research inquiry that is inherently patriarchal in nature may particularly apply to areas that investigate hardwired brain sex differences. While there is debate surrounding the definition of "hardwired brain sex differences," this term refers broadly to the idea of gendered behaviors, abilities, and cognitions as fixed and biologically determined (Grossi, 2017). It usually emphasizes differences in brain structures between women and men as stemming from differences in an underlying genetic blueprint, often with an evolutionary or essentialist basis (Fine et al., 2019; Zell et al., 2016). One area where this research has been traditionally carried out is within cognitive neuroscience which is defined as research into the structure of the brain and how brain structure impacts behaviors and cognitive functions. Also relevant in this context is evolutionary psychology (i.e., a branch of psychology concerned with understanding how evolutionary adaptation has impacted human psychology and behavior; Buss & Schmitt, 2011) and in particular sex selection theory (SST). SST posits that females and males of all species (including humans) have evolved hardwired gender-specific traits in areas of differential adaptive problems such as in mating and sexuality (Buss & Schmitt, 2011); Fine et al. (2013) note that this is usually inferred as being based on biology rather than culture. As such, neuroscientific investigations into brain sex differences and aspects of SST share similar ideas about the causes of behavioral and cognitive differences between women and men. Specifically, these investigations largely view hardwired and innate sex differences

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as present in women's and men's brains and suggest that these differences result from the underlying genetic blueprint as opposed to cultural constraints. Typically, these investigations further suggest that these differences cause observable behavior, and that they may partially explain sex differences in a variety of contexts such as sexual behavior and mental capabilities (Fine et al., 2013; Rippon, 2019). The potential societal implications of the sex brain difference research are, therefore, vast (e.g., Eliot et al., 2021).

Claims of hardwired brain sex differences mostly view sex/gender as exclusively binary (Jordan-Young & Rumiati, 2012) which is challenged by neuroscientific investigations into brain mosaicism (Rippon et al., 2014). Fine (2013) has also argued that investigations seeking to uncover hardwired and innate brain sex differences may reinforce and legitimize rigid, often misogynistic, gender norms. This means that the methods available to feminists in these research areas who seek to challenge some of these claims may originate from (and as such reinforce) reductive ways of conducting research and working with data. As such, these methods may cement, rather than challenge, oppressive hierarchies (Bluhm et al., 2012; D'Ignazio & Klein, 2020; Rollins, 2021). This problem may, therefore, be understood in the context of Lorde's (1984, p.112) suggestion that "the master's tools can never dismantle the master's house." That is, strategies drawn from the context of an oppressive reality will struggle to be successful in dismantling that very reality. In the context of research methods, this would mean that dominant epistemologies and scientific inquiries (e.g., associated with questionable research practices [QRPs], publication biases, and limited transparency—further detailed in subsequent sections of this article) may serve to reinforce rather than challenge oppressive structures about gender (Collins, 2002; Zell et al., 2016). In other words, there may now be time to consider whether new perspectives on how empirical research should be conducted, with a specific focus on transparency in research processes, can be useful for feminists to challenge claims relating to brain sex differences.

This consideration forms the basis of the current article where we consider the implications of hardwired brain sex differences research alongside an overview of some issues with research methodologies in this area. In light of feminist concerns over the robustness of this research, we question whether the rapidly emerging "open science" movement can provide useful tools for remedying these issues (Schmitz & Höppner, 2014). Consistent with Morgenroth and Ryan's (2020) integrative theoretical framework of the gender/sex binary, we define sex as biologically based and gender as the social expression or performance of this. However, we acknowledge that group assignment in brain research in the context of sex is nearly always based on self-identity (as is the case for evolutionary investigations) making our definition somewhat limited in scope (Eliot et al., 2021). Finally, we also note the entanglement of sex and gender as brain plasticity means that the brain is shaped by formal and informal experiences in the social world which includes gender (Rippon et al., 2014). This means that when it comes to brain development, sex and gender are often intertwined and cannot always be readily separated.

