Men, Women, and STEM

Why the Differences and What Should Be Done?

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Abstract

It is a well-known and widely lamented fact that men outnumber women in a number of fields in STEM (science, technology, engineering and maths). The most commonly discussed explanations for the gender gaps are discrimination and socialization, and the most common policy prescriptions target those ostensible causes. However, a great deal of evidence in the behavioural sciences suggests that discrimination and socialization are only part of the story. The purpose of this paper is to highlight other aspects of the story: aspects that are commonly overlooked or downplayed. More precisely, the paper has two main aims. The first is to examine the evidence that factors other than workplace discrimination contribute to the gender gaps in STEM. These include relatively large average sex differences in career and lifestyle preferences, and relatively small average differences in cognitive aptitudes – some favouring males, others favouring females – which are associated with progressively larger differences the further above the average one looks. The second aim is to examine the evidence suggesting that these sex differences are not purely a product of social factors but also have a substantial biological (i.e. inherited) component. A more complete picture of the causes of the unequal sex ratios in STEM may productively inform policy discussions.

KEYWORDS: Discrimination; Equality; Gender; Sex Differences; STEM.

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Why the Differences and What Should Be Done?

Never has the issue of gender disparities been as widely discussed, or as bitterly contested, as it has been in recent years. From the Oscars to the political podium, from TV shows to the workplace, disparities are identified and debate inevitably ensues. In the occupational realm, one of the primary focuses of this debate has been the differential representation of men and women in STEM (science, technology, engineering, and maths; see Box 1). This was epitomized by the infamous "Google memo," in which then-Google employee James Damore (2017) questioned the extent to which observed gender disparities in STEM are a product of workplace discrimination. The memo, and Damore's subsequent dismissal from Google, provoked a great deal of discussion and debate about the causes of STEM disparities and the origins of human sex differences. Unfortunately, much of this debate was decidedly inaccurate in its presentation of the research on the topic. A great deal was said about bias and discrimination, but relatively little about other factors contributing to STEM gender gaps (e.g., Chachra, 2017). Furthermore, to the extent that other factors were mentioned – factors such as average sex differences in academic interests – these were typically attributed to socialization, rather than to biology or to a complex interaction between biological and sociological causes (e.g., Campbell, 2017; a notable exception is Eagly, 2017).

--------------------Insert Box 1 about here--------------------

The goal of this paper is to redress the balance. We do not aim to provide a complete survey of the literature on sex differences in STEM; to do so would require a book-length treatment of the topic. Our goals are much more modest. The first is to argue that gender gaps in STEM are shaped to an important extent by factors other than workplace discrimination, including sex differences in preferences, aptitudes, and within-sex variability. The second is to argue that these sex differences are not due solely or primarily to learning, socialization, or culture. Biology matters as well.

Critics might respond that no one claims otherwise, and that to suggest that they do is merely to attack a straw person. We defend our emphasis, however, on three main grounds. First, it is far from clear that the only people rejecting a significant role for biology in shaping STEM gender gaps are made out of straw. As the psychologist Alice Eagly (2018) has noted, many feminist psychologists have rejected a role for biology in shaping *any* psychological sex differences. Second, although few experts explicitly deny that biological factors contribute to STEM gender disparities, these factors are often downplayed or ignored. Wang and Degol (2017), for instance, suggest that, although biological factors cannot be "definitively dismissed," sociocultural factors are a more likely explanation (p. 123), and Cheryan et al. (2017) do not even mention biological factors in their analysis of the causes of the gender gaps in STEM. It would be easy for non-experts and policy makers to get the impression that, according to many experts, biology is essentially irrelevant. Third, even if everyone *did* agree that biological factors make a significant contribution (over and above simply encoding the effects of experience), it would presumably still be appropriate to make the case for this position, rather than simply accepting it in the absence of arguments and evidence.

We divide the paper into six main parts. First, we survey the research suggesting that men and women differ, on average, in their career and lifestyle preferences, and argue that these differences are due in part to biological influences. Second, we consider the possibility that men and women differ, again on average, in certain cognitive aptitudes – that men, for instance, score somewhat higher on most tests of spatial ability whereas women score somewhat higher on verbal tests. Third, we look at the controversial suggestion that men are more variable than women in cognitive ability, such that there are more men at the top of the ability distribution, and more men as well at the bottom. Fourth, we look at the issue of gender discrimination, and argue that, although discrimination plays a role in shaping STEM gender gaps, it plays a smaller one than people often assume, and sometimes favours women rather than men. Fifth, we look at how the arguments and evidence in the first four sections might inform the discussion of policy interventions aimed at addressing STEM gender gaps. Sixth and finally, we consider whether the ultimate aim of such interventions should be to eliminate sex differences in STEM, or simply to eliminate bias and barriers, then let the cards fall where they may.

Sex Differences in Preferences and Priorities

To begin with, we examine arguably the most important contributor to the differential representation of men and women in STEM: sex differences in career-relevant preferences. Specifically, we look at sex differences in interest and occupational preferences, and sex differences in life priorities. Having sketched an origins-agnostic outline of these differences, we then make the case that biological factors play an important part in shaping them, and speculate about the evolutionary pressures that might have helped shape the biological contribution.

Interests and Occupational Preferences

A large literature in psychology shows that men and women differ, on average, in the kinds of occupations that interest them (Konrad et al., 2000; Morris, 2016). One of the most important recent papers on this topic was a comprehensive meta-analysis by Su et al. (2009). The paper focused on two main areas: occupation-relevant interests (e.g., interest in people vs. things) and preferences for specific STEM careers (e.g., engineering vs. mathematics). In both cases, the authors found substantial sex differences that, regardless of their causes, plausibly go some way toward explaining observed STEM gender gaps.

Occupation-Relevant Interests. Starting with occupation-relevant interests, by far the largest sex difference was that for interest in things (i.e., objects, machines, or abstract rules) vs. interest in people. Members of both sexes can be found at every point on the things vs. people continuum; however, more men than women exhibit a stronger interest in things, whereas more women than men exhibit a stronger interest in people. Averaging across studies, Su et al. (2009) found an effect size of $d = 0.93$ for the people vs. things sex difference. This is notably larger than most human sex differences (Hyde, 2005; Lippa, 2010; Stewart-Williams & Thomas, 2013a, 2013b), and indeed than most effects in psychology (Eagly, 1995). To get an intuitive sense of the magnitude of the difference, if one were to pick pairs of people at random, one man and one woman, the man would be more things-oriented than the woman around 75% of the time.

The people vs. things sex difference immediately suggests an explanation – or rather a partial explanation – for the fact that men outnumber women in fields such as physics, engineering, and mathematics, whereas women are at parity with or even outnumber men in psychology, the social sciences, and the health sciences: The former fields are of interest to more men than women, and the latter to more women than men, and people tend to gravitate to fields that interest them most (Diekman et al., 2017; Yang & Barth, 2015).[1]

[1] Note that there is little evidence that sex differences in the Big 5 personality traits contribute to gender gaps in STEM (Lippa, 1998; Vedel, 2016). For conscientiousness, openness, and neuroticism, this is unsurprising; although these traits predict some occupational outcomes, it is not clear why they would predict the decision to go into a maths-intensive or objects-oriented field vs. a non-maths intensive or people-oriented field. One might, in contrast, expect agreeableness and extraversion to predict interest in objects- vs. people-oriented occupations. As it turns out, however, neither variable correlates consistently with people's occupation-relevant interests (Lippa, 1998). Note as well that sex differences in conscientiousness, extraversion, and openness are small at best and not always found (Kajonius & Johnson, 2018), and that even the largest personality sex differences –

Preferences for Specific Occupations. Research looking at preferences for specific occupations leads to a similar conclusion. As Su et al. (2009) report, males on average express considerably more interest than females in engineering (d = 1.11), and somewhat more interest in science and mathematics (d = 0.36 and 0.34, respectively). These differences are present by early adolescence and closely match the observed numbers of men and women working in the relevant fields. Su et al. (2009) point out that, if we make the reasonable ballpark assumption that people working in a given field tend to come from the 25% of people most interested in that field, sex differences in occupational interests would account for the entirety of the engineering gender gap and much of the gap in science and mathematics. In short, sex differences in occupational and academic preferences are far from trivial, and plausibly make a substantial contribution to observed occupational gender gaps.

Life Priorities

Gender gaps in STEM – and especially in the higher echelons of STEM – may also be shaped in part by average sex differences in life priorities. As with occupational preferences, people vary a lot in their life priorities, and the full range of priorities can be found within each sex. Nonetheless, some priorities are more common among men than women, and others among women than men (Bolotnyy & Emanuel, 2019; Hakim, 2005, 2006; Konrad et al., 2000; Schwartz & Rubel, 2005). One longitudinal study found, for instance, that among adults identified as intellectually gifted in early adolescence, the average man reported placing more importance on career success and income than did the average woman, whereas the average woman reported placing more importance on work-life balance and making time for one’s family and friends (Benbow et al., 2000; Lubinski et al., 2014). These differences

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those for agreeableness and neuroticism – are notably smaller than sex differences in occupation-relevant interests (Lippa, 1998).

were particularly pronounced among people with children, apparently because women's priorities shifted after they became mothers (Ferriman et al., 2009). Moreover, sex differences in self-reported priorities were evident in real-world behaviour. As Lubinski et al. (2014) observed, for instance, over the course of the last fifteen years, the men in their sample spent an average of 51 hours a week doing paid work, whereas the women spent an average of 40.

Of course, sex differences in lifestyle preferences do not explain why the sex ratio is so much more male-biased in maths-intensive STEM fields than in most others. Still, the differences do plausibly help to explain the fact that, in STEM and elsewhere, men outnumber women among the minority in the higher echelons: Rising to the top is a priority for fewer women than men, and thus fewer women than men are willing to make the sacrifices required to achieve that goal. To be clear, some women *are* willing to make those sacrifices, and the majority of men are not. However, *more* men than women are willing, and this is plausibly *part* of the reason that the sex ratio at the top is so often male-biased. Note that, according to one large US study ($N \approx 4{,}000$), the sex difference in career-mindedness is not a result of women thinking that career advancement is impossible for them. The average woman views advancement as just as achievable as the average man, but as less desirable (Gino et al., 2015).

The Nature and Nurture of Sex Differences in Preferences and Priorities

Sex differences in occupational preferences and priorities suggest one possible reason that more men than women go into maths-intensive STEM fields. The reason, put simply, is that more men than women *want* to go into these fields. To the extent that this is the case, it implies that workplace discrimination accounts for a smaller fraction of the gender disparities in STEM than we might otherwise suppose. That said, even if preferences explained the *entirety* of observed STEM gender gaps (which we are not suggesting), this would not imply that discrimination plays no role. After all, preference differences themselves need to be explained, and some would argue that sexist stereotypes and discriminatory socialization practices are the primary drivers of these differences.

For many decades now, this has been the dominant explanation in the social sciences, and the one most often highlighted in papers and discussions of the topic (e.g., Cheryan et al., 2015; Dasgupta & Stout, 2014). Preferences and priorities do not just appear in a vacuum, point out proponents of this position; they are powerfully shaped by the people and the world around us. Parents, teachers, and other authority figures may inadvertently nudge boys toward object-related activities, and girls toward person-related activities. Engagement in these activities may then help to kindle an interest in them among boys and girls, respectively – after all, not only do interests help shape activities but activities help shape interests (Schmidt, 2011). In addition to parental nudging, children may nudge themselves in certain directions. Most children display a stronger preference for activities they learn are preferred by members of their own sex, even in studies looking at novel and unfamiliar activities (Shutts et al., 2010; although see Hines et al., 2016). As such, if children pick up the traditional stereotype that STEM is primarily for boys, boys' interest may spike while girls' may often dwindle. Stereotypes about STEM careers may have similar effects. Careers in STEM are commonly perceived as male-dominated (Miller et al., 2018), and as involving social isolation and a strong focus on inanimate materials and mechanisms (Cheryan et al., 2015). This may make a career in STEM seem unappealing to more girls than it does boys. Finally, girls and women may experience bias in the STEM classroom or workplace, or come to believe this is likely, and this too may cause a decline in their interest not only in STEM careers but also in STEM subjects themselves (Thoman & Sansone, 2016).[2]

But although social factors like these no doubt help to shape sex differences in interests and occupational preferences, several lines of evidence suggest that the differences are also shaped in part by unlearned biological factors. First, sex differences in occupational preferences have remained remarkably stable throughout the half-century or so that psychologists have measured them, even in the face of significant shifts in women's social roles and place in society (Su et al., 2009). In particular, the sex difference in interest in things vs. people seems stubbornly resistant to change. One analysis found, for instance, that whereas the number of women pursuing high-status professions increased a great deal since the 1970s, the number pursuing things-related professions remained virtually static (Lippa et al., 2014). Notably, this was the case despite the fact that, during the same period, a wide range of initiatives were established to try to entice women into those very professions. The stubbornness of the people-vs.-things sex difference is not what one would expect if the difference were shaped largely by culture.

