

Sex Differences in Vulnerability



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SEX DIFFERENCES IN VULNERABILITY

Biologists have known for decades that many traits involved in competition for mates or other resources and that influence mate choice are exaggerated, and their development and expression is influenced by the individuals' exposure to and ability to tolerate a variety of environmental and social stressors. In nonhuman species, conspecifics (members of same species) use these condition-dependent traits to identify less resilient competitors and avoid unhealthy mates. These traits, however, can be reframed to provide a nuanced approach to understand more fully the heightened sensitivity of a host of physical, social, psychological, cognitive and brain traits in humans. This principle can be used to identify children, adolescents or populations at risk for poor long-term outcomes and identify specific traits in each sex and at different points in development that are most easily disrupted by exposure to stressors. This article overviews the approach and provides several examples.

Introduction

Historically, boys and men have been cast as the more vulnerable of the sexes (e.g. Greulich, 1951, p. 55; Stini, 1969, p. 417; Stinson, 1985, p. 123). Even Darwin (1871, Vol. I, pp. 174–9) noted that premature mortality is more common in males than females across a great variety of species, including our own. Even with the dramatic declines in overall mortality over the past two centuries, infant boys are more likely to die than girls (Martin, 1949, p. 438; Read et al., 1997, p. 192), and surviving boys are over-represented among children with mild to serious medical conditions (Jacobziner et al., 1963, p. 1937). These risks continue into adolescence and adulthood, in part because boys and men engage in more intense competition and risk taking, that in turn results in higher rates of homicide and accidental death than those found in girls and women (e.g. Wilson and Daly, 1985, p. 59). Even in old age, when intense competition and risk taking have waned, men have a shorter life expectancy than women (Allman et al., 1998, p. 6866). These are certainly important vulnerabilities and can be placed in the context of the evolution of life histories (e.g. environmental influences on the timing of reproductive competition), but there are other, more nuanced ways to frame vulnerability.

The more subtle question is why some traits – specific physical features, behaviours or cognitive competencies – are more easily disrupted by exposure to stressors than others, and why these trait-specific vulnerabilities can differ between the sexes and across species. Poor nutrition during adolescence, for instance, affects the physical growth of boys and girls differently, disproportionately compromising boys' height and girls' pelvic width (Hautvast, 1971, p. 421; Prista et al., 2003, p. 952). Prenatal exposure to toxins compromises the spatial-navigation abilities of male deer mice (*Peromyscus maniculatus*), but leaves unaffected the spatial abilities of same-species females or males of their cousin species, the California mouse (*Peromyscus californicus*; Jašarević et al., 2011, p. 11715; Williams et al., 2013).

In a recent book (Geary, 2015, p. 2), I proposed that these and many other sex-specific vulnerabilities can be explained by a simple conceptual model – *traits that have been elaborated through sexual or social selection are especially vulnerable to disruption by exposure to environmental and social stressors* – that places all of them in a unifying evolutionary context. The model enables the identification of sex- and species-specific traits whose development and

expression are vulnerable to disruption by disease, poor nutrition, social stressors and exposure to man-made toxins (e.g. environmental toxins and chemotherapy).

The core idea that pulls these vulnerabilities together is based on Darwin's (1871, Vol I., p. 253) sexual selection – competition for mates and mate choices – and West-Eberhard's (1983, p. 155) social selection – competition for reproductively relevant resources (e.g. high quality food) other than mates. The key is that over evolutionary time these social dynamics result in the exaggeration of traits that facilitate competition or that make one attractive to mates. These traits are either signalled directly (e.g. through physical size) or indirectly (e.g. through feather colour that is correlated with health), and can be physical, behavioural or involve brain and cognition. Whatever the trait, they are effective social signals because they convey information about the individuals' level of exposure to stressors and the ability to cope with them.

Identifying vulnerable traits and the conditions that can undermine their development and expression is complicated, however. This is because a trait that signals competitive ability, for instance, in one sex or species may or may not signal competitive ability in the other sex or in other, even closely related species (Andersson, 1994, pp. 3–31). For either sex or any species, the identification of vulnerable traits requires an understanding of the evolutionary history of the species; specifically, the traits that facilitate competition for mates and other resources and that influence mate choices. I provide a few examples in the next section. I then illustrate how these same principles can be applied to understand more fully and predict human vulnerabilities.