Hardwired Brain Sex Differences and Neurosexism

Neurosexism is a term used to critically describe investigations into hardwired sex differences between women's and men's brains (Bluhm et al., 2012; Fine, 2013) often based on an underlying ideological agenda of these investigations and the resulting effects on gender stereotypes in society. Crucially, claims from the neurosexism literature are used to inform brain-behavior inferences (Fine et al., 2013; Jordan-Young, & Rumiati, 2012) in that brain sex differences research has traditionally been used to provide "evidence" for the legitimization of gender norms (Rippon, 2016). Therefore, reports of hardwired brain sex differences between women and men have been used to legitimize an unequal distribution of power and correspondingly gendered social roles, which position women as inferior or "other" (Bentley et al., 2019a; Wood & Eagly, 2002). Due to this, it is perhaps not surprising that exposure to biological essentialism (i.e., the idea that people are largely defined by their biology, rather than social or cultural influences) in the context of sex seems to cement and increase stereotypical views of gender roles (Brescoll & LaFrance, 2004; Coleman & Hong, 2008; Skewes et al., 2018).

The implications of more recent engagement with biological essentialism can be further seen in the backlash against feminism (Ging, 2019; Skewes et al., 2018) and in the rise of the manosphere (loosely connected anti-feminist groups, usually based online). The manosphere has been found to employ neuroscientific literature alongside evolutionary psychology's SST to inform core ideology on women's and men's "true nature," often focusing on women's brains as fundamentally different to those of men (Ruti, 2015; Van Valkenburgh, 2018). Specifically, aspects of neuroscience and evolutionary psychology have been conceptualized as forming the basis for the intellectual arm of the feminist backlash as this backlash uses and misrepresents "science" to justify women's inferiority (Skewes et al., 2018; Van Valkenburgh, 2018; Westmarland, 2015). Because of the above, feminists have long been critical of this research area more generally as regardless of the intentions of the original researchers, findings are frequently misrepresented to vindicate gender stereotypes and justify social inequality (O'Connor & Joffe, 2014; Şahin & Yalcinkaya, 2020; Skewes et al., 2018) including in technology (Lewis, 2017) and educational settings (Maney, 2015). In addition, and as particularly relevant to the current article is the sustained criticism based on the methodology and robustness of this research as outlined below.

The robustness of brain sex differences research has been questioned by feminist psychologists for decades (e.g.,

Kitzinger, 1994) but there has yet to be a systematic examination of the utility of open science to counter key areas of concern within research into hardwired brain sex differences from a feminist perspective. As such, there may now be value in systematically examining the new tools available to feminist researchers to scrutinize the claims of hardwired brain sex differences with a particular focus on questioning the imagined objectivity which surrounds this research (D'Ignazio & Klein, 2020). This is particularly relevant in the context of an increased attention to research transparency and meta-research in psychology more generally (Kathawalla et al., 2021) and the questioning of science as inherently objective or apolitical (Rollins, 2021). Recently, psychology has put reproducibility (the ability for researchers to reproduce the same findings with the same data) and replicability (the ability to replicate the same results using new data; Plesser, 2018) at the forefront of its research agenda. In addition, an increasing number of voices are re-evaluating the ways in which data are being put to use and for what purpose (D'Ignazio & Klein, 2020).

An Open Science Perspective on Brain Sex Difference Research

Open science is becoming an increasingly relevant paradigm within psychology (Kathawalla et al., 2021; Open Science Collaboration, 2015). It has offered novel strategies to examine robustness of methodology, design, and data which may be particularly relevant for feminists seeking to scrutinize claims about innate sex differences and dominant cultural beliefs about binary biological essentialism. Open science also presents a credible language with which to articulate frustrations about the political bias of sex difference research (as per Wickham, 2020), which may be especially important given the longstanding history of critical women's voices being marginalized in the mainstream (Murphy et al., 2020; Whitaker & Guest, 2020). However, before exploring the different tools that may provide a useful opportunity to challenge the brain sex differences evidence, we first outline the main areas of scientific concern within the research on hardwired sex brain differences.