Second, the same sex differences in occupational preferences have been found in every society where psychologists have looked for them. In one large study (N ≈ 200,000), Lippa (2010) found the differences in 53 out of 53 nations: a level of cross-cultural unanimity almost unheard of within psychology. Importantly, the gender gap in occupational preferences was no larger in nations with higher levels of gender inequality, suggesting that gender inequality is not a major determinant of the gap. Meanwhile, other research suggests

[2] If we adopt a broad definition of STEM, it is actually debatable whether women are less interested in STEM subjects than men are. Some data show, for instance, that just as many women as men enrol in university STEM courses, suggesting similar levels of interest (HESA, 2018). That being the case, the sociocultural explanations would have to apply primarily to more objects-oriented or maths-heavy STEM fields.

that the gender gap in STEM *career pursuit* (as opposed to STEM-related career preferences) is actually *smaller* in more gender unequal nations, perhaps in part because economic hardship in those nations means that people have less scope to act on their personal preferences, and a greater need to place financial security above self-fulfilment in choosing a suitable occupation (Stoet & Geary, 2018).[3]

Third, at least some of the relevant sex differences appear in a nascent form early in the developmental process. Indeed, the first glimmer of the people vs. things difference may be evident in the first few days of life. Connellan et al. (2000) presented 102 newborn babies with two objects, one after the other: a human face and a mechanical mobile. Many babies looked for equal amounts of time at both. However, among those who looked for longer at one than the other, more boys than girls looked for longer at the mobile (43% vs. 17%), whereas more girls than boys looked for longer at the face (36% vs. 25%). Various criticisms have been raised against the Connellan et al. study, including the fact that it is unclear whether the stimuli the researchers used map onto the people-vs.-things orientation (see, e.g., Spelke, 2005). One reason to take the findings seriously, though – and in particular, the findings related to females' heightened interest in social stimuli – is that analogous results have been observed in at least one nonhuman primate: Among macaques, newborn females are more attentive to faces than are newborn males (Simpson et al., 2016).

Finally, several lines of evidence suggest that people's interests, career preferences, and life priorities are shaped in part by prenatal hormones. The most persuasive evidence comes from research on females with *congenital adrenal hyperplasia* (or *CAH*), a condition involving exposure to abnormally high levels of prenatal androgens. CAH females tend to be

[3] For a critique of the claim that the gender gap in STEM education is smaller in more gender-unequal nations, see Richardson et al. (2020). For a response to the critique, see Stoet and Geary (2020).

more things-oriented and less people-oriented than the average female (Beltz et al., 2011). As children, they tend to be more interested in male-dominated occupations such as architect or engineer (Berenbaum, 1999), and as adults, they're more likely to work in such occupations (Frisén et al., 2009). CAH females also tend to be less interested in infants, less interested in becoming mothers, and more interested in having a career rather than staying at home (Dittmann et al., 1990; Leveroni & Berenbaum, 1998; Mathews et al., 2009). Evidence from non-clinical samples points in a similar direction. One research group found that prenatal testosterone levels, measured via amniocentesis, are negatively correlated with eye contact at one year of age (Lutchmaya et al., 2002), and quality of social relationships at four (Knickmeyer et al., 2005), consistent with a prenatal contribution to the people-vs.-things sex difference. Furthermore, a large Internet survey found that women exposed to higher levels of androgens in the womb, indexed by 2D:4D ratios (that is, the ratio of the index finger to the ring finger), are more likely to work in male-dominated professions (Manning et al., 2010).[4] Certainly, some of these findings have yet to be independently replicated, and certainly the hormonal evidence is somewhat mixed, with small sample sizes increasing the risk of both false positives due to chance and false negatives due to insufficient power (Berenbaum & Beltz, 2011). This precludes any definitive conclusions about the role of prenatal hormones. Still, the available hormonal data are at the very least suggestive, and in our view, quite persuasive. Taken together with the other data surveyed in this section, it seems reasonable to think that sex differences in interests, occupational preferences, and life priorities are not purely a product of culture or socialization. Biology plays a role as well.

[4] Note that the validity of 2D:4D as a measure of prenatal androgen exposure is currently the subject of debate (Leslie, 2019; Swift-Gallant et al., 2020; Voracek et al., 2011).

Evolutionary Rationale

Although we have good reason to think that there *is* an inherited contribution to men and women's occupational and lifestyle preferences, we have much less idea why this might be the case. The most plausible evolutionary explanation is for sex differences in lifestyle preferences. In most parental species, females invest more than males into offspring (Janicke et al., 2016; Trivers, 1972). Among mammals, for instance, females gestate and nurse the young, and females usually provide the bulk of the direct parental care. In our species, sex differences in parental investment are comparatively modest: Both sexes tend to invest substantially in their young, rather than only the females. But there is still a difference; men in all known cultures invest less into offspring than women, and this has probably been the case for most of our evolutionary history (Stewart-Williams & Thomas, 2013b). Importantly, the *minimum* biological investment is also notably smaller for men than for women. Women's minimum is a nine-month pregnancy and – until recently – several years of breastfeeding. Men's minimum is the time and effort required to impregnate the woman.

As a result of these sex differences in parental investment, ancestral men could potentially produce many more offspring than ancestral women, simply by mating with multiple partners (Clutton-Brock & Vincent, 1991). Consequently, human males evolved to be more interested than females in seeking multiple partners (Schmitt, 2005; Schmitt & International Sexuality Description Project, 2003), less choosy about their low-commitment sexual partners (Buss & Schmitt, 1993; Kenrick et al., 1993), and – of particular relevance to the present topic – more inclined to compete and take risks to obtain the status and resources that typically made them attractive to women (or women's families, in the case of arranged marriages; Byrnes et al., 1999; Daly & Wilson, 2001; M. Wilson & Daly, 1985). In light of this theoretical framework – which is well-supported by research on other species (Andersson, 1994; Janicke et al., 2016) – it is little surprise that more men than women prioritize the pursuit of status over family, whereas more women than men prioritize family and work-life balance.

Evolutionary explanations for sex differences in occupational preferences are somewhat more of a stretch. For most of human evolution, there were no scientists, no technologists, no engineers or mathematicians. As such, any innate contribution to sex differences in interest in these vocations must be a byproduct of traits selected for other reasons. One possibility is that the differences trace back to the sexual division of labour among our hunter-gatherer forebears, and specifically the fact that women specialized in caring for the young whereas men specialized in hunting and perhaps waging war with other groups (a division of labour found as well among our close relatives, the chimpanzees; Muller et al., 2017). To fit them to these roles, women may have evolved a stronger attentiveness to the needs of the young, and to people in general (Hrdy, 2009; S. E. Taylor et al., 2000), whereas men may have evolved a stronger interest in the tools used for hunting and warfare (Archer, 2019; Geary, 2010). Sex differences in interest in people-focused vs. things-focused occupations may be an adaptively neutral side effect of these ancient, more primal differences. It is worth emphasizing that, although this hypothesis seems reasonable, it has yet to be rigorously tested. Regardless of the ultimate explanation, however, the evidence for an inherited contribution to the relevant sex differences is strong.

Sex Differences in Cognitive Aptitudes

Sex differences in occupational preferences are not the only reason we might expect uneven sex ratios in certain STEM fields, even if discrimination were entirely removed from the picture. A second, more controversial suggestion is that STEM gender gaps are due in part to average sex differences in a small subset of STEM-relevant cognitive capacities, which result in somewhat more men than women having a suitable profile of aptitudes for working in some STEM fields. This statement could easily be misconstrued, so it's important to be absolutely clear what is meant.

First, the claim is not that men perform better than women in every cognitive domain. On the contrary, men perform better in some domains whereas women perform better in others. The best-known examples are that men score higher than women on most tests of spatial ability, whereas women score higher than men on most tests of language ability, including verbal comprehension, reading, and writing (Halpern, 2012; Reynolds et al., 2015). Note that, although there are reliable sex differences in various *specific* cognitive abilities, most commentators agree that there are no average differences in *general* cognitive ability in representative samples (Halpern, 2012).

Second, even in areas where men do perform better, the claim is not that all men – or even most – perform better than all or most women. As with occupational preferences, members of both sexes vary enormously in every cognitive aptitude, and the distribution for men overlaps almost entirely with that for women (Hyde, 2005). However, for some aptitudes, the distribution for one sex is shifted somewhat to the right of that for the other, such that the average score for the former is somewhat higher. In saying this, it's worth stressing that the average score does not describe all members of the group, or even the typical member, but merely represents the central tendency within a broad array of scores. Most people fall above or below the average.

Third, the claim is not that these cognitive sex differences are especially large. On the contrary, at the centre of the distribution, they tend to be quite small (Hyde, 2005; Stewart-Williams & Thomas, 2013a, 2013b). The only reason they matter at all is that even small differences at the mean are associated with progressively larger differences the further from the mean one looks (see Figure 1). For jobs requiring normal-range abilities – including many lower-level STEM jobs – cognitive sex differences are likely to make little difference: The pool of potential female candidates is similar in size to the pool of potential males. However, for jobs requiring exceptional abilities, the sex ratio of possible candidates may be somewhat skewed in favour of one sex or the other – even when the relevant sex differences in the general population are small or even negligible (Halpern, 2012; Halpern et al., 2007; Steven Pinker, 2002).

--------------------Insert Figure 1 about here--------------------

Fourth, the claim is not that women lack the cognitive talents to make it in STEM. *Most* people lack the cognitive talents, and of those who do possess them, some are men and some are women. The claim is simply that, because of small average differences in a small subset of abilities, *somewhat* more men than women may be suited to work in *some* areas of STEM – and for the same reason, somewhat more women than men may be suited to work in others.

The Relevant Differences

With these important qualifications in mind, let us now consider some of the sex differences in cognitive aptitudes that may help to explain the uneven sex ratios found in certain STEM disciplines.

Spatial Abilities. The first concerns sex difference in spatial abilities. As mentioned, the average score on most spatial tests is moderately higher for men than for women (visuospatial ability: d = 0.48; spatial visualization: d = 0.23; mental rotation: d = 0.66; Archer, 2019). This is a well-established finding (Voyer et al., 1995), especially with respect to mental rotation (Maeda & Yoon, 2013), and it seems reasonable to think that it might be part of the reason that somewhat more men than women gravitate to fields that require above-average spatial abilities – fields such as physics and engineering. Consistent with this assessment, more than fifty years of research in educational psychology indicates that spatial ability is indeed an important predictor of STEM success (Wai et al., 2009).

Mechanical Reasoning. A second, less widely known cognitive sex difference is that, on average, males as a group score higher than females as a group on tests of mechanical reasoning – that is, tests of the ability to solve problems involving mechanical principles and physical laws (Flores-Mendoza et al., 2013; Lemos et al., 2013). Unlike most cognitive sex differences, this one is rather large even at the mean (d = 0.8-1), and thus larger still at the right-hand tail of the distribution (Hedges & Friedman, 1993; Hedges & Nowell, 1995). As with the spatial sex difference, the sex difference in mechanical reasoning has clear implications for the gender composition of fields such as engineering and physics.

Mathematical Ability. A third difference relates to mathematical ability; in this case, however, the findings are less straightforward. Sex differences in mathematical ability are highly variable: In some nations, boys do better on average; in others, girls do; and in others still, there are no overall sex differences (Else-Quest et al., 2010; Hyde et al., 2009; Stoet et al., 2016). At the same time, though, there are several maths-related differences which may be relevant to STEM outcomes. First, whereas females tend to do better in tests of mathematical computation (d = 0.14), at least in childhood, males tend to do better – at least from adolescence – in tests of mathematical *reasoning* or problem solving (d = 0.3; Hyde et al., 1990; see also Benbow, 1988; Halpern, 2012). This is a potentially important finding because, as Hyde et al. (1990) note, mathematical reasoning "is critical for success in many mathematics-related fields, such as engineering and physics" (p. 151). Second, despite small and cross-culturally variable differences in *average* scores, males tend to outnumber females at the highest levels of mathematical performance. Wai et al. (2010) report, for instance, that in the US since the 1990s, the male-to-female ratio among the top 1% on the SAT-Math has been around 1.1-to-1, among the top 0.5% has been around 1.6-to-1, and among the top

0.01% has been around 4-to-1. Similar ratios have been found in other countries and using other tests (Baye & Monseur, 2016; Makel et al., 2016; Reilly et al., 2015). The upshot is that somewhat more men than women are likely to have the mathematical acumen to work in maths-intensive STEM fields – even though, once again, many women do too, and most men do not.

Furthermore, several lines of evidence suggest that absolute levels of maths ability are not all that matters when it comes to occupational outcomes. The relative balance between people's maths ability and their language ability matters too, and the sexes differ in this respect. First, more males than females exhibit "maths tilt" (maths > verbal), whereas more females than males exhibit "verbal tilt" (verbal > maths; Coyle et al., 2015; Lubinski et al., 2001; Stoet & Geary, 2018; Wai et al., 2018). Importantly, maths-tilt predicts interest in STEM, whereas verbal-tilt predicts interest in the humanities – even for people with high-level maths abilities. Second, among the minority of people who possess exceptional mathematical abilities, the women are more likely to possess exceptional language abilities as well. This means that mathematically gifted women have more vocational options than their male counterparts, and consequently that fewer mathematically gifted women end up pursuing a STEM career (Wang et al., 2013; see also Breda & Napp, 2019). To the extent that this explains the gender gap in maths-intensive fields, the gap results not from mathematically gifted women having fewer options, but rather from them having more.

Systemizing and Empathizing. A final cognitive difference bearing on the question of STEM sex ratios relates to Baron-Cohen's (2003) distinction between *systemizing* and *empathizing*. Systemizing refers to the desire and ability to understand or build "systems," including mechanical systems like cars, physical systems like galaxies, and abstract systems like logic and mathematics. Empathizing, in contrast, refers to the desire and ability to understand people: their thoughts, their desires, their feelings. Virtually every human being possesses both abilities to a greater or lesser extent. On average, though, men score higher than women on tests of systemizing (*d* = 1.21), whereas women score higher than men on tests of empathizing (*d* = 0.87-0.91; Archer, 2019; Baron-Cohen et al., 2001). As usual, these differences are not overwhelmingly large among the majority in the normal range (see Stewart-Williams & Thomas, 2013a, 2013b, on the interpretation of effect sizes). However, among the minority of exceptional empathizers, women considerably outnumber men, and among the minority of exceptional systemizers, men considerably outnumber women (Baron-Cohen et al., 2014; Greenberg et al., 2018). It seems reasonable to suppose that sex differences in systemizing and empathizing are part of the reason that more men than women gravitate to fields such as physics and engineering, whereas more women than men gravitate to fields such as psychology and education. Consistent with this suggestion, a survey of nearly half-a-million people by Ruzich et al. (2015) revealed that STEM workers score consistently above workers in non-STEM fields on measures of systemizing ability.