Evolution of Vulnerable Traits



Figure 1: Two male northern elephant seals (*Mirounga angustirostris*) fighting for control of a harem. Larger and more aggressive males have higher reproductive success than other males and this in turn has resulted in the evolution of large sex differences in physical size and behavioural aggression. Photo credit: Dawn Endio, 2004. Creative Commons License. http://commons.wikimedia.org/wiki/File:Elephant_seal_fight_Part-1.jpg

As was richly illustrated by Darwin (1871, Vol. II, pp. 1–315), competition for mates and mate choices typically result in the elaboration of physical (e.g. body size), behavioural (e.g. courtship displays) or brain and cognitive (e.g. as related to bird song) traits in one sex (typically males) or the other and the evolutionary emergence of sex differences in these traits; examples of these traits are shown in Figures 1 and 2.



Figure 2: To attract mates, males of the magnificent frigatebird (*Fregata magnificens*) inflate their regular pouch, spread their wings and point their beak upwards. Males with higher testosterone levels and in better physical condition engage in this courtship display more frequently than do other males. These males in turn are better at provisioning females and their offspring. Photo credit: Andrew Turner, 2011. Creative Commons License: http://commons.wikimedia.org/wiki/File:Fregata_magnificens_-_Galapagos,_Ecuador_-_male-8.jpg

In comparison to naturally selected traits – those important for survival (Darwin, 1859, p. 6) – the development and expression of the traits that have been exaggerated by competition and mate choice are especially sensitive to environmental and social conditions. In other words, the full expression of these traits requires the right combination of genes and good environmental (e.g. low parasite levels) and social (e.g. parental provisioning) conditions during development and in adulthood. Individuals with this mix of genes and experiences are more likely to develop these traits fully than are other individuals, and as a result have competitive advantages and are preferred as mates. Other individuals are at risk of never reproducing.

One result is that the benefits of cheating and the costs of being cheated are high. Males that are in poor condition (e.g. poor immune system) may cheat, in theory, by diverting resources to the development of these traits (e.g. larger horns, colourful plumage feathers) and thus bluffing other males from directly competing with them or enticing females to mate with them. Cheating can be reduced if the development and expression of these traits are costly to less fit individuals (Getty, 2006, p. 83; Zahavi, 1975, p. 205). The question then becomes what determines who is fit or not and why, and this is where sensitivity to environmental and social conditions becomes critical. Parasites are a ubiquitous environmental stressor that can significantly compromise health and behaviour. Some males are better able to tolerate parasites than others, and those that tolerate parasites generally sire offspring that tolerate them as well (Hale et al., 2009, p. 1284; Welch et al., 1998, p. 1928). It is in females' best interest to choose mates that tolerate

parasites and it is in these males' best interest to signal parasite resistance (Hamilton and Zuk, 1982, p. 384). For a reliable signal of parasite resistance to evolve, the expression of the trait must be modifiable by level of parasite infestation and must be elaborated to the extent that unfit males cannot express the trait and simultaneously cope with parasites (Folstad and Karter, 1992, p. 603).

The result is the evolution of traits – such as the colourful plumage of the males of many species of bird (e.g. peacock tail; *Pavo cristatus*) – whose expression is dependent on, in this example, the ability to tolerate parasites. These typically conspicuous traits signal the males' competitive ability to other males and signal that these males are likely to sire healthy offspring to females. Some other traits, such as bird song, are indirect signals of brain and cognitive functioning and these may signal resilience in the face of developmental stressors (e.g. poor early nutrition; Nowicki et al., 1998, p. 179). For these species, early stressors compromise the development of the brain regions that support song and this is signalled to females in adulthood during courtship displays. Critically, if song-learning brain regions are compromised, other regions developing at the same time and that support functional behaviours, such as foraging, might also be compromised (Pravosudov et al., 2005, p. 1368). In this way, females can gauge the ability of males to forage and provision them and their offspring based on their song. Other traits, such as the spatial-navigational abilities of male deer mice, are directly related to competition and are functional in and of themselves. Both direct and indirect signals are found in a spectacular variety of living organisms, from stalk-eyed flies (*Diasemopsis meigenni*; Bellamy et al., 2013, p. 2662) to African elephants (*Loxodonta africana*; Hollister-Smith et al., 2008, p. 1829).