Replication Concerns

If empirical research is to be robust and reliable, researchers should be able to directly and conceptually replicate its core findings. While a lack of replication is an issue across psychology (Chambers, 2017), it is especially concerning in sex differences research given how this field impacts gender stereotypes in society. Feminist scholars have for some time expressed concerns over the overall lack of successful replications in sex difference research (e.g., McHugh et al., 1986; O'Donnell et al., 2018). They have noted that the only way to fully understand sex differences in neuroscience is to conduct research that is robust and transparent with an emphasis on statistical reproducibility and replicability. This will improve the practical implications of the neuropsychological and evolutionary field and allow for key claims to be verified. This will ultimately benefit the broader scientific community as well. There have been some recent successful sex differences replication attempts (e.g., in autism; Floris et al., 2020) which have provided useful standards for research more generally in this area. More broadly, however, most of the key claims about women and men's brains fail to replicate consistently across individual studies as outlined in a detailed meta-synthesis of three decades of human brain sex difference findings by Eliot et al. (2021). The authors note that a failure to consistently correct for brain size in this literature contributes to the limited replicability and that across studies, sex accounts for no more than 1% of brain variability. Finally, despite recent shifts in acknowledging the value of direct and conceptual replication studies, Yeung (2017) evaluated publishing policies of neuroscience journals and noted that out of 465 journals only 6% explicitly stated that they welcome and accept replication contributions.

Publication Bias

Publication bias refers to the tendency for journals to publish statistically significant (as compared to non-significant) results meaning that papers demonstrating significant effects are more likely to be accepted for publication than those that do not (Chambers, 2017). Research further confirms that there is an inflated and disproportionate rate of positive significant results in the psychological literature (Poldrack et al., 2017; Simonsohn et al., 2014). The prevalence of publication bias across the social sciences is well established (Open Science Collaboration, 2015), and this extends to the literature on brain sex differences (David et al., 2018). Overwhelmingly, investigations into sex comparisons of the brain focus on evidence of difference with very few studies paying attention to the similarities of neuroscience (Patsopoulos et al., 2007) as noted in a screening of titles and abstracts in the area by David et al. (2018). This overinflated focus on difference does not account for the value of studying similarities within brains (as per the gender similarities hypothesis; Hyde, 2005, 2014). This concern was also noted in the meta-synthesis by Eliot et al. (2021) who specifically searched for research beyond sex differences as otherwise the search would have mainly located positive findings.

However, given the principles of probability one would expect that even if "true" effects existed, given the prolificity of sex differences research there will be studies that inevitably demonstrate null effects even if these are Type II errors. Rippon (2019) attributes the disproportionate number of significant differences to "selective publication," whereby non-significant results that contradict previously popularized findings remain unpublished. In this context, concepts such as "the vast graveyard of undead theories" (Ferguson & Heene, 2012, p. 555), as emanating from open science, presents a credible language that feminists can use to articulate these

issues. Within this concept, Ferguson and Heene (2012) argue that science in its current form is unable to falsify ideologically popular theories as non-significant results are unlikely to be accepted for publication. Therefore, theories with little factual basis but that have broad appeal remain unfalsified or "undead." This is in line with central tenets of feminist activism more generally which has traditionally highlighted the need for a shared language to articulate problems (Collins, 2002).

The issues of publication bias and selective publication are particularly relevant in the context of hardwired brain sex differences, which have popular appeal, as they are perceived to "make sense" (Fine, 2012) and reflect things as they "really are" (Fine et al., 2019; Ruti, 2015). This is exemplified in the popularity of dating advice which serves to entrench differences between women and men; this advice encourages heterosexual couples to understand and accept hardwired differences to promote relationship harmony (e.g., the enormously popular titles by John Gray; [Fine et al., 2013] and also in news reports and information-based websites [Maney, 2016]). Ruti (2015) proposes that some of the popularity of biological explanations of sex differences stem from how they require little complex consideration and generally do not challenge dominant norms in society. As such, these ideas fit well into the concept of "undead theories" (Ferguson & Heene, 2012, p. 555). Specifically, the lay theory of fundamental brain sex differences remains popular and widely disseminated in public and professional discourse (e.g., Maney, 2016; Rippon, 2019). This theory is likely aided by a general reluctance to publish non-significant, or no difference, findings in the context of hardwired differences between women's and men's brains. While publication bias is certainly not limited to the field of brain sex differences, the combination of publication bias together with gender lay theories in society (O'Connor & Joffe, 2014) favor the perpetuation of the idea of women's and men's brains as fundamentally different. In this context this means that data which contradict popularized notions of hardwired sex brain differences can be dropped at the point of collection ("data hoarding") or is "massaged" (Chambers, 2017) until significant results can be found, entrenching the positive skew in published findings. Again, this exemplifies how open science can lend feminists a credible language with which to articulate some of these concerns. Further, the massaging of data and research methodology have been referred to as part of a broader set of "QRPs" and have come under increased scrutiny within the scientific community.