Most commentators agree that sex differences in cognitive aptitudes are too small to explain STEM gender gaps in their entirety, and that sex differences in occupational preferences are a much more important contributor (Ceci et al., 2009; Dekhtyar et al., 2018; Johnson et al., 2008; Wai et al., 2018). Still, the evidence for the cognitive differences is robust, and it is perfectly plausible that they help to shape men and women's career choices and trajectories. Indeed, given the clear relevance of the aptitudes in question to STEM, it would be surprising if this were *not* the case.

The Nature and Nurture of Sex Differences in Cognitive Aptitudes

Where do these cognitive sex differences come from? One common view is that they are primarily a product of widely held stereotypes of the sexes: stereotypes that females are bad at maths, for instance, or that males alone possess the kind of innate brilliance supposedly required for certain academic fields (Bian et al., 2017, 2018; Nosek et al., 2009).

In a number of ways, such stereotypes may function as self-fulfilling prophesies. First, they may lead parents and teachers to steer girls away from activities related to male-dominated areas such as maths, physics, and computer programming, or to overlook or undervalue female giftedness in these domains and thus fail to adequately nurture it (Cheryan et al., 2017; Eccles et al., 1990; Lavy & Sand, 2018). Second, the stereotypes may persuade girls themselves that these areas are unlikely to be their fortes, which may lead them to lose interest in them and devote more time to other activities. This time-allocation pattern will naturally help determine which skills they end up developing. Finally, stereotypes about females' mathematical or intellectual abilities, when made salient, may cause girls and women to underperform in high-stakes, time-limited tests as a direct result of their anxiety about confirming the denigrating stereotypes (a putative example of a phenomenon known as *stereotype threat*; Nguyen & Ryan, 2008; Schmader et al., 2008; Spencer et al., 1999).

The sociocultural explanations are intuitively plausible, and they all have at least some research backing them up. At the same time, however, the explanations are vulnerable to a number of criticisms. To begin with, it is unclear to what extent current social influences actually point in the direction these explanations presuppose. According to one study, by four years of age, girls tend to assume that boys are academically inferior, and by seven, boys assume the same thing (Hartley & Sutton, 2013). Similarly, teachers tend to view their female students as superior at maths and reading, even when aptitude tests indicate that the boys are doing better (Robinson & Lubienski, 2011). Popular culture often mirrors these trends, with girls depicted as academically superior to boys (consider, for instance, Bart and Lisa from *The Simpsons*, and Ron and Hermione from the *Harry Potter* series; see Synnott, 2016, for discussion of modern cultural depictions of boys and men). Certainly, several studies suggest that people see extreme brilliance as a male trait more than a female one (Bian et al., 2017, 2018). Nonetheless, it is far from obvious that, on balance, stereotypes about academic ability favour boys more than girls. Moreover, although stereotypes *can* bias social perception and function as self-fulfilling prophesies, the effects tend to be weak and the main reason that stereotypes correspond to social realities appears to be that they *reflect* those realities, rather than that they create them (Jussim, 2015).

As for stereotype threat, a recent slew of studies has failed to find evidence that situations likely to induce threat do in fact hamper females' performance in maths or other cognitive domains. The studies in question include several meta-analyses (Flore & Wicherts, 2015; Stoet & Geary, 2012), a number of large, pre-registered replications (Finnigan & Corker, 2016; Flore et al., 2019), and an analysis of 5.5 million chess games played in international tournaments, which found that women's performance was better, rather than worse, under conditions of stereotype threat (Stafford, 2018; although see Smerdon et al., 2020). Meanwhile, on the other side of the ledger, a recent study failed to replicate the finding that stereotype threat impairs *men's* performance on tests of language ability (Chaffee et al., 2020). At the very least, the effects of stereotype threat are more modest and situationally contingent than was originally assumed.

Still, even if the current crop of sociocultural theories requires refinement, it seems undeniable that social factors play a role in shaping cognitive sex differences. Aside from anything else, the relevant abilities can be improved with practice and training (Uttal et al., 2013), and the magnitude of the sex differences varies from place to place and from time to time (Hoffman et al., 2011; Hyde et al., 2009). Social forces are clearly part of the story. The question is whether social forces are the *entirety* of the story – and the answer is that they're almost certainly not. Various lines of evidence suggest, once again, that biological factors play a pivotal role as well.

First, many of the sex differences under discussion appear early in the developmental process. The sex difference in mental rotation, for instance, can be detected by three months of age (Moore & Johnson, 2011; Quinn & Liben, 2014; although see Miller & Halpern, 2014), and the sex difference in language ability can be detected by seven months (Bando et al., 2016). These findings do not *rule out* purely environmental explanations, but they do render them less plausible. At a minimum, they eliminate the possibility that social influences appearing after the age of one could provide a *complete* explanation for the differences. (Note, though, that later-appearing differences are not necessarily products of social causes alone; to some extent, they may be part of the natural maturational process. This is especially likely when the changes coincide with puberty; Berenbaum & Beltz, 2011.)

A second line of evidence for a biological contribution is that several of the traits under discussion have been linked, albeit somewhat tentatively, to sex hormones (Berenbaum & Beltz, 2011). Most of the relevant research has focused on spatial abilities. Various studies have found that girls and women with CAH do better than unaffected controls on a range of spatial tasks (Berenbaum et al., 2012; Hampson et al., 1998; Mueller et al., 2008; Resnick et al., 1986). Admittedly, not all studies have found this pattern (see, e.g., Hines et al., 2003; Malouf et al., 2006). One possible explanation for the mixed findings, however, is that most studies in the area have small sample sizes, and thus some fail to detect an effect, even when the effect is there (Berenbaum & Beltz, 2011). Consistent with this suggestion, a meta-analysis of CAH studies concluded that females with the condition have better spatial skills than unaffected controls (Puts et al., 2008; although see Hines, 2009). Whereas females exposed to high levels of testosterone in early life appear to have above-average spatial abilities, males exposed to *low* levels – including males with *idiopathic hypogonadotropic hypogonadism* (or *IHH*) – appear to have below-average abilities (Buchsbaum & Henkin, 1980; Hier & Crowley, 1982). On top of that, the link between testosterone and spatial abilities has been demonstrated experimentally in various nonhuman mammals (summarized in Hampson et al., 1998), making it a reasonable default hypothesis for our own species. In addition to the spatial-skills findings, testosterone has been linked to higher systemizing, and to lower social skills, empathizing, and verbal ability (Auyeung et al., 2006; Chapman et al., 2006; Lutchmaya et al., 2001, 2002; although see Nadler et al., 2019, on the testosterone/low-empathy link). It is unclear at this stage whether hormones affect abilities directly, or do so indirectly through their effects on people's activity preferences (see, e.g., Schmidt, 2011). Based on present evidence, however, a reasonable supposition is that they do both (Berenbaum et al., 2012).

Third, sex differences in cognitive abilities appear to transcend cultural boundaries. Across cultures, girls typically outperform boys on tests of linguistic ability (Stoet & Geary, 2013), whereas boys typically outperform girls on most spatial tasks (Cashdan et al., 2012; Lippa et al., 2010; although see Hoffman et al., 2011). Certainly, as mentioned, there is variation in the magnitude of these differences from nation to nation and from generation to generation, suggesting a sizeable role for malleable social factors. Still, the direction of the spatial/linguistic differences is essentially invariant. This is not what one would expect if these differences had a purely environmental origin.

Fourth, efforts to eliminate the gaps quickly seem to reach the point of diminishing returns. Wai et al. (2010) looked at the ratio of boys-to-girls in the top 0.01% of US seventh graders taking the SAT-Math test between 1981 and 2010. In the early 1980s, the ratio was 13 boys for every girl. By the early 1990s, this had dropped to just four boys for every girl, perhaps as a result of increasing access to a good maths education for girls (see also Hyde et al., 1990). Since then, however, the ratio of boys-to-girls among the top maths performers has remained largely the same, despite intensified efforts to eliminate the remaining gap.[5]

[5] In fact, some research suggests that the ratio of males-to-females at the top levels of mathematical reasoning has *increased* in recent years (Lakin, 2013).

Meanwhile, the ratio of girls-to-boys among the top performers on tests of verbal and reading ability has consistently favoured girls (Makel et al., 2016; Wai et al., 2010). Again, these findings are not what one would expect if the gaps were due entirely or even primarily to sociocultural causes.

Fifth and finally, a large meta-analysis by Xu et al. (2017; N = 254,231) concluded that gay men tend to have spatial and linguistic abilities comparable to those of straight women, whereas lesbians tend to have spatial abilities comparable to those of straight men (but female-typical linguistic abilities). These findings are not readily explicable on the assumption that social forces alone create the usual pattern of sex differences. Gay men were presumably subject to essentially the same gender-specific social forces as straight men, and lesbians the same gender-specific social forces as straight women. As such, the near-reversal of the usual spatial vs. language pattern is hard to reconcile with the claim that this pattern is due largely to social forces. Other variables, such as prenatal hormones, appear to play a larger role.

To be clear, none of this is to deny a role for social forces in general or for stereotypes in particular. Indeed, even if the stereotypes ultimately trace back to genuine, unlearned differences between the sexes, they could still further shape people’s interests and choices, and therefore help determine which skills they practice and hone (Ellemers, 2018). Nonetheless, it is difficult to explain all the data without assuming a non-trivial biological contribution.

Evolutionary Rationale

It seems reasonable to conclude that the cognitive sex differences considered in this section are moulded to an important degree by unlearned biological factors. However, as with sex differences in occupational preferences, it is not at all obvious why this might be the case. Some argue that sex differences in spatial ability trace to the fact that *Homo sapiens* is an *effectively polygynous* species: that is, a species in which males have somewhat greater reproductive variability than females (Betzig, 2012; Labuda et al., 2010). In effectively polygynous species, the argument goes, males tend to have larger ranges than females, and therefore tend to evolve stronger spatial and wayfaring skills (Gaulin, 1992). The polygyny-related spatial sex difference may have been further amplified in our species by the fact that human males are specialized for hunting and tracking animals, and perhaps also for engaging in coalitional warfare with neighbouring groups (Silverman & Phillips, 1998; see Archer, 2019, for an overview of adaptationist explanations).

Many evolutionary psychologists are unpersuaded by these ideas, however. In their view, cognitive sex differences were not specifically favoured by natural selection, but instead are byproducts of other sex differences that were. Clint et al. (2012) argue, for instance, that the male advantage in spatial skills is merely a side effect of hormonal sex differences that were selected for other reasons. If this is right, then the spatial sex difference may have an innate basis but not be a direct product of natural selection.

At this stage, the ultimate origins of human cognitive sex differences are uncertain. What does seem certain, though, is that the differences are not solely a product of social forces. To some extent – perhaps to an important extent – they are a part of human nature.

Sex Differences in Variability

We see, then, that small mean differences in certain STEM-relevant aptitudes may result in somewhat more males than females occupying the right-hand tail of the distribution for those aptitudes. However, even if there were *no* differences at the mean, males could still outnumber females among the minority at the right-hand tail. This is because males and females differ in another way as well. In a wide variety of traits, males as a group are more variable than females: The male distribution is slightly flatter, and stretches out somewhat further on both sides of the mean (see Figure 2). This is the case for a range of physical traits, including birth weight, adult weight, adult height, and running speed (Lehre et al., 2009), average heart rate during exercise (Hossack & Bruce, 1982), and various aspects of brain structure (Ritchie et al., 2018; Wierenga et al., 2020). It also appears to be the case for a range of psychological traits, including creativity (Karwowski et al., 2016), general knowledge (Feingold, 1992), physical aggression (Archer & Mehdikhani, 2003), and at least four of the Big 5 personality traits (Borkenau et al., 2013). Of particular relevance to the present topic, males seem to be more variable than females in a number of cognitive abilities relevant to STEM (Baye & Monseur, 2016; Feingold, 1992). In this section, we outline these differences, then make the case that they are shaped to a significant degree by biological factors.

--------------------Insert Figure 2 about here--------------------

Variability in STEM-Relevant Cognitive Capacities

Specific Cognitive Capacities. To begin with, many studies have found somewhat greater variability among males than females in specific cognitive capacities, including mathematical aptitude, spatial ability, and science knowledge. In one classic paper, Hedges and Novell (1995) analysed the cognitive test scores of six large, nationally representative US samples, together covering a 32-year period. They found that, for 35 of the 37 tests examined, male variability was greater than female. Importantly, this included all the tests of mathematics, spatial ability, mechanical reasoning, and science knowledge. In most cases, sex differences in average scores were small. Nevertheless, because males were more variable, they tended to outnumber females among the minority with especially high scores.

(An exception was reading comprehension, for which males outnumbered females at the bottom – the usual pattern – but females outnumbered males at the top.)

Similar results have been found in other nations and using other tests. For example, in a large sample of UK students (N ≈ 320,000), Strand et al. (2006) found that, although sex differences were small at the mean, males somewhat outnumbered females at the top and the bottom of the distribution for both quantitative and nonverbal reasoning; for verbal reasoning, in contrast, males outnumbered females only at the bottom (see Lohman & Lakin, 2009, for a US replication of this exact pattern). Likewise, analyses of data from the Organisation for Economic Co-operation and Development (OECD) and the International Association for the Evaluation of Educational Achievement (IEA) show that, in most countries for which test scores are available, males are more variable than females in maths, reading and science (Baye & Monseur, 2016; Machin & Pekkarinen, 2008). More recently, an analysis of 1.6 million students by O'Dea et al. (2018) found again that, although on average girls did better than boys at school, boys exhibited greater variability and thus outnumbered girls among the highest performers. For grades in STEM subjects, the top 10% contained equal numbers of boys and girls; any higher than the top 10%, however, contained more boys. Note that the variability gap was somewhat smaller for grades than for test scores, perhaps as a result of ceiling effects for the former. Curiously, the variability gap was *larger* for non-STEM subjects than for STEM ones, contrary to the authors' predictions.