Human Vulnerabilities

As stated, the key to understanding sex-specific vulnerabilities in any species is to understand the natural history of the species and in particular the dynamics of sexual and social selection. This of course is a controversial endeavour when it comes to humans (Hyde, 2005, p. 581; Wood and Eagly, 2002, p. 699), but nevertheless the possibilities can be constrained by general patterns that emerge across species (Plavcan and van Schaik, 1997, p. 37) and across human cultures (Ember, 1978, p. 439); for a thorough discussion see Geary (2010, pp. 130–44).

As with the northern elephant seal (*Mirounga angustirostris*) shown in Figure 1, intense physical competition for access to females or control of the resources females need to reproduce (e.g. nesting sites) will result in the evolution of larger and physically stronger males than females. Human sex differences in physical size and strength are well known (Tanner, 1990, pp. 51–79), and examination of the fossil record and our most likely ancestors allows us to estimate differences in the size of males and females of these species. About four million years ago, our male predecessors of the species *Australopithecus anamensis* were at least 50% larger than our female predecessors (Leakey et al., 1998, p. 62), a pattern that continued with *A. afarensis* and that may have lessened slightly with *A. africanus* (McHenry and Coffing, 2000, p. 125). The differences approached those seen in modern humans roughly 1.8 million years ago with the emergence of *Homo erectus*. These patterns are highly consistent with sexual selection during our evolutionary past and especially intense male-male competition.

Many studies of traditional societies in which violence has not been suppressed by central authorities support this conclusion. The nature of male-male competition under these conditions is well documented in the ethnological and archaeological records (Chagnon, 1988, p. 985; Ember, 1978, p. 439; Keeley, 1996, pp. 59–70; Walker and Bailey, 2013, p. 29; White and

Burton, 1988, p. 871), and essentially involves one-on-one physical and political competition to achieve dominance within the male social hierarchy and cooperation with in-group members to compete better against coalitions of other males (i.e. out-groups). The result is 15–30% male mortality due to violence in these societies and moderate to substantial reproductive skew (Betzig, 2012, p. 309); some men have many children with several wives and others never reproduce.

None of this is to say that women are not competitive with one another, they are. From a traditional perspective on sexual selection, female-female competition and male choice of mates follow from men's investment in children (Geary, 2000, p. 55). However, given that marriage partners are typically chosen by parents or other kin in traditional societies (Apostolou, 2007, p. 403), the opportunity for female-female competition over mates may be diminished – males must still compete to gain status or resource control before parents will consider them attractive partners for their daughters. Nevertheless, there is ample opportunity for competition and choice even with arranged marriages. These can manifest in the context of extra-marital relationships, which are more likely with arranged marriages than free choice marriages (Scelza, 2011, p. 889), and in the context of polygynous marriages (Geary et al., 2014, pp. 398–408). In the latter, competition among co-wives for the resources and attention of their husband is rife and has reproductive consequences (Jankowiak et al., 2005, p. 81; Strassmann, 1997, p. 688). Of course, female-female competition as well as female choice and male choice blossom in the absence of arranged marriages, as would be expected of evolved biases and preferences (Buss, 1989, p. 1). A key feature of female-female competition in these contexts is that it generally does not involve direct physical confrontation but rather subtle manipulation of social relationships, which is called relational aggression (Archer and Coyne, 2005, p. 212). The associated dynamics have resulted in the elaboration of girls' and women's sensitivity to subtlety in language, facial expressions, gestures and body posture, as well as advantages in theory of mind (Geary, 2010, pp. 352–72).

I detail a myriad of physical, behavioural and brain and cognitive sex differences that follow from these patterns of competition and choice (Geary, 2015, pp. 156–9), and argue that the associated traits will be more susceptible – depending on the point in the lifespan – in one sex or the other to disruption by exposure to poor nutrition, parasites, the stresses of social competition and man-made toxins. I cannot detail all of these traits here but provide a few illustrations. On the basis of the sex difference in height for instance and the likelihood that this has been exaggerated in men over evolutionary time as a result of both male-male competition and female choice, I predicted that height will be a more vulnerable trait in boys than girls, especially during adolescence. This sex-specific vulnerability has in fact been well documented.