Questionable Research Practices

Questionable research practices are research practices which are not strictly illegal (and as such, do not generally constitute fraud) but fall short of ideal ways to manage data and analysis decisions and can, particularly when present in many forms, distort results in the direction of desired significance (Chambers, 2017). Importantly, the traditional requirements of a published paper present readers with little opportunity to discern whether these practices have taken place. The undisclosed flexibility of a researchers' analytical approach can lead to what Gelman and Loken (2013, p. 10) refer to as the "garden of forking paths" (i.e., how singular decisions within the scientific process can impact the final "destination" of the data), which is another useful concept for feminist researchers seeking to identify problematic research processes in the context of hardwired brain sex differences. It has been suggested that these practices are prevalent across the cognitive domain (Poldrack et al., 2017) and that they may be exacerbated in the area of sex difference research specifically (David et al., 2018).

One QRP especially relevant in the context of brain sex differences is that of multiple statistical testing (Fine, 2012) where post hoc (i.e., with no evidence of this analysis being planned during study design) analysis is performed until a significant result is found (as part of the broader practice of "*p*-hacking; " Head et al., 2015). When this occurs within sex differences research, it cannot be clear whether the study of sex differences (or, indeed, sex similarities; Hyde, 2005) was among the primary hypotheses of the reported study. As noted by David et al. (2018), sex differences can in theory be analyzed with any given neuroscientific dataset and may therefore be a convenient alternative analysis when other core hypotheses within the data are not confirmed. Similarly, Fine et al. (2019) noted that it is "easy and intuitive" for researchers to check for sex differences in their data even if this was not an a priori research question. This may help explain why Patsopoulos et al. (2007) found that the majority of sex difference claims in gene-disease association studies were spurious or inadequately documented. Similar concerns are present with evolutionary psychology where claims about evolutionary bases for gendered behavior can be difficult to refute given that data can be interpreted in a multitude of ways depending on whether the researcher acknowledges the pervasive effects of culture (Cameron, 2015; Maney, 2015).

As such, the lack of robust replications, combined with publication bias, and QRPs, all combine to favor studies which demonstrate significant hardwired brain sex differences, regardless of whether this is painting a true picture. QRPs can dramatically increase one's chances of obtaining a significant effect which, combined with the pressure to publish prolifically, can work to ostensibly favor researchers who engage in these practices (Chambers, 2017) thus limiting the potential for successful replications. The desire to find significant results may be particularly true for brain sex differences research as these findings have considerable appeal, and as such impact, which is an important feature of publishing in higher education (Chambers, 2017). Moreover, this research area may be especially prone to misrepresentation as findings are often disseminated directly to the wider public through "popular" science books and media outlets (Cassidy, 2006; Rippon, 2019). Specifically, findings on hardwired sex differences are often covered uncritically or misrepresented in the

media (Rippon, 2019), for example, in using findings to make brain-behavior inferences and vindicate gender stereotypes even in cases where the original papers make no such claims (O'Connor & Joffe, 2014). As noted by Maney (2015), without a detailed understanding of scientific reporting, public audiences may be prone to overestimating the real-life effects of reported brain sex differences.

Without addressing these concerns it is impossible to draw definitive conclusions about women's and men's abilities. It is clear that feminist researchers need to re-interrogate some of these claims using appropriate tools, especially in the context of how this research may further a broader anti-feminist discourse within the public domain (Ging, 2019). We propose that registered reports; the sharing of data, materials, and software; and accountability are some of the novel tools needed to achieve this.