General Cognitive Ability. As well as greater male variability in specific cognitive aptitudes, males may be more variable in general cognitive ability or IQ (Deary et al., 2007; Feingold, 1992; Strand et al., 2006). The gold-standard study on this topic is Johnson et al. (2008). Unlike earlier studies, which used potentially unrepresentative samples, Johnson and colleagues utilized IQ data from two population-wide surveys of 11-year-old school children in Scotland. As expected, IQ variability was greater among boys than girls, such that there were somewhat more boys at both extremes of the IQ distribution: more at the top, but also more at the bottom (although see Iliescu et al., 2016, for a recent failure to replicate this pattern in a large, nationally representative Romanian sample).

To the extent that greater male variability results in more males than females occupying the upper echelons of ability, whether for specific aptitudes or general cognitive ability, this may help to explain why more males than females occupy the upper echelons of certain fields in STEM (Levy & Kimura, 2009; Steven Pinker, 2002). It's important to emphasize that this could not be a *complete* explanation of observed STEM gender gaps. As various experts have pointed out, sex differences in variability are not nearly large enough to explain these gaps in their entirety (Hyde, 2014; Johnson et al., 2008; O'Dea et al., 2018). Moreover, variability differences would not explain gender gaps at lower levels of the STEM hierarchy (where extreme abilities are not required), and would not explain why the gaps are larger in some fields than others. Still, taken together with preferences, cognitive specializations, and stereotypes, greater male variability may be one more piece of the STEM puzzle. See Box 2 for further discussion.

--------------------Insert Box 2 about here--------------------

The Nature and Nurture of Sex Differences in Variability

What might explain sex differences in cognitive variability? Given that the magnitude of these differences fluctuates across cultures and times, it seems unlikely that they are attributable solely to biological factors (Feingold, 1992; Gray et al., 2019; Hyde et al., 2009). However, as with average differences in preferences and aptitudes, various lines of evidence suggest that biological factors play a crucial role.

First, greater male variability is found not only in psychological traits, but also in traits that are largely impervious to social pressure and cultural norms, such as height, birth weight, and BMI (Lehre et al., 2009). The sex differences in *psychological* variability thus appear to be part of a broader pattern. Considerations of both parsimony and plausibility suggest that this pattern probably has a single, common cause, rather than distinct causes for its physical and psychological components.

Second, sex differences in variability emerge in early childhood (O'Dea et al., 2018). The sex difference in IQ variability, for instance, appears before children begin school (Arden & Plomin, 2006). This does not definitively rule out a Nurture Only explanation for the difference. However, it does add some weight to the scales on the biological side of the argument, and it reduces the range of non-biological factors that any Nurture Only explanation can invoke. Whatever the *ultimate* causes of greater male variability in IQ, those causes appear to be in place by three years of age at the latest. And other variability sex differences have been detected even earlier. One mega-analysis of brain-imaging data from 16,683 individuals revealed that greater male variability in brain structure was present by one year of age (suggesting a role for genetic factors), and was highly stable throughout the lifespan (suggesting a relatively modest role for the environment; Wierenga et al., 2020).

Third, greater male variability is not unique to humans but is found as well in many nonhuman animals, including most mammals (Reinhold & Engqvist, 2013). Among red deer, for instance, males are not only larger than females but are also more variable in size (Clutton-Brock et al., 1982); among primates, males are more variable in lifespan (Colchero et al., 2016); among guenons (a genus of Old World monkeys), males are more variable in skull size (Cardini & Elton, 2017); and among chimpanzees – as among humans – males are more variable in brain structure (DeCasien et al., 2020). When we find this pattern in other mammals, the only realistic explanation is a biological one. When we then find the *same* pattern in our own species, considerations of parsimony and plausibility suggest again that a biological explanation is appropriate for us, too. Indeed, without a strong reason to think otherwise, the default assumption should be that humans fit within the same explanatory framework that applies to the rest of the animal kingdom, and thus that greater male variability in our species has the same root cause as that in our nonhuman kin.

Evolutionary Rationale

If greater male variability has a biological basis, what evolutionary pathways might have produced it? Once again, the answer is not yet certain, but biologists have put forward a number of plausible suggestions. Two in particular stand out: one adaptationist explanation and one non-adaptationist explanation.

The adaptationist explanation traces greater male variability in general to another, more fundamental sex difference: greater male variability in reproductive success (see, e.g., Pomiankowski & Møller, 1995; Rowe & Houle, 1996). As a result of sex differences in parental investment, males in many species are more variable than females in the number of offspring they produce (Clutton-Brock & Vincent, 1991; Trivers, 1972). At one extreme, some males have a relatively high number of offspring: more than any female. At the other, because mating opportunities are finite, some males have no offspring or relatively few. Most females, in contrast, fall somewhere in between. In species where male reproductive variability is high, selection favours any trait that increases a male’s chances of being among the few that have many offspring, rather than the many that have few or none. One such trait appears to be risk-proneness. In many species, selection has favoured a greater willingness among males to risk life and limb in the pursuit of status, resources, and mating opportunities. Male risk-taking sometimes paid off for the risk-taker and sometimes did not. When it did pay off, however, it paid off so handsomely that, on average, risk-taking males had more offspring than males who were more risk-averse. For females, in contrast, risk-taking offered fewer reproductive advantages, because the ceiling number of offspring for females is so much lower. Thus, males in many species evolved a greater propensity to take risks than did females (Daly & Wilson, 2001).

According to the reproductive-variability explanation for greater male variability, this calculus applies not only to behaviour but to development: Male development is somewhat more “risk-prone” than female development, such that males have a greater chance of developing especially impressive traits but also a greater chance of developing less impressive ones. The former males have a sufficiently high number of offspring that, on average, males with the risky developmental program have more offspring than those with a more conservative or risk-averse one. As such, the risk-prone male developmental program is selected – and with it, greater male variability in a wide range of traits.

Might this apply to humans? Compared to most mammals, the human sex difference in reproductive variability is rather modest (Stewart-Williams & Thomas, 2013b). Nonetheless, genetic and anthropological data strongly suggest that there is such a difference (Betzig, 2012; Labuda et al., 2010; summarized in M. L. Wilson et al., 2017, Table 1). This may have resulted in the evolution of males that are somewhat more risk-prone than their female counterparts, not just behaviourally but developmentally as well.

An alternative, non-adaptationist explanation is that sex differences in variability are a byproduct of the fact that, in our species and many others, biological sex is determined by sex chromosomes (as opposed, for instance, to temperature; Johnson et al., 2009; Reinhold & Engqvist, 2013). In many species with chromosomal sex determination, one sex is heterogametic (members of that sex have two different sex chromosomes), whereas the other is homogametic (members have two identical sex chromosomes). In mammals, males are heterogametic (XY chromosome), whereas females are homogametic (XX); in birds, it’s the other way round (ZW females vs. ZZ males). According to the “sex-chromosome hypothesis," in species with this arrangement, the heterogametic sex is usually more variable. This is because the sex chromosome unique to the heterogametic sex (e.g., the Y chromosome in mammals) typically has very few genes, other than those that trigger the development of that sex. As a result, the heterogametic sex has only one copy of most genes on the *non*-unique sex chromosome (e.g., the X chromosome). In contrast, the homogametic sex has two copies. If these copies differ from one another, their effects on their owner are typically averaged, which reins in the effect of any extreme genes. For the heterogametic sex, on the other hand, with just one copy of most genes, there is rarely any reining in of extreme genes. The net effect is that, for any trait influenced by the sex chromosome shared by both sexes, the heterogametic sex is normally more variable.

Consistent with this hypothesis, Reinhold and Engqvist (2013) found that, in two groups of species with heterogametic males (mammals and certain insects), the males tended to be more variable in body size, whereas in two groups with heterogametic *females* (birds and butterflies), the *females* tended to be more variable. Note that, as well as providing initial support for the sex-chromosome hypothesis, these findings cast doubt on the reproductive-variability explanation, which would predict greater male variability across the board (although see Wyman & Rowe, 2014). For other evolutionary explanations of greater male variability, see Archer and Mehdikhani (2003) and Del Giudice et al. (2018).

Certainly, as Hyde et al. (2009) have shown, the size of the variability gender gap varies across cultures, suggesting that social forces play a role in shaping the gap – perhaps enlarging it and perhaps sometimes making it smaller. The basic pattern itself, however, is plausibly a part of our evolutionary heritage: one that helps to shape the modern occupational landscape.

Bias and Discrimination in the Workplace

We have now discussed three factors that, in principle, could explain why men and women would not be equally represented in STEM even if there were no discrimination within STEM fields. This does not imply, of course, that there *is* no discrimination within STEM fields, or that discrimination is not one of the factors contributing to existing gender gaps. Even if fewer women than men are interested in working in maths-intensive STEM fields, it could still be the case that those who *are* interested face a hostile environment in the classroom and the workplace, are subject to disparaging stereotypes and low expectations, experience sexual harassment on the job and at conferences, and are less likely to be hired, promoted, published, cited, or awarded grants than their male counterparts (Dasgupta & Stout, 2014).

The discrimination hypothesis for STEM gender gaps is clearly worth taking seriously; after all, no one denies that there was considerable discrimination in STEM prior to the second wave of the feminist revolution, and it may be unduly optimistic to think that this would evaporate completely in little more than half-a-century. At the same time, though, the hypothesis constitutes a rather serious accusation against people working in STEM and a rather serious indictment of existing institutions. As such, it is only fair to look carefully at the evidence for and against the hypothesis. For the reasons given already, gender disparities are not in themselves direct evidence of discrimination; unless the sexes were psychologically identical, equality of opportunity would almost certainly not translate into equality of outcomes (Steven Pinker, 2002; Radcliffe-Richards, 2014). Nonetheless, various lines of evidence do bear on the question of how much discrimination remains in the world of STEM. In the following, we survey the evidence for discrimination against women in STEM, then look at evidence that complicates the picture – including evidence suggesting discrimination against men.

Bias and Discrimination against Women in STEM

The most abundant source of evidence for bias against women in STEM comes from experimental studies looking at people's reactions to hypothetical applicants for STEM jobs. Otherwise identical job applications are given either a female or a male name, and then evaluated by participants naïve to the purpose of the study. In one widely cited paper in this genre, Moss-Racusin et al. (2012) had science faculty from six major universities rate applications for a laboratory manager position. They found that the raters – female and male alike – gave higher ratings to supposedly male applicants than they did to supposedly female ones. Specifically, participants rated the males as more competent and hireable, and as deserving a higher salary. In another, earlier study, Steinpreis et al. (1999) found that, for middling job applications, academic psychologists – again, female and male alike – expressed greater willingness to hire a male job candidate than an identical female one. For outstanding applications, on the other hand, there was no effect of gender.

Admittedly, both of these studies had a number of weaknesses, including the fact that the samples included only 127 and 238 participants, respectively. However, the findings are broadly consistent with a large body of research in the area. A meta-analysis of studies looking at simulated employment decisions (N = 22,348) found little or no gender bias in female-dominated or gender-balanced fields, but a small-to-moderate pro-male bias among males in male-dominated fields (d = 0.3; Koch et al., 2015, Table 2). Furthermore, although participants in male-dominated areas exhibited little gender bias when judging candidates with unambiguously positive or negative traits, they did exhibit a pro-male bias when judging participants with average traits or a mixture of positive and negative (Koch et al., 2015, Table 3). The meta-analysis did not focus specifically on STEM-related hiring decisions; however, given that many STEM fields are male-dominated, the results nonetheless increase the plausibility of the STEM-specific findings.

Of course, even if the results are valid, it is not clear whether they generalize to real-world hiring decisions, where decision makers have more experience and are more motivated to make the best decision. Indeed, the Koch et al. meta-analysis showed that pro-male biases were effectively eliminated in those circumstances ($d = 0.01$). Furthermore, as we discuss later, other research suggests that the hiring bias in STEM may sometimes go the other way (Ceci et al., 2014; Williams & Ceci, 2015). Still, it is entirely possible that anti-female bias plays a role in STEM hiring decisions, at least in some cases.

Moreover, hiring is not the only domain in which discrimination could occur. Other studies have uncovered other possible examples of discrimination, in STEM and in academia more broadly. Among the best conducted and most persuasive studies are the following:

- A study of Israeli primary schools found that boys got higher marks in maths assessments where the students' gender was known than in gender-blind ones, whereas *girls* got higher marks in the gender-blind assessments. In other words, maths teachers tended to favor boys when assessing students' maths abilities. Teacher favoritism was associated with greater subsequent maths achievement among boys, and a greater likelihood of enrolling in advanced maths classes in high school (Lavy & Sand, 2018).
- Professors in the US are less likely to respond to informal inquiries about a PhD program when the inquirer is a woman (Milkman et al., 2015).
- In 2018, several Japanese medical schools admitted favouring male applicants to their programs (Cyranoski, 2018).
- In several online samples, people were more likely to refer a man than a woman for a hypothetical job when the job was described as requiring extreme intellectual ability (Bian et al., 2018).
- In a large audit study (in which fictitious job applications are sent out in response to genuine job advertisements, and subsequent call-backs counted), high-achieving men received twice as many call-backs as high-achieving women – and three times as many among maths majors (Quadlin, 2018).
- Economics papers authored by women need to be better written to be accepted into top-tier journals (Hengel, 2017).

- Neuroscience papers with a male first author and male last author are more likely to be cited than those with first and last authors of different sexes, or those with a female first author and female last author (Dworkin et al., 2020). This is driven largely by men's citation practices.
- Male researchers in animal psychology and social cognition are more likely to share their data and published research with other men than with women (Massen et al., 2017).
- According to one major meta-analysis, men have a 7% better chance of being awarded research grants (Bornmann et al., 2007).
- Female academics less often give talks at prestigious US universities, even controlling for the rank of the available speakers, and even though women are apparently no more likely to turn down an invitation (Nittrouer et al., 2018).
- Women commonly get lower ratings than men in teaching evaluations (Rosen, 2018), even in experimental studies that equalize teaching quality (MacNell et al., 2015; Mengel et al., 2018).
- Women may encounter sexism or harassment at work, in the field, or at conferences, which may contribute to a desire to leave STEM or academia (Biggs et al., 2018; Clancy et al., 2014; Funk & Parker, 2018).