Nearly all of the studies of stressor exposure during adolescence show that boys' growth is more vulnerable to disruption than girls' growth, height being the most commonly assessed growth trait. The sex difference in vulnerability is related to socioeconomic status (Dreizen et al., 1953, p. 189), poor nutrition (Jardim-Botelho et al., 2008, p. 458), anaemia (Zemel et al., 2007, p. 607) and infestation with parasites (McGarvey et al., 1992, p. 571). It is not simply that boys need more calories than girls during pubertal development, there are also differences in their nutritional needs (Prasad, 1985, p. 341). As an example, several randomised control studies have found that zinc supplementation – much of zinc is naturally obtained through animal protein – improves the growth of boys more than that of girls in childhood (e.g. Castillo-Durán et al., 1994, p. 833) but may be especially important during periods of rapid growth during infancy and pubertal development (Halsted et al., 1972, p. 277). The mechanisms through which these effects work are not fully understood, but contributing factors may be improved appetite for young boys (smaller effect on girls; Krebs et al., 1984, p. 270) and improved

testicular development and testosterone synthesis during pubertal development (Prasad, 1985, p. 341).

Stressor-related disruptions in girls' and women's social-cognitive traits have not been as thoroughly studied as disruptions in physical development, but the available evidence is consistent with a sex-specific vulnerability. Of these traits, the literature is the most extensive for language. The language studies range from the effects of premature birth on natural language development (Largo et al., 1986, p. 333) to the deficits (e.g. difficulty remembering common words) that emerge during the early stages of Alzheimer's disease (Henderson and Buckwalter, 1994, p. 90). The other stressors that have been studied include poor nutrition (Zimmermann et al., 2006, p. 108) and exposure to toxins (Bender et al., 2006, p. 422), including chemotherapy. Overall, these studies suggest that exposure to stressors will more strongly affect girls' and women's language competencies than those of boys and men.

An illustration is found with Largo et al.'s (1986, p. 333) and Jennische and Sedin's (2003, p. 364) large and comprehensive longitudinal studies of the natural language competencies of preterm and term children. Jennische and Sedin found that by six years of age term girls' language competencies were generally better than those of term boys, and those of preterm girls generally exceeded those of preterm boys. The subtle deficits of preterm girls became apparent when they were compared to term girls. Girls born at about 30 months' gestation showed deficits in word articulation, word fluency, sound discrimination and grammatical structure of utterances, among other deficits, relative to their term peers. In contrast, there were few language differences between preterm and term boys.

Largo et al. (1986, p. 333) followed the language development of preterm infants – born at 33 weeks' gestation on average – for five years. Over the course of the study, the language development of these infants and a group of term peers was assessed ten times in the lab and their mothers completed multiple assessments of their word usage at home. At five years of age, these children were assessed on overall language competencies, and term girls had an advantage over term boys, as found by Jennische and Sedin (2003, p. 364). However, preterm boys' overall language competencies were better than those of preterm girls. There were also differences between preterm girls and boys in the age of achieving significant language milestones, as shown in Figure 3. The dashed line shows the cutoff for the slowest 10 per cent of term children, and the bars show the percentage of preterm children that achieved the milestone later than these relatively delayed term children. As an example, 11 per cent of the preterm boys started to coo at about the same time or a little later than the slowest 10 per cent of term children, that is, the latest developing preterm boys were not much different than the latest developing term children. Twice as many preterm girls in contrast were delayed in the onset of cooing, and in the onset of sound imitation, learning the names of body parts and following directions, and three times as many preterm girls as boys were delayed in the age of learning their own name. The reversal of girls' typical advantage over that of boys in language competencies is striking.

Functionally, the importance of girls' language deficits is not in relation to the deficits of preterm boys but between preterm girls and term girls. This is because boys and girls self-segregate during development, meaning that girls navigate childhood and much of adolescence in the midst of relationships with other girls. In this social context, language is crucial for developing and maintaining girls' same-sex friendships and of course for engaging in relational aggression. In other words, these deficits place girls at a disadvantage relative to other girls, just as deficits in boys' height place them at a disadvantage relative to other boys.