Open Science Tools for Combatting Neurosexism

Registered Reports

Registered reports are research papers where research design, methodology, and analysis strategy are submitted for peer-review prior to data collection and papers are accepted or rejected for eventual publication based on the quality of these (Chambers, 2017). This means that decisions relating to design, methodology, and analysis cannot be altered post hoc and importantly, eventual results are not factored into the in-principle decision. Consequently, papers are published on the merit of their methodology rather than whether the results are "interesting" or fit with popular "undead" theories. Through this, registered reports address many of the concerns outlined above including those relating to QRPs (as study methodology and analysis plan cannot be significantly altered after in-principle acceptance) and publication bias (the journal agrees to publish the study regardless of results; Ioannidis et al., 2014). As such there is increased potential for successful replications. Early evidence suggests that registered reports can improve the validity of research (Hardwicke & Ioannidis, 2018; Poldrack et al., 2017) such that they have a lower frequency of reporting significant results compared with typical articles (Scheel et al., 2021) reflecting a more accurate percentage of true null results.

Similarly, pre-registration (i.e., registering a study's method, design, and analysis plan prior to data collection and making this information publicly available once the paper is published) is another useful method to improve the reliability and robustness of the study (van't Veer & Giner-Sorolla, 2016). General pre-registration is a similar process to Registered Reports, but does not typically involve submitting these details for review prior to data collection. They rather serve as a quality check once the study has been conducted. There have been some useful guidelines for the pre-registration of neurological work including guidelines for pre-registering electroencephalogram research (Paul et al., 2021) and fMRI research (Flannery, 2018). Because of the potential for replication attempts, implementing registered reports and pre-registrations across neuroscience will be a useful tool for verifying (and ultimately painting a truer picture of) claims relating to brain sex differences or sex similarities (e.g., Bentley et al., 2019b).

Sharing

For pre-registrations and registered reports to fully facilitate research transparency, all aspects relating to research methodology need to be made openly available (Poldrack et al., 2017). Most commonly this involves publishing data, materials, and details needed for data analysis.

Open data. While some research contexts have a stronger tradition of mandating data sharing such as randomized clinical trials (Krumholz & Peterson, 2014), the open science movement calls for the depositing of datasets to become routine for both unpublished and published papers. There have already been some promising initiatives for data sharing within neuroscience, for instance developments under the umbrella of "Open Neuroscience" (Choudhury et al., 2014). Another exciting initiative is OpenNeuro (Gorgolewski et al., 2017) which facilitates open data storage from human brain imaging research studies.

Making data open allows the original claims of the data to be further scrutinized and verified which in turn improves reliability (Chambers, 2017; Ioannidis et al., 2014). Open data would allow any critical researchers to fully verify claims of sex difference research as data can be re-analyzed and detailed results inspected; this was the case in the review by Patsopolous et al. (2007). It would also allow for all data in investigations on sex and the brain (including that which is statistically non-significant and as such often not reported in published papers or included in paper abstracts and titles; David et al., 2018; Eliot et al., 2021) to be analyzed in meta-analytical research on the topic.

Relatedly, an increasingly open data culture would also allow feminist researchers to highlight what is *not* being recorded which may in some instances be even more important than that which is being recorded (D'Ignazio & Klein, 2020). For example, within neuroscience there is a lack of data being collected treating sex as a spectrum rather than as a binary, and there is also a lack of data focusing on sex similarities rather than differences (Bentley et al., 2019a; Eliot et al., 2021). Making datasets openly available would allow for this gap in the research to become visible. Finally, and as outlined in greater detail below, the sharing of datasets would also allow feminist researchers in the area of sex difference research to pool resources.

Open materials. To complement open data, the open science movement also encourages researchers to make all materials

(including detailed documentation of experimental procedures) openly available and this priority has been echoed by neuroscientists (e.g., Gilmore et al., 2017). This openness allows for materials to be scrutinized (as well as to be reused in future research, benefitting the wider scientific community) which may be of particular importance when evaluating claims that support hardwired brain differences between women and men. The importance of scrutinizing research materials is exemplified in the research by evolutionary psychologist Buss (2005). Buss (2005) based several of his academic papers and a best-selling relationship advice book on one large scale study which supposedly evidenced women's and men's different dating preferences across cultures, something which the research argued was largely hardwired. Although these conclusions ignore the social conditions that may exist globally to shape such preferences (Fine et al., 2013), Ruti (2015) further argues that Buss cherry-picked items from the large battery of questions to highlight disparities. In reality, much of the data suggested that women and men largely preferred the same traits in partners; however, this was only evident when examining all of the questions posed to participants. This highlights the need for materials to be routinely accessible in the context of claims relating to innate and hardwired brain sex differences. The sharing of materials also enables marginalized and under-funded researchers to access much-needed resources which will be very useful for feminist researchers (Westmarland & Bows, 2018). Finally, one encouraging initiative that is highly relevant (but not limited) to neuroscience is Databrary (2021) which facilitates the sharing of all study materials as well as videos of the experimental procedures (Gilmore et al., 2017, 2018), something that would considerably improve the potential for replications.