One might point to weaknesses in any particular study, or worry about a general tendency to seek, report, and cite only results that confirm a narrative of female disadvantage and male privilege (Duarte et al., 2015; Honeycutt & Jussim, 2020; Seager & Barry, 2019). Still, the sheer number of studies finding anti-female bias makes it difficult to maintain that there is no bias at all, even if the level of bias might sometimes be overstated.

Challenges to the Discrimination Explanation for STEM Gender Gaps

At the same time, a number of cautions and qualifications are necessary. First, it is important to emphasize that workplace discrimination is almost certainly not the whole story when it comes to STEM gender gaps. As discussed, sex differences in preferences and cognitive specializations are well-documented, and regardless of the ultimate causes of these differences, it is unrealistic to imagine that they have no effect on people's occupational outcomes.

Furthermore, discrimination alone cannot readily explain why women are less well represented in some fields than others. Why would discrimination stop women from going into fields such as physics and engineering, but not into other prestigious, high-paying fields such as law, medicine, or veterinary science? One suggestion might be that the former fields are particularly inhospitable to women as a result of the stereotype that women lack the mathematical ability or intellectual brilliance to succeed in these domains. The problem with this idea, though, is that, when universities first began opening their doors to women, many people thought that women lacked the intellectual ability to succeed in *any* academic field (Boddice, 2011; Clabaugh, 2010). Despite that, women were able to reach parity with men, or even surpass them, in virtually every other area. Why would discrimination only hold women back in maths-intensive fields or fields currently assumed to require intellectual brilliance? And why would it hold them back in the same fields everywhere in the world, rather than, say, maths-intensive fields in the United States, psychology in South Africa, and law in Scandinavia? Bias and discrimination fail to explain why women are consistently underrepresented in some fields but not in others. In contrast, sex differences in interests and cognitive specializations provide a straightforward explanation for the pattern.

Not only does discrimination fail to explain major trends in the data, but the evidence for discrimination in STEM is considerably more mixed than is often assumed. Certainly, as we have just seen, many studies have found evidence of anti-female discrimination in STEM. At the same time, however, many *other* studies have failed to find such discrimination, or have found discrimination in *favour* of women. This raises the possibility that our picture of the level and nature of discrimination in STEM is somewhat distorted.

The most important voices on this topic are Stephen Ceci and Wendy Williams (2011). In their view, the idea that women are routinely discriminated against in STEM, while true in earlier generations, is no longer true. The culture of STEM has changed a great deal over the last half century, but people's *beliefs* about that culture have not kept pace with the change.

Take hiring decisions. Real-world data going back to the 1980s suggest that, although fewer women apply for jobs in fields such as maths, physics, chemistry, biology, and engineering, those who do apply are no less likely to be interviewed and no less likely to be offered the job. On the contrary, they are generally *more* likely to be (Ceci, 2018).[6] This is the opposite of what we would expect if there were pervasive anti-female bias in STEM. If anything, it looks like there may be a *pro*-female bias, at least in the modern West.[7]

Of course, an alternative explanation would be that the female candidates tend to be better than the males, perhaps because those few females who manage to survive and thrive in male-dominated fields need to be especially gifted. Ceci and Williams assessed this hypothesis in several ways. First, they compared male and female applicants on various objective measures of productivity, including number of publications, citation counts, and grant capture. The comparison revealed no overall difference in the quality of male vs. female applicants (Ceci et al., 2014). Second, they conducted a large-scale hiring-decision study: the largest such study to date (Williams & Ceci, 2015). The pair sent hypothetical job applications from identically qualified applicants to tenure-track professors in biology, economics, engineering, and psychology, and asked them to assess the applicants' suitability

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[6] Several studies suggest that the same is true in philosophy, another male-dominated field (Allen-Hermanson, 2017; Sesardic & De Clercq, 2014).

[7] The situation in non-Western nations is less clear. In some cases, overt anti-female discrimination may still be prevalent (see, e.g., Cyranoski, 2018).

for a tenure-track position. The final sample included nearly 900 professors from 371 US universities. Averaging across conditions, Williams and Ceci found a 2:1 bias in favour of *female* applicants. This pro-female bias was found in all four fields and among both male and female faculty. (The only exception was male economics professors, who showed no significant bias in either direction.) Thus, rather than being biased *against* women, this study suggests that, when it comes to employment decisions, STEM faculty are biased in their favour.[8]

As well as finding little evidence for anti-female bias in hiring, Ceci and Williams find little evidence for bias in college admission, recommendation letters, promotions, article acceptances, citations, or grant funding (Ceci et al., 2014; Ceci et al., 2020; Ceci & Williams, 2011). Studies that purport to find such bias are often widely discussed and cited (e.g., Budden et al., 2008, on gender bias in acceptance rates for papers first-authored by females,[9] and Wennerås & Wold, 1997, on gender bias in grant success). However, according to Ceci and Williams (2011), a systematic review of *all* the available evidence suggests that deviations from gender equality are rare, and that they just as often favour women as men. Again, this is not what we would expect if anti-female bias were endemic.

Earlier, we listed some of the studies finding anti-female bias in STEM and academia in general. In the interests of balance, we now present a comparable list of some of the studies that failed to find such bias, or that arguably found bias in the opposite direction.

- Comparisons of gender-blind and non-blind assessments suggest that teachers sometimes favour *girls* when evaluating student achievement. For example, one study found that French middle-school

[8] A similar pro-female preference has also been documented outside STEM, in the Australian Public Services (Hiscox et al., 2017). Such findings are consistent with the idea that concerns about anti-female discrimination might sometimes overshoot and inadvertently produce anti-male discrimination instead.
[9] Note that a reanalysis of the data by Webb et al. (2008) found that there was in fact no evidence of gender bias in the review process, prompting a correction by the original publishing journal, *Nature* (Clarke, 2008).

teachers favour girls in maths assessments (Terrier, 2020), while another found that Israeli high school teachers favour girls in assessments in both the sciences and the humanities (Lavy, 2008).

- At some elite universities, the academic threshold for admission is higher for men than for women. This is true, for instance, at Oxford University in the UK (Bhattacharya et al., 2017) and Harvard University in the US (Arcidiacono et al., 2019, Table D5).
- STEM professors are more receptive to meeting requests from female students than male students (Young et al., 2019).
- Female college students in male-dominated fields are less likely than other female students to switch majors: the opposite of what one would expect if women faced an especially hostile environment in these fields. Male students in *female*-dominated fields, on the other hand, are *more* likely to switch majors (Riegle-Crumb et al., 2016).
- The STEM pipeline from bachelor's degree to PhD no longer leaks more women than men (Miller & Wai, 2015; see also Porter & Ivie, 2019).
- In teacher accreditation exams in France, examiners discriminate in favour of women in male-dominated fields (and, to a lesser extent, in favour of men in female-dominated ones; Breda & Hillion, 2016).
- Although fake-résumé audit studies sometimes find anti-female bias, often they find no bias or bias in favour of women (Baert, 2018). The findings with respect to gender are much more mixed than those for race/ethnicity.
- Higher-ranked computer science departments recruit women at above-expected rates, relative to the number of female computer scientists (and, as a result, *lower*-ranked institutions end up recruiting women at *below*-expected rates; Way et al., 2016).
- In one large study (N=1,599), South African students watching lectures with identical slides and scripts, but with the sex of the lecturer varied, gave higher ratings to female lecturers than to male (Chisadza et al., 2019).
- Female scientists attribute higher levels of science-related traits such as objectivity, rationality, and intelligence to their female colleagues than their male colleagues; male scientists, in contrast, attribute similar levels of these traits to colleagues of both sexes (Veldkamp et al., 2017).
- In one large-scale experiment (N = 989), reviewers in the biosciences rated articles just as favourably if told that the author was a woman as they did if told the author was a man (Borsuk et al., 2009).
- An analysis of journal articles from 145 journals and 1.7 million authors found no evidence for bias against female authors in the peer-review process (Squazzoni et al., 2021).
- Although some studies find higher journal-article acceptance rates for men, studies that control for factors such as publication record and academic rank have generally found either no sex differences (e.g., Blank, 1991; Card et al., 2020) or higher acceptance rates for women (e.g., Lerback & Hanson, 2017).
- In computer science, conference papers that include female authors are just as likely to be accepted when the reviewers know the authors' names (and thus potentially their sex) as when they don't have this information (Tomkins et al., 2017).

- An analysis of 10,000 papers in social-science journals found that female-led papers are just as likely to be cited as male-led papers (Lynn et al., 2019).
- A large meta-analysis found no evidence that men were more likely than women to be awarded grants, and some evidence for the reverse. The absence of a male advantage was robust across academic fields, nations, and year of awards (Marsh et al., 2009).
- One study found that, without controlling for research productivity and NIH experience, men and women were just as likely to receive NIH grants; however, when controlling for these variables, women were *more* likely to receive them (Ginther et al., 2016).
- In a large US experiment, NIH-grant proposals were rated just as favourably when the supposed principal investigator was a woman as they were when the PI was a man (Forscher et al., 2019).
- In Sweden, medical grant proposals headed by women are given scores 10% higher than those headed by men, all else being equal (Sandström & Hällsten, 2008).
- An analysis of the publication records of 1,345 recently promoted Swedish professors found no evidence that women are held to a higher standard than men when it comes to promotion. In fact, in some fields, *men* may be held to a higher standard (Madison & Fahlman, 2020).
- An analysis of archival promotion data found that women in IT were more likely to be promoted than men, contrary to the researchers' predictions (Langer et al., 2020).
- Among German sociologists, women can get tenure with 23% to 44% fewer publications than men (Lutter & Schröder, 2016).

As with studies finding anti-female bias, it would no doubt be possible to pick holes in individual studies. Again, though, the sheer number of studies finding no gender disparities, or finding a female advantage, suggests that we should take the general thrust of the evidence seriously – just as we should with the studies showing anti-female bias.

A Mixed Picture

In summary, it seems fair to say that the evidence for gender discrimination in STEM is mixed, with some studies finding pro-male bias, some finding the reverse, and some finding none at all. What should we conclude? In our view, there are two main interpretations. The first is that the apparently mixed findings are not in fact inconsistent. Rather than there being uniform bias against women, or uniform bias against men, there are pockets of bias against both sexes (and presumably no gender bias at some institutions and in some cases). The second interpretation is that, at this stage, the findings are inconclusive: The jury is still out. But this in itself suggests that sex-based discrimination could not be *hugely* prevalent in STEM; if it were, it would be easier to detect a clear signal and the research would paint a more consistent picture of the situation. This, in turn, suggests that factors other than discrimination – in particular, sex differences in occupational preferences – are the main explanation for the persistence of gender gaps in STEM.[10]

A Hidden Barrier to the Progress of Women in STEM?

Before shifting topics, we should briefly consider another potential barrier to the progress of women in STEM – one that is often overlooked: stereotypes of the sexist academy. In the quest to promote women in STEM, academics and activists may sometimes inadvertently overstate the ubiquity of bias and discrimination against women in this sector. An unintended consequence may be to scare away some women who would otherwise be interested in a STEM career (Sesardic & De Clercq, 2014; Williams & Ceci, 2015). Diekman et al. (2017) point out that people's decision to enter or avoid a field is shaped to an important degree by their beliefs about the culture of the field in question (see also Cheryan et al., 2015). If women are given the impression that the STEM workplace is a hotbed of sexism and an unwelcome place for women, many might quite understandably decide to look for other fields in which to make their mark (Adams et al., 2006; Ganley et al., 2018; Thoman & Sansone, 2016). Ironically, the consequent dearth of women in STEM might then itself be taken as further evidence that STEM is a hotbed of sexism, creating a self-reinforcing, vicious cycle.

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[10] To pre-empt a common misunderstanding, this is not to deny that there are instances of discrimination against women in STEM. As Sesardic and De Clercq (2014) point out, it is perfectly possible that there are occasional instances of discrimination against members of many groups – including groups less often discussed in this context: men, conservatives, people with degrees from lower-status universities, and so on. (Indeed, we have just seen evidence for discrimination against men.) The question is whether anti-female discrimination is *endemic* in STEM, and whether it is the primary cause of current STEM gender disparities. The available evidence raises reasonable doubts about both possibilities.

Needless to say, if the STEM workplace really *were* a hotbed of sexism, this would be something we would need to confront, even if doing so put off some budding female scientists. However, given that the evidence for pervasive sexism in STEM is mixed, and that at least some experts conclude that – for the most part – STEM is fair for women and discrimination rare, conveying such a dark image of the STEM workplace may do more harm than good. See Figure 3 for a summary of the many factors contributing to the gender gaps in STEM.

--------------------Insert Figure 3 about here--------------------

Policy Implications

Sex differences in STEM representation are not just an academic matter. The question of what should be done about these differences – or indeed whether anything should be done – is one of the most widely discussed political issues related to the modern academy. Various interventions have been suggested and implemented over the years, including bolstering key skills in early life or in college, signalling a commitment to diversity in the workplace, and providing same-sex mentors and role models for women (Cheryan et al., 2017; Dasgupta & Stout, 2014; Diekman et al., 2015; Uttal et al., 2013; Walton et al., 2015; for a comprehensive list of policy options, see Williams et al., 2017). The literature on this issue is voluminous and beyond the scope of this article. What we aim to do in this section, however, is outline some of the ways in which the ideas discussed thus far may contribute to the discussion of policy options. One thing to make clear at the outset is that these ideas do *not* imply that we should do nothing or that nothing we do will work. Although our analysis may undermine some arguments for some policies, it may bolster the case for others and suggest novel avenues for intervention as well.