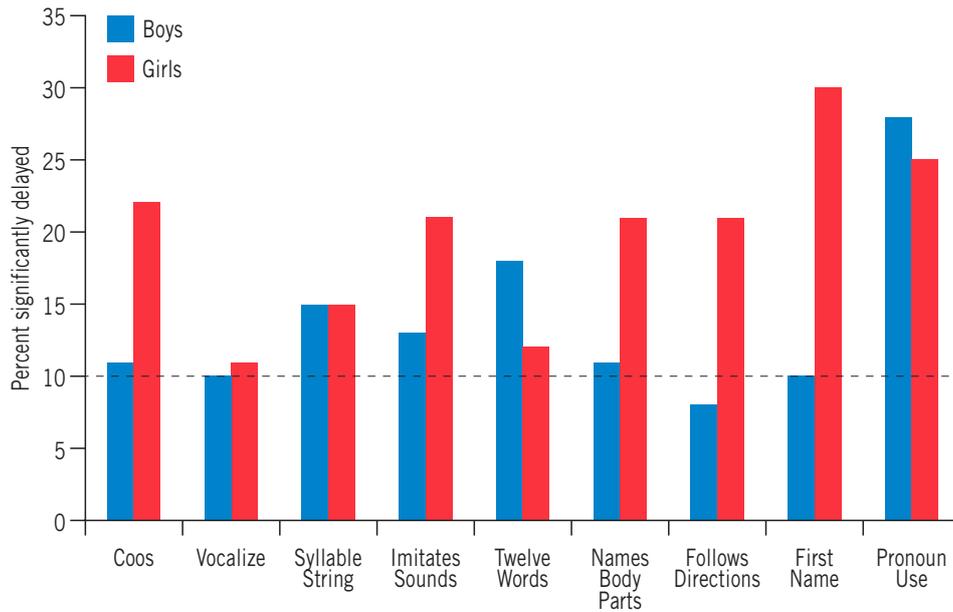


Figure 3: Delays in the onset of significant language milestones for girls and boys born prematurely. The dashed line is the cutoff for the slowest 10 per cent of term children (boys and girls combined), and the bars show the percentage of preterm children that achieved the milestone later than these relatively delayed term children. The figure is based on data presented in Largo et al. (1986, p. 337).

Conclusion

The evolved function of sexually- and socially-selected traits is to allow competitors and would-be mates to identify individuals that have been exposed to environmental or social stressors and are unable to cope effectively with them; the functioning of most individuals will be compromised by exposure to stressors but some individuals are more resilient than others. These patterns have been extensively studied in nonhuman species but largely overlooked in humans. My proposal is that we can reframe the condition dependence of these traits to understand more fully and assess how people respond to stressors, and specifically how sensitivity to them varies across sex, age and trait. In this book, I provided examples of the utility of this approach for understanding the vulnerability of boys' height and girls' language development, and provide extensive discussion and review of sex-specific vulnerabilities for a variety of behavioural, physical and brain and cognitive traits elsewhere (Geary, 2015, pp. 153–281).

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Backlist of Papers Published in Insights

No.	Author	Title	Series
2008 Volume 1			
1	Boris Wiseman	Lévi-Strauss, Caduveo Body Painting and the Readymade: Thinking Borderlines	General
2	John Hedley Brooke	Can Scientific Discovery be a Religious Experience?	Darwin's Legacy
3	Bryan R. Cullen	Rapid and Ongoing Darwinian Selection of the Human Genome	Darwin's Legacy
4	Penelope Deutscher	Women, Animality, Immunity – and the Slave of the Slave	Darwin's Legacy
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8	Eric Winsberg	A Function for Fictions: Expanding the Scope of Science	Modelling
9	Willard Bohn	Visual Poetry in France after Apollinaire	Modelling
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11	Nancy Cartwright	Models: Parables v Fables	Modelling
12	Atholl Anderson	Problems of the 'Traditionalist' Model of Long-Distance Polynesian Voyaging	Modelling
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3	Ronaldo I. Borja	Landslides and Debris Flow Induced by Rainfall	Modelling
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5	Paul Ormerod	21st Century Economics	Modelling
6	Peter C. Matthews	Guiding the Engineering Process: Path of Least Resistance versus Creative Fiction	Modelling
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8	Roger Smith	Locating History in the Human Sciences	Being Human
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10	Mark Turner	Thinking With