Open software. Open science also signals a shift away from subscription-based (and often very costly) software such as SPSS, Envivo, and Endnote, toward free and open access software such as R, JASP, Jamovi, RDQA, and Zotero. An example of this in the context of neuroscience is the platform Neuroconductor which provides a centralized repository of R packages for image analysis (Muschelli et al., 2019). While on the surface this may seem to have little implication for feminist researchers, open access software contributes to a larger environment of community science which has always been at the forefront of feminism (Westmarland & Bows, 2018). Together with open data and materials, open and accessible software can encourage this type of community science where those outside an academic environment can be active participants in research.

The above is particularly relevant when considering the popular appeal research claiming hardwired brain sex differences has and the tendency for these findings to be misrepresented and oversimplified by the popular press or reported uncritically (Maney, 2016; O'Connor & Joffe, 2014; Rippon, 2019). Open software would in theory afford journalists or members of the public the opportunity to re-analyze datasets from these studies to either verify claims made in the paper itself (as in Patsopoulos et al., 2007) or perhaps more importantly, to clarify media misrepresentations of the findings. This will be particularly important in this area as findings on hardwired brain sex differences are often covered by general journalists rather than dedicated science journalists (Cassidy, 2006). A greater proximity to the scientific process may improve this type of reporting. An intuitive software which requires little formal training to use such as JASP may be particularly useful here, both for journalists themselves and for members of the public. Finally, open and intuitive software also promotes a collaborative and inclusive research community which may be important in increasing the appeal of this type of research to groups traditionally underrepresented in this area (Murphy et al., 2020).

Accountability

A key tool within open science is the ability to hold science accountable and make visible the hierarchies which govern the way in which research is conducted. Through scrutinizing how and by whom data come to be created (and to what purpose), it questions the imagined objectivity which has long been a feature of quantitative research (D'Ignazio & Klein, 2020). This is particularly relevant with research into hardwired brain sex differences (both in the context of neuroscience and evolutionary psychology) which is often positioned as "hard" and "objective" science, something that limits the degree to which its biases are made visible (Cassidy, 2006; Fine, 2012). The problems with seemingly objective methods of research in the area of neuroscience have been noted by Rollins (2021) who argues that these methods may also serve to reinforce racism. There have been attempts to discredit scientists who promote sociocultural theories of gender differences (as opposed to biological ones) through alleging the interference of (left wing) political bias (Fine, 2020). This positions biological and evolutionary theories of brain sex differences as the more objective and value-neutral option. Open science practices therefore have the potential to demonstrate claims on hardwired brain sex differences as socially situated (D'Ignazio & Klein, 2020) rather than neutral.

There should also be accountability for how data is used and to what purpose. As outlined by Saini (2017), neuroscience has traditionally been used to reinforce the culturally constructed concept of race. Rollins (2021) further notes that neuroscientific investigations, even without explicit focusing on "race," can reinforce beliefs about fixed differences. Relatedly, data have long been collected from minoritized groups without consent or agency in how this data is being used (D'Ignazio & Klein, 2020) which reflects the biological sciences problematic history with racism (Rollins, 2021). Feminist open science should, therefore, examine how and to what purpose data is being put to use and place agency of data at the forefront of research. Practically, this should involve

ethical data collection and a transparency with research participants about the ways in which their data will be used (and why) including any sharing of this data. Moreover, feminist open science should question the traditional power imbalances that exist between researcher and participant in the context of neurosexism (Westmarland & Bows, 2018).

Challenges for Feminist Open Science

As outlined above, the theory behind the open science movement aligns itself well with feminist research as both movements aim to challenge dominant norms. Although the tools discussed above are useful, there are also a number of challenges involved in feminist engagement with open science in the context of the research on hardwired brain sex differences and the neurosexism literature (Bentley et al., 2019a, 2019b).