Outreach

An initial, relatively uncontroversial intervention is outreach: educating children and young people about STEM-related careers, and emphasizing that these are careers that females as well as males should consider (Vennix et al., 2018; J. R. Young et al., 2017). This can be done overtly or by including female STEM professionals among those providing the outreach (Dasgupta & Stout, 2014).[11] Advocates of such interventions would not need to deny that there are average differences between the sexes in STEM-relevant traits. On the contrary, average sex differences provide an argument in favour of the intervention. After all, even if gender gaps in STEM representation are primarily a result of sex differences in preferences, aptitudes, and variability, the mere existence of these gaps could still help sway the career choices of individuals whose interests and talents buck the usual trend. Some girls and women who would otherwise pursue a STEM career might be put off by the fact that more men than women take that path, at least in fields where the gap is especially large (Dasgupta & Stout, 2014). That being the case, it might always be necessary to encourage and support these individuals, and to encourage everyone else to accept atypical career choices and be tolerant of individual differences. (Notice, incidentally, that the same argument would weigh just as heavily toward encouraging boys and men with atypical career preferences to follow *their* interests too – something far less often discussed.)

An understanding of average sex differences could also help educators pitch STEM to girls and women. As mentioned, part of the reason that fewer girls and women are interested in a career in STEM (or rather a career in a certain subset of STEM fields) may be widespread stereotypes about what that career would entail. These include such stereotypes

[11] Note that some evidence suggests that same-sex role models have no effect on female STEM participation or even a negative effect (see, e.g., Bamberger, 2014; Betz & Sekaquaptewa, 2012; Carrington et al., 2008).

as that STEM careers offer few opportunities to pursue communal goals (e.g., working with and helping other people), that STEM careers involve social isolation and a strong focus on mechanisms and materials, and that STEM workplaces are sexist and unwelcoming of women (Cheryan et al., 2015; Diekman et al., 2017). One way to encourage more girls and women to consider a career in a male-dominated STEM field, then, may be to challenge these common stereotypes (Cheryan et al., 2015). (Needless to say, this should be done only to the extent that the stereotypes in question are in fact inaccurate.)

Of course, as with any intervention, outreach has the potential to cause harm as well as good. One possible harm could come from programs that focus only on girls: girls-only STEM workshops, for instance, or advertising campaigns that depict girls but not boys engaged in STEM-related activities (see, e.g., Mervis, 2018). Such programs could inadvertently convey the message to boys that they are no longer welcome in STEM, and that if they choose to pursue a career in that area, they may face an uphill battle due to institutional favouritism toward girls and women. This is a speculation, certainly, but one consistent with common arguments about the factors that can turn *girls* away from a career in STEM (Thoman & Sansone, 2016). Girls-only programs could also risk losing the support of people who would otherwise be allies, but who worry that the issue has been captured by a strain of gender politics more concerned about eliminating sex differences than about opening the doors for all (Mervis, 2018).

Another potential harm is that well-meaning efforts to encourage girls to pursue careers in STEM could sometimes tip over into excessive pressure to take that path. Susan Pinker (2008) interviewed women who had left successful STEM careers to pursue careers in other areas. Many reported that, as girls and young adults, they were so strongly encouraged to go into STEM that they ended up in jobs they did not especially enjoy. Granted, this is only one of many reasons that women give for leaving STEM (Glass et al., 2013). Still, in light of this potential pitfall, we suggest that the aim of outreach should not be to get women into STEM per se, but rather to give everyone accurate information about STEM career options so that they can make an informed choice about what would suit them best. (For evidence that having a job that matches one's interests and skills predicts job satisfaction, see, e.g., Bretz & Judge, 1994; De Fruyt, 2002; Verquer et al., 2003.)

Incentives for Women to Go into STEM

A second broad class of interventions involves offering incentives for women to go into male-dominated STEM fields. Examples include female-only scholarships, fee waivers, and monetary incentives for completing one's training in a targeted area. As with outreach, this is already a common practice, and it seems probable that the incentives on offer would encourage more women to make gender-atypical choices (Navarra-Madsen et al., 2010).

But although the incentives probably work, a number of arguments can be levelled against the practice. One is that it discriminates on the basis of sex: It offers advantages and opportunities to some individuals but not others, purely on the basis of a fixed biological attribute. Even leaving this aside, however, it is worth considering the wisdom of devoting large amounts of resources to encouraging women to do something they would not otherwise do. Although rarely described that way, this is clearly what the practice amounts to; after all, if the targeted women *did* want to do it anyway, the incentives would not be necessary. By interfering with women's choices, it is possible that immediate incentives could nudge some women away from options that might suit them better in the longer term and which might ultimately make them happier (Bretz & Judge, 1994; De Fruyt, 2002; Verquer et al., 2003).[12] Of course, people are not always right about what will make them happy. It seems unlikely,

[12] To be clear, this is *not* because STEM does not suit women; like anything, it suits some but not others. The point is that the incentives may encourage some women who might be better suited to other areas to take the STEM path instead.

however, that the incentives under discussion would *increase* people's chances of getting it right – especially given that the aim of these incentives is not to raise people's happiness but rather to minimize sex differences.

Gender-Blind Evaluation

A third intervention is gender-blind evaluation of job applications, journal article submissions, grant applications, and the like – that is, removing any evidence of the applicant or author's sex before beginning the evaluation process (Jones & Urban, 2013). Where this can be done, it is a relatively easy way to neutralize the potentially distorting effects of demographic stereotypes. A possible criticism of the practice, at least as applied to hiring decisions, is that it could only be implemented during the earliest stages of the hiring process: Gender can be largely concealed in a CV, but not in an interview or job talk. Against such concerns, however, a great deal of research suggests that stereotypes exert most of their influence on person perception during those earliest stages, when perceivers have little individuating information about the person being perceived (Koch et al., 2015; Rubinstein et al., 2018). As such, blind evaluation could well eliminate most of the biasing effects of demographic stereotypes. Another advantage of blind evaluation is that it automatically eliminates *all* forms of bias, including not only anti-female bias but anti-male bias too. Moreover, if there is little bias in either direction, gender-blind evaluation would simply have no effect. In other words, the procedure automatically calibrates the size of its impact to the level of gender bias, unlike most anti-bias strategies.

Despite its merits, gender-blind evaluation may prove to be a politically unpopular option. If Ceci and Williams (2011; Williams & Ceci, 2015) are right that women are often favoured rather than disfavoured in STEM hiring, blind evaluation of job applications would presumably result in somewhat fewer women being hired than is presently the case. Given the strong push toward increasing the numbers of women in STEM, such an outcome is likely to rule against the policy. This is not mere speculation; the Australian Public Services recently suspended a blind-evaluation trial when they discovered that the practice slightly increased men's chances of getting hired, and slightly decreased women's (Hiscox et al., 2017). Notice that, in abandoning the trial, the policy makers effectively revealed that their goal is equality of outcome rather than equality of opportunity – a key distinction we return to soon.

Anti-Bias Training

Another intervention aimed at weeding out discrimination in STEM is diversity training, also known as anti-bias training. This intervention takes many forms, but the common thread is the aim of increasing awareness and tolerance of diversity in the workplace, and helping people from different backgrounds to avoid bias and to work together harmoniously. The practice has become increasingly popular over the last half-century, and is now a billion-dollar industry (Hansen, 2003).

In spite of its laudable aims and popularity, though, a number of criticisms and concerns have been raised about anti-bias training. For present purposes, the most important is that, in its application to STEM gender gaps, the entire enterprise is premised on the assumption that bias is the primary cause – or at least a major cause – of the differential representation of men and women in STEM. As we saw earlier, however, the evidence for endemic anti-female bias is inconclusive at best, and the main cause of the gender gaps in STEM appears to be average sex differences in people's vocational preferences. This raises serious questions about the utility of anti-bias training. If bias is no longer the main driver of STEM gender gaps, then interventions targeting bias are likely to have little positive impact. And if that's the case, then anti-bias training represents a considerable waste of resources: resources that could otherwise be channelled into interventions more likely to achieve their aims.

Consistent with this assessment, research on the efficacy of anti-bias training paints a decidedly mixed picture. Various studies have concluded that the most popular programs and policies have little impact on diversity outcomes (Bradley et al., 2018; Chang et al., 2019; Kalev et al., 2006). More than that, in some cases, anti-bias interventions may backfire, increasing rather than reducing bias (Duguid & Thomas-Hunt, 2015; Moss-Racusin et al., 2014; Vorauer, 2012).

The concept of *implicit* or *unconscious bias* has been a particular focus of critical attention in recent years. Several studies have concluded that tests of implicit bias (in particular, the *Implicit Association Test* or *IAT*) have poor test-retest reliability (Gawronski et al., 2017), and fail to predict discriminatory behaviour (Cameron et al., 2012; Greenwald et al., 2009; Oswald et al., 2015). Furthermore, though interventions may change people's implicit biases to some degree – or do so, at least, in the short-term – the effects of such changes on behaviour are trivially small or non-existent, even in the immediate wake of the intervention (Forscher, Lai, et al., 2019). For all these reasons, it seems unlikely that interventions targeting implicit bias represent a wise allocation of resources.

Of course, it is possible in principle that anti-female bias is still pervasive in STEM but that we have yet to find effective interventions to tackle it. In light of our earlier discussion, however, it seems more likely that anti-bias interventions are simply not targeting the main causes of women's lower representation in STEM.

Preferences and Quotas

Another strategy for shrinking STEM gender gaps would be to establish preferences for women in male-dominated fields. Sometimes known as *positive discrimination* or *affirmative action*, this approach would include everything from giving preference to women from among similarly qualified candidates, to earmarking jobs for women only, to establishing strict quotas for women in STEM in terms of hiring, promotion, or grant funding.

To some extent, such policies exist already, both formally (Baker, 2019; Boisvert & Hancock, 2018; Dance, 2019; Davey, 2016; Matthews, 2017) and informally (Ceci, 2018; Williams & Ceci, 2015). Some argue, however, that the policies should be rolled out more widely in the effort to combat STEM gender gaps (Crosby et al., 2003; Wallon et al., 2015). Among the most common arguments for this position are that preferences would provide a counterweight to existing discrimination, compensate for the lingering effects of past discrimination, hasten the pace of scientific progress by increasing viewpoint diversity, enlarge the pool of same-sex role models and mentors for girls and women, and break the cultural “habit” of male-dominance in certain STEM fields in a way that more *laissez-faire* approaches so far have not (Fullinwider, 2018).

Perhaps unsurprisingly, preferences and quotas seem to increase the representation of targeted groups in areas where these policies are utilized (Kurtulus, 2016; Wallon et al., 2015). Nonetheless, as with other policy options, various concerns have been raised regarding the practice, especially in its more heavy-handed forms. The first is a question of ethics. Pro-female favouritism represents an explicit rejection of the principle of equality of opportunity in favour of discrimination on the basis of sex: precisely what feminism originally set out to overcome. As the philosopher Janet Radcliffe Richards (2014) argued, one of the main moral foundations of the women’s liberation movement – and indeed of all liberation movements – is the idea that individuals should be treated fairly and equally, and that unjust barriers should be removed. A policy that advantages members of one demographic group over those of another necessarily abandons those principles. In doing so, it risks leaving the women’s movement without one of its main moral foundations.

One response to this argument might be to point out that, throughout history, men were often advantaged over women in exactly this kind of way. As a stand-alone argument, however, this seems unpersuasive. Why should any individual woman today be advantaged over any individual man just because *other* men were advantaged over other women in the past? Reversing historical injustices does not erase them; it merely adds to the total number of injustices in the world. The question we face today, therefore, is this: Is the appropriate response to injustice to try to eliminate it, or to turn it on its head?

Of course, some would argue that preferences and quotas for women in STEM would not in fact be unjust; on the contrary, they would help to equalize men and women's chances of advancing in STEM, which are currently unequal due to present-day anti-female discrimination or the persisting effects of anti-female discrimination in the past (Crosby et al., 2003; Radcliffe-Richards, 2014; Walton et al., 2013). As discussed, however, the evidence for pervasive present-day discrimination in STEM is equivocal, with some studies suggesting that, at least in certain ways, women are favoured over men (Williams & Ceci, 2015). Moreover, though it is certainly possible that current STEM gender gaps are partly a cultural holdover from past discrimination, we are unaware of any rigorous attempt to demonstrate or measure this, or to weigh the effects of past discrimination against the countervailing effects of contemporary efforts to attract more women into STEM. Given that advantaging one demographic group over another is not an ethically trivial act, we should be circumspect about adopting such a policy on the basis of conflicting and contested evidence – especially given that other policy options are available.

Furthermore, it is not only men who may be harmed by preferences and quotas. In a number of ways, women could be harmed as well. To begin with, such policies could cast a shadow of doubt over women's genuine accomplishments (Heilman et al., 1992; Heilman et al., 1997). If the policies become widespread, then whenever women win jobs, grants, or awards, people might find themselves wondering – secretly and despite their best intentions – whether the women in question were judged by a lower standard, simply because of their sex (a rather sexist practice in itself, one might argue). This is not only a pitfall for onlookers;

successful women themselves could end up harbouring doubts about their own achievements (Unzueta et al., 2010; although see M. C. Taylor, 1994).

As well as casting doubt on the success of individual women, preferences and quotas could harm the image of women in STEM more generally. One of the primary goals of the women-in-STEM movement has been to eliminate the pernicious and demonstrably false stereotype that women cannot succeed in STEM. Preferences and quotas are unlikely to contribute to that project. On the contrary, the policies could bolster the stereotype. Aside from the fact that they might seem to imply that women need the extra help, strong preferences could lower the average level of performance of women working in STEM (cf. Haidt & Jussim, 2016). This is not because any individual woman would perform any worse, but rather is a simple statistical consequence of the fact that the pool of female STEM candidates is smaller than that of the males. As Figure 4 shows, if equal numbers of top performers are taken from two samples, but one of those samples is smaller than the other, then – all else being equal – the mean level of ability of those from the smaller sample will be lower than that from the larger, even if the means and variances of the two samples are identical. In effect, equalizing the number of individuals taken from each group would mean lowering the minimum standard for the smaller group.

This could have damaging consequences for women. In the absence of preferences or quotas, a person's sex tells you little about their probable STEM abilities: Any woman who has been accepted to a given university, or secured a job at a given institution, is likely to be just as talented as any man at the same university or at the same institution. However, if strong preferences or quotas are put in place, sex suddenly *does* tell you something about women's probable STEM abilities: It tells you that they might not *necessarily* be as good (cf. Haidt & Jussim, 2016). Again, this is not because women cannot succeed in STEM – some can and some cannot, just like men. Instead, it is a predictable consequence of the fact that enacting strong preferences for members of a smaller group generally means lowering the minimum standard by which members of that group are judged.

Family-Friendly Policies

A final proposal is that STEM career paths could be reconfigured in ways that would make them more family-friendly (Mason et al., 2013). This is a view that Ceci and Williams (2010, 2011; Williams & Ceci, 2012) have championed. In their estimation, one of the main remaining barriers to career success for women in STEM is the incompatibility of jobs in this area with the demands of motherhood. Not only do women alone get pregnant and nurse their young, but women are more likely than men to take time out from their careers to care for their children, and more likely to leave STEM altogether after first becoming parents (Cech & Blair-Loy, 2019). Of course, to some extent, this may reflect evolved differences in men and women's motivations, rather than just norms and social pressure (Stewart-Williams, 2018), and we are not suggesting that women are necessarily wrong to make these choices. However, the structure of STEM may sometimes create tensions between women's careers and motherhood that are unnecessary and that could potentially be eliminated.

Nowhere is the clash between STEM and motherhood more apparent than with regard to the academic tenure system in the United States and Canada. As Ceci and Williams (2010) put it:

> The tenure structure in academe demands that women having children make their greatest intellectual contributions contemporaneously with their greatest physical and emotional achievements, a feat not expected of men. When women opt out of full-time careers to have and rear children, this is a choice – constrained by biology – that men are not required to make. (p. 278)

It is worth noting that the family-friendliness of STEM jobs varies a great deal from nation to nation, and that the US typically has less family-friendly policies than Europe and other Western regions. It is also worth noting that a lack of family-friendly policies would not explain why women are less well represented in maths-intensive fields than in most others. Nonetheless, finding ways to make STEM occupations more compatible with motherhood could help to level the playing field in maths-intensive and non-maths-intensive fields alike. Suitable policies might include providing paid leave for having or adopting children, increasing the provision of subsidized or on-campus childcare, instructing hiring and promotion committees to ignore family-related gaps in parents' CVs, and increasing the flexibility of the window in which academics are able to complete the requirements of tenure (Williams & Ceci, 2012; Williams et al., 2017).

Of course, some might take issue with the "assumption" that women are the primary caregivers for their young. But this is not an assumption in any normative sense; it is simply an observation about what tends to happen. And given that it *is* what tends to happen, and that the tendency may be rooted in psychological sex differences that are partly inherited and thus difficult to change (even assuming it would be ethically permissible to try to change other people's preferences), family-friendly policies might help to equalize men and women's opportunities by removing a barrier that faces more women than men. Furthermore, if enacted in a gender neutral way, such that mothers *or* fathers could avail themselves of any parental benefits, the policies would not exert any special pressure on women to take the primary caregiver role. Either sex could take it, if they so desired.[13]

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[13] Note that gender-neutral policies would not necessarily equalize men and women's *outcomes*, and in some cases could do the reverse. One study found, for instance, that gender-neutral tenure clock-stopping policies *reduced* women's tenure rates in economics, but increased men's (Antecol et al., 2018). This raises some difficult questions. Should women have the option to stop the tenure clock, even if it decreases their chances of achieving tenure? Or should that option be taken away from women to keep their tenure rates as high as possible? In other words, should women's options be curtailed in order to keep men and women's outcomes as similar as possible, despite their somewhat different preferences and priorities? Alternatively, should *only* women have the option to stop the tenure clock? Is it reasonable for policy makers to effectively decide on behalf of every heterosexual couple that, if either parent is going to take time off to care for their child, it has to be the mother?

Levelling the Playing Field vs. Equalizing Sex Ratios

Having looked at how our analysis of STEM gender gaps might inform the conversation about policy options, we should step back and ask another, more fundamental question: What should the ultimate goal of these policies be? Should we strive for a 50:50 sex ratio in every area where men currently dominate? Or should we strive instead simply to eliminate bias and equalize people's opportunities, then let the cards fall where they may?[14]

If men and women were identical in their aspirations and aptitudes, these would quite possibly amount to the same thing: Levelling the playing field would automatically result in a 50:50 sex ratio, or something close to it. However, given that men and women are *not* identical in their aspirations and aptitudes, we have no reason to expect gender parity, even under conditions of perfect fairness. On the contrary, the natural expectation would be that men and women would *not* be at parity, but rather that men would be more common in some fields, and women in others, as a result of their freely made choices. To the extent that this is the case, it becomes much more difficult to justify pursuing a 50:50 sex ratio in every field. Most women do not want a career in STEM and nor do most men. Why should the small fraction of women who *do* want such a career be the same size as the small fraction of men? To put it another way, as long as everyone has the opportunity to pursue a STEM career, and as long as the selection process is fair, why would it be important to get as many women as men into jobs that fewer women want?

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[14] Strictly speaking, these are not the only options; one might aim, for instance, to increase the numbers of women in STEM without aiming for perfect parity. However, a 50:50 sex ratio is the logical endpoint of the idea that unbalanced sex ratios are inherently problematic, and thus that is what we focus on here. Note, though, that most of our arguments apply with equal force to efforts to achieve any particular sex ratio, as opposed to just aiming for an unbiased process.

The Pursuit of Happiness

One way to start tackling this question would be to observe that a 50:50 sex ratio in STEM is presumably not a good in itself, but is a good only in as much as that it increases human wellbeing. Importantly, though, to the degree that occupational disparities are a product of men and women acting on their own preferences and pursuing their own best interests, it is doubtful that forcing a 50:50 sex ratio would actually achieve this end.

To begin with, men and women could have different life outcomes, but still be happy with their lives. One longitudinal study found that, among two cohorts of individuals identified as academically gifted as children, men and women had somewhat different aspirations and took somewhat different paths, but ended up similarly happy with their careers, their relationships, and their lives overall (Lubinski et al., 2014). In other words, even among those best positioned to achieve their life ambitions, occupational gender parity appears not to be necessary for happiness.

Not only might it not be necessary, but policies that artificially engineer gender parity – financial incentives and quotas, for instance – could potentially *lower* aggregate happiness. To the extent that these policies work, they necessarily mean that some people will be funnelled into occupations that are less in line with their tastes and talents. To get more women into university physics programs, for instance, would require persuading at least some women to choose that option when they otherwise would not have done so. (At the same time, unless enrolment numbers were increased, it would also mean turning away some men who otherwise would have.) The women in question would presumably not come from the ranks of housewives or secretaries; more than likely they would be women who would otherwise have gone into other, equally prestigious fields, such as law or medicine. Is there any reason to think that these women would be happier doing physics? Given that people tend to choose careers they think will suit them best and be most satisfying for them, it seems plausible to think that, on average, they might be somewhat *less* happy (Bretz & Judge, 1994; De Fruyt, 2002; Verquer et al., 2003).

Admittedly, this whole line of argument is premised on the assumption that the wellbeing of individual STEM workers ought to be the deciding factor, and some might reject that assumption. Anyone who does, though, should, we think, be expected to make a strong argument for that position. Why should we put a statistical, collective goal – i.e., more equal sex ratios in STEM – above the happiness and autonomy of the flesh-and-blood individuals who constitute those collectives? Why should policy makers' preference for gender parity take precedence over individual men and women's preferences regarding their own careers and lives?[15]

Sex Differences as a Sign of Social Health

A recurring theme in discussions of occupational gender disparities is the often-unspoken assumption that sex differences are inherently problematic, or that they constitute direct evidence of sexism and the curbing of women's opportunities. Some research, however, points to the opposite conclusion. A growing body of work suggests that, in nations with greater wealth and higher levels of gender equality, sex differences are often *larger* than they are in less wealthy, less equal nations. This is true for a wide range of variables, including aggression (Nivette et al., 2019), attachment styles (Schmitt et al., 2003), the Big Five personality traits (Schmitt et al., 2008), crying (van Hemert et al., 2011), depression (Hopcroft & McLaughlin, 2012), enjoyment of casual sex (Schmitt, 2015), interest in and

[15] One possible answer is that greater gender diversity might increase productivity and accelerate scientific progress (see, e.g., Nielsen et al., 2017), and that this could compensate for any decrement in the happiness of STEM workers. This is certainly an argument worth taking seriously. Note, though, that at this stage, the evidence for the productivity benefits of greater diversity is relatively weak, with meta-analyses commonly finding no net effect or a negligible one (Eagly, 2016). Furthermore, even if artificially increasing gender diversity *did* produce such benefits, we would still need to consider the ethics of potentially harming the wellbeing of workers to achieve wider social goals.

enjoyment of science (Stoet & Geary, 2018), intimate partner violence (Schmitt, 2015), self-esteem (Zuckerman et al., 2016), spatial ability (Lippa et al., 2010), STEM graduation rates (Stoet & Geary, 2018), subjective wellbeing (Schmitt, 2015), and values (Falk & Hermle, 2018).[16] Importantly, the pattern is also observed for objectively measurable traits such as height, BMI, and blood pressure (Schmitt, 2015), which gives some reason to think that it is not simply a product of cross-cultural differences in the ways that people answer questionnaires or take tests.

What, then, *is* the cause of the pattern? One possibility is that when people grow up in an enriched and relatively unconstrained environment, nascent differences between individuals – and average differences between the sexes – have more opportunity to emerge and grow. In the case of psychological traits, the suggestion would be that men and women in wealthier, more developed nations have greater freedom to pursue what interests them and to nurture their own individuality. This freedom may, in turn, result in larger psychological sex differences (Schmitt et al., 2008; although see Fors Connolly et al., 2019; Kaiser, 2019).

Regardless of the reason, though, if certain sex differences are larger in societies with better social indicators, then rather than being products of a sexist or oppressive society, these differences may be indicators of the opposite: a comparatively free and fair one. If so, this casts society's efforts to minimize the sex differences in an entirely new light. Rather than furthering gender equality, such efforts may involve attacking a positive *symptom* of gender equality. By mistaking the fruits of our freedom for evidence of oppression, we may institute policies that, at best, burn up time and resources in a futile effort to cure a "disease" that isn't

[16] For a critique of the Stoet and Geary (2018) finding, and of the gender-equality measure used in many of the above studies (the *Global Gender Gap Index* or *GGGI*), see Richardson et al. (2020). For a response to the critique, see Stoet and Geary (2020).

actually a disease, and at worst actively limit people's freedom to pursue their own interests and ambitions on a fair and level playing field.

The Sexist Assumption Underlying the Demand for Parity

Finally, the strong emphasis on increasing the numbers of women in male-dominated fields is arguably somewhat sexist. As Susan Pinker (2008) argues, it tacitly assumes that women do not know what they want, or that they want the wrong things and thus that wiser third-parties need to "fix" their existing preferences. It also tacitly assumes that the areas where men dominate are superior. The psychologist Denise Cummins (2015) put the point well when she observed that, "The hidden assumption underlying the push to eliminate gender gaps in traditionally male-dominated fields is that such fields are intrinsically more important and more valuable to society than fields that traditionally attract more women." Given that traditionally *female*-dominated fields include education, healthcare, and social work, this assumption is not only sexist; it is also clearly false. As Judith Kleinfeld observed:

> We should not be sending [gifted] women the message that they are less worthy human beings, less valuable to our civilization, lazy or low in status, if they choose to be teachers rather than mathematicians, journalists rather than physicists, lawyers rather than engineers. (cited in Steven Pinker, 2002, p. 359)

Certainly, many female-dominated fields pay less, on average, than male-dominated STEM fields.[17] There is a great deal of debate about the reasons for this, and the extent to which it is a product of sexism vs. factors such as market forces (e.g., the fact that many female-dominated fields have a greater supply of workers) and personal preferences (e.g., the

[17] Note that this is not always the case. Various non-STEM professions, including law, medicine, and pharmacy, pay considerably more than most STEM jobs, and now attract more women than men (Susan Pinker, 2010).

fact that, on average, women view pay as a less important consideration in choosing a career than men, and view things such as job security and flexible work hours as more important; Funk & Parker, 2018; Gino et al., 2015; Lubinski et al., 2014; Redmond & McGuinness, 2019). Such matters are beyond the scope of this article. We would point out, though, that even if current pay disparities were *entirely* due to sexism, the most appropriate solution would presumably be to strive for fair pay in female-dominated fields, rather than trying to get more women into fields that pay more but which, on average, they find less appealing. And to the extent that the explanation is that women place less weight on a high income in choosing a career, and more weight on other things, efforts to get women to prioritize income tacitly assume, once again, that women's existing priorities are misguided, and that they ought to adopt more male-typical priorities instead.

To be clear, we completely agree that we should endeavour to root out sexism wherever it still lurks, and tear down any lingering barriers to the progress of women in STEM (as well as any barriers to the progress of men). These are eminently good goals. However, for the reasons discussed, striving for a 50:50 sex ratio – or indeed any pre-specified sex ratio – is not a good goal.