Inclusivity and Accessibility

Because of the disruptive nature of open science and its aim to challenge dominant norms in scientific conduct, the (White) male dominance within the movement (see "Bropen Science"; Guest, 2019) is somewhat ironic given that this movement contains some of the novel tools to effectively dismantle the "master's house" (Lorde, 1984) of masculine conventions in science (D'Ignazio & Klein, 2020). As noted by Whittaker and Guest (2020), the male dominance in open science movements has contributed to an environment of exclusivity where anyone who is not an ostensibly knowledgeable White man may feel unwelcome. This is especially concerning as disciplines such as neuroscience already suffer from an underrepresentation of women (Schrouff et al., 2019) and, as such, adding another layer of exclusivity to research practices in this and related areas would seem unwise. The notion of "Bropen Science" is therefore particularly problematic as open science's use of open materials and software would signal a shift away from academic exclusivity. In the long run, this not only hinders feminist engagement with research transparency but it also stifles the movement and risks the re-building of "the master's house" only with novel tools. In other words, while an open science movement with limited diversity may still provide theoretical access to open science tools (for some people), it will fail to challenge the more fundamental issue of hierarchies within the scientific process and as such limit the degree to which it is compatible with feminism. As noted above, it may also stifle efforts to improve female representation within neuroscience (Schrouff et al., 2019) which would be detrimental to scientific inquiry (Murphy et al., 2020). We therefore propose that open science groups consider diversity within the movement (as should feminist researchers; Westmarland & Bows, 2018) and this could be practically achieved through promoting the learning of and broad engagement with open science of any degree rather than exclusivity. The suggestion that open science should function like a buffet as opposed to being an exhaustive three-course meal, where people should feel welcome to use the aspects most useful for them in the way most suitable to their needs may be particularly useful here (Whitaker & Guest, 2020). Practically, this should be an ethos running through institutional open science groups and a general theme for associated conferences and workshops; this also mirrors suggestions by Schrouff et al. (2019) for improving female representation within academia more generally.

Finally, here we focus specifically on claims about hardwired sex differences. The feminist reappraisal of neuroscientific claims should also consider the intersecting identities (Crenshaw, 1989) that are not captured fully by mainstream neurological data with a particular focus on working critically with binary categories of any kind (D'Ignazio & Klein, 2020). This would include neuroracism (Saini, 2019) which highlights how Black, Asian, Indigenous, and Ethnic Minority people are positioned as inferior through a lens of problematic neuroscience much as women are in neurosexism. In the context of racism within neuroscience, Rollins (2021) calls for a critical examination of the tools available to researchers in this area and recommends that scientific empiricism is accurately positioned as political, rather than neutral. A continued focus on intersectionality would also align with traditional feminist notions of examining subjective and dynamic positions rather than rigid, binary hierarchies (Collins, 2002).

False Binaries in Research Methodologies

Another challenge for feminists engaging in open science is the degree to which reproducible research practices have traditionally centered quantitative approaches associated with a positivist epistemology (Smith & McGannon, 2018). Positivist epistemologies have long been problematized by feminist theorists and activists. This is partly because these approaches are seen to perpetuate false binaries between emotion and reason as detrimental to women and minority groups (Collins, 2002; D'Ignazio & Klein 2020). This is particularly relevant given the previously discussed "imagined objectivity" which surrounds research into hardwired sex differences (Cassidy, 2006; Fine, 2012); it would be a shame if this was further buttressed by engaging with the open science movement.

As such, many of the tools from within this movement including some of those discussed in earlier sections have been largely applicable to quantitative data, suggesting to some that open science is not compatible with (or even relevant for) qualitative methods. Although discussions surrounding open science and qualitative research are growing (e.g., Elman & Kapiszweksi, 2014), the open science movement remains governed predominantly by researchers stemming from quantitative epistemologies. However, to fully understand and appreciate the nuances of sex differences in a way that encompasses feminist concerns for understanding the

lived experiences of these perceived differences, open science should continue the recent momentum of engaging with qualitative research practices (e.g., Haven & van Grootel, 2019). Practically, feminists critical of the discourse surrounding hardwired brain sex differences may in addition to scrutinizing the research base itself (utilizing quantitative approaches) also wish to further incorporate qualitative considerations of the impact of this research. This type of research could focus specifically on the lived experience resulting from claims about hardwired brain sex differences (D'Ignazio & Klein, 2020) and make visible the social consequences of these research claims. Another final avenue is the integration of qualitative and quantitative data and analysis as exemplified by open data visceralization (D'Ignazio & Klein, 2020; data visualizations with an emphasis on affect, rather than imagined objectivity); this would be a promising future avenue for research into sex differences as well as sex similarities (Hyde, 2014; Zell et al., 2016).