Conclusion: Many Factors at Play

In summary, any exhaustive discussion of the relative dearth of women in certain STEM fields must take into account the burgeoning science of human sex differences. If we assume that men and women are psychologically indistinguishable, then any disparities between the sexes in STEM will be seen as evidence of discrimination, leading to the perception that STEM is highly discriminatory. Similarly, if we assume that such psychological sex differences as we find are due largely or solely to non-biological causes, then any STEM gender disparities will be seen as evidence of arbitrary and sexist cultural conditioning. In both cases, though, the assumptions are almost certainly false. A large body of research points to the following conclusions:

> (1) that men and women differ, on average, in their occupational preferences, aptitudes, and levels of within-sex variability;
> (2) that these differences are not due solely to sociocultural causes but have a substantial inherited component as well; and
> (3) that the differences, coupled with the demands of bearing and rearing children, are the main source of the gender disparities we find today in STEM. Discrimination appears to play a smaller role, and in some cases may *favour* women, rather than disfavouring them.

These conclusions have important implications for the way academics and policy makers handle gender gaps in STEM. Based on the foregoing discussion, we suggest that the approach that would be most conducive to maximizing individual happiness and autonomy would be to strive for equality of opportunity, but then to respect men and women's decisions regarding their own lives and careers, even if this does not result in gender parity across all fields. Approaches that focus instead on equality of *outcomes* – including quotas and financial inducements – may exact a toll in terms of individual happiness. To the extent that these policies override people's preferences, they effectively place the goal of equalizing the statistical properties of groups above the happiness and autonomy of the individuals within those groups. Some might derive different conclusions from the emerging understanding of human sex differences. Either way, though, it seems hard to deny that this understanding should be factored into the discussion.

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Boxes/Figures

Box 1: What Are We Talking About?

The idea that men outnumber women in STEM has become the conventional wisdom over the last few decades. Strictly speaking, however, the gender disparity is not in STEM per se, but rather in STEM fields that focus on the non-living world, or that have a strong spatial or mathematical component. According to Ceci et al. (2014), STEM fields should be divided into GEEMP fields (geoscience, engineering, economics, mathematics/computer science, and the physical sciences) and LPS fields (life science, psychology, and social science). Men outnumber women in GEEMP fields, but women are at parity with men, or even outnumber them, in LPS fields. Overall, men and women are about equally represented in STEM, at least according to some analyses (Funk & Parker, 2018; HESA, 2018).

Figure 1.

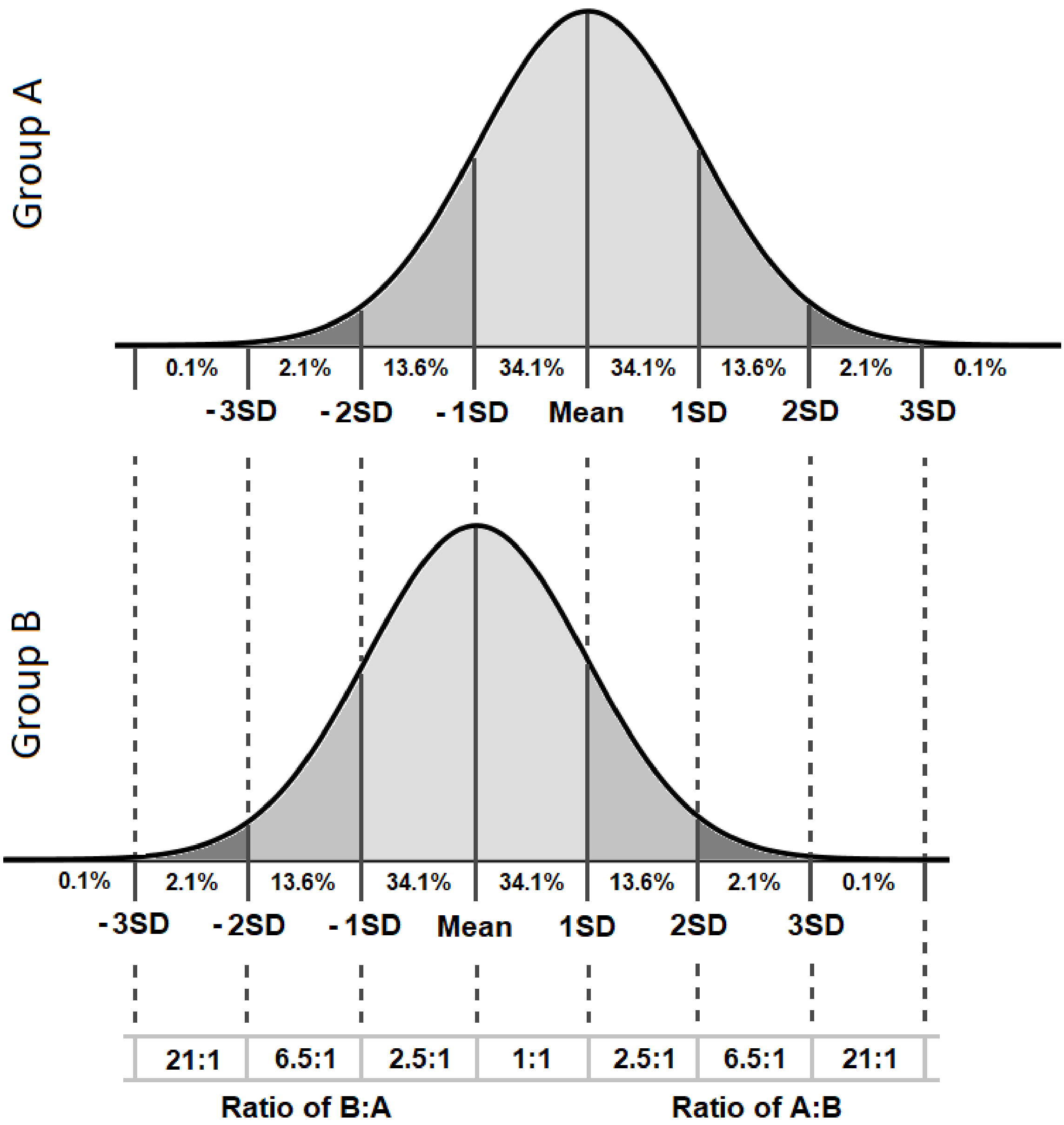

Figure 1. For two groups, A and B, for which the average score on a normally distributed variable is higher for the former than the latter, the ratio of A-to-B gets progressively larger the further above the mean one looks. For both groups, fewer and fewer people occupy each segment above the mean, with the percentage decline getting larger with every step. Thus, the number of people falling between 1 and 2 standard deviations above the mean is 40% of that falling between the mean and 1 standard deviation, whereas the number of people falling

between 2 and 3 standard deviations above the mean is only *15%* of that falling between 1 and 2 standard deviations. This is the case for both groups. However, because the lower-scoring group (B) starts this accelerating decline before the higher-scoring group (A), the percentage decline for the lower-scoring group is always larger than that for the higher-scoring one. The net result is that the ratio of A-to-B gets progressively larger for scores above the mean. Meanwhile, for the equal-but-opposite reason, the ratio of B-to-A gets progressively larger for scores *below* the mean. The difference depicted in Figure 1 is large – a full standard deviation between the mean for each group – and thus the skew quickly gets large as well. However, even small differences at the mean may be associated with high levels of skew at sufficiently extreme levels of any trait.

Figure 2.

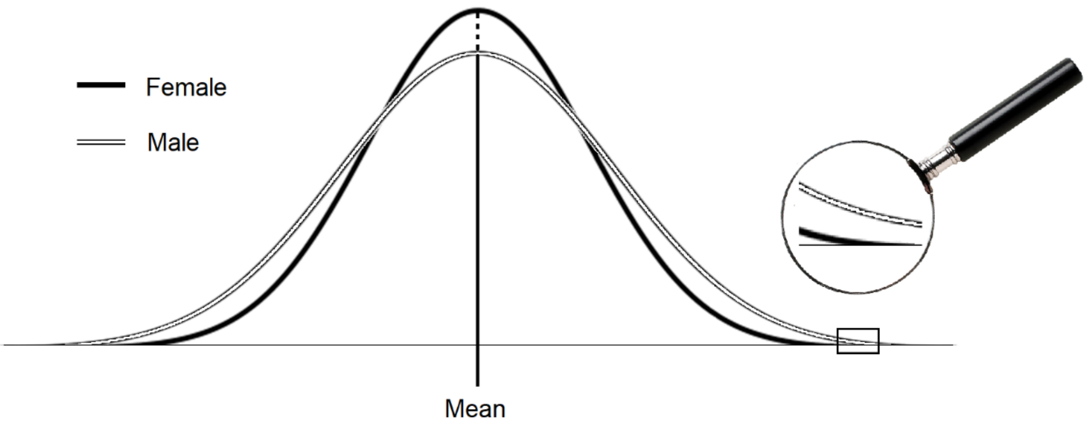

Figure 2. A fundamental sex difference in humans and many other animals: For a wide range of traits, males are more variable than females. As such, although only a small percentage of people occupy either extreme of the distribution, more males do than females, even when the mean scores for both sexes are identical.

Box 2: Exploring the Implications of Greater Male Variability

The claim that men are more variable than women in cognitive ability is controversial. Here are some questions to ask about this claim:

1. Is it sexist? Is it sexist even if it turns out to be true?
2. If it is sexist against women to say that there are more men than women at the highest levels of ability, is it sexist against men to say that there are also more men than women at the lowest levels? If not, how might we explain this asymmetry?
3. Assume for a moment that males really are more variable in cognitive ability. Should we suppress this information? *Could* we suppress it, even if we wanted to?
4. Might it be possible instead to emphasize the importance of avoiding exaggerating small differences, of keeping sight of the variation among individuals within each sex, and of treating individuals as individuals, rather than as instantiations of the statistical properties of the groups to which they belong?

Figure 3.

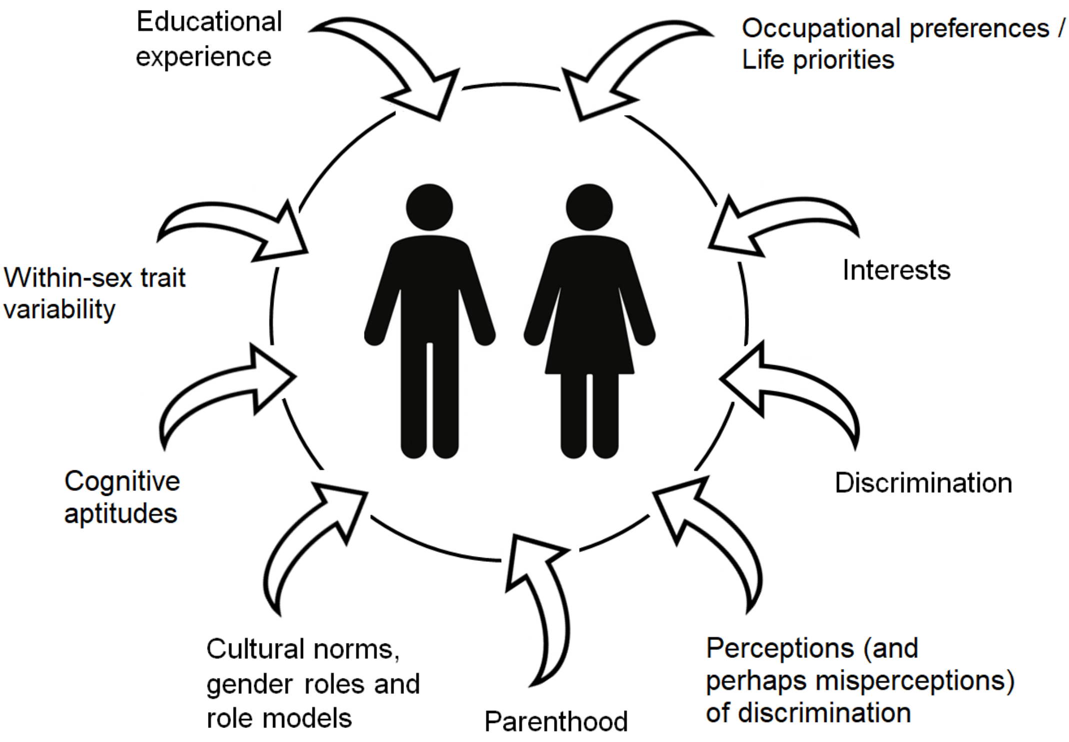

Figure 3. Occupational outcomes are a product of many different factors; workplace discrimination is only one among many.

Figure 4.

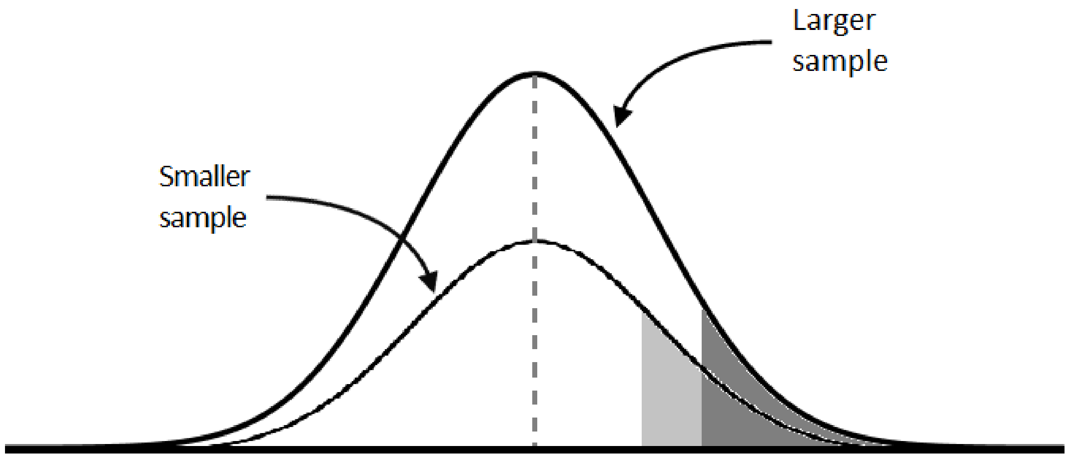

Figure 4. If equal or similar numbers of top performers are drawn from samples of different sizes (represented here by the shaded areas of the two distributions), the average level of ability of those drawn from the smaller sample will be lower than that of those drawn from the larger. This is the case even if the means and variances of the two groups are identical.