Precarity and Agency

A final important consideration in the context of feminist engagement with open science in examining claims about hardwired brain sex differences is whose responsibility it is to correct past neurosexist claims using the tools discussed in earlier sections of this article (Bentley et al., 2019a). There will likely be a vast amount of labor involved in this process; this includes research-related labor and emotional labor. This "hidden" emotional labor of academia is also inherently gendered (Macoun & Miller, 2014) and disproportionally affects early career researchers (ECRs). While precarious employment and unattainable expectations are features of many academic positions, they are particularly salient for ECRs (Pitt & Mewburn, 2016; Tynan & Garbett, 2007) and this disproportionately affects women, working class academics, and minoritized groups (Thwaites & Pressland, 2016). Again, this highlights the importance of considering intersecting identities. This means that while engaging in open science presents opportunity, it can also come at a cost, something that may be particularly salient for women. However, encouragingly, Murphy et al. (2020) noted open science research as a promising avenue for increased female participation and agency in academia. The responsibility to question past literature on hardwired brain sex differences must therefore correspond to a sufficient agency to do so and should not unfairly tax those already lacking sufficient agency.

It is therefore imperative that senior academics collaborate with ECRs to jointly change institutional research policies, for instance through the allocation of time and resources to allow for an equal engagement in open science particularly in the context of workload. Another relevant avenue would be the creation of paid PhD and post-doctoral positions with a focus on replicating past claims about hardwired brain sex differences using some of the tools outlined above. In fact, the potential benefits of employing researchers with a purpose of replicating past claims in psychology was highlighted already by Cohen (1962), a suggestion that can certainly be taken up by feminist researchers in this area and beyond.

It is clear that while open science presents many relevant opportunities for feminist researchers seeking to challenge claims about hardwired brain sex differences, this engagement needs to be considered with the challenges present within this movement in mind. It is also likely that future feminist engagement within these groups will uncover further tensions. However, as we have outlined above, the present challenges also have potential solutions, indicating that it is worthwhile for feminists to engage with open science with a particular emphasis on ensuring this movement stays relevant for a broader scientific community as well as truly disruptive. Encouragingly, many of these issues, particularly regarding diversity and representation, are already being discussed within open science communities (e.g., Whitaker & Guest, 2020) and incorporated into mission statements (e.g., SIPS, 2021) indicating a promising potential for ongoing feminist engagement. Moreover, there has been promising progress in the feminist neuroscientific or neurofeminist literature. An example of this is the NeuroGenderings network which directly considers issues of gender, sex, and the implications of these for neuroscience research (Schmitz & Höppner 2014) and other feminist interventions on sex/gender differentiations in neuroimaging research (e.g., Bryant et al., 2019).

Conclusion

The continued investigations into hardwired brain sex differences remain key concerns for feminist researchers. This is particularly salient given the renewed anti-feminist utilization of evolutionary psychology and neuroscientific language. While there are challenges involved for feminists in engaging with open science, especially in the context of the limited diversity of voices within the movement, open research strategies are nonetheless valuable tools for re-examining claims about hardwired brain differences between women and men. These tools may also be able to promote collaborative and inclusive research practices. Pre-registration and registered reports offer an opportunity to limit ad-hoc investigations of sex differences as well as the cherry-picking of significant variables. Transparency allows for data to be objectively evaluated and contextualized as well as contributing to traditional feminist notions of community science. Accountability makes visible the imagined objectivity within quantitative research. We note in this article that there are several promising initiatives within neuroscience and related disciplines that both advocate and create opportunity for engagement with open science principles which have done much to improve the rigor of the field. These should be encouraged by feminist researchers. We therefore conclude that the rethinking of traditional data management through the use of open science tools is a valuable opportunity for feminist researchers to begin the dismantling of traditional power structures within academic research into hardwired brain sex

differences, and this can contribute long-term to the building of ethical science and scholarship.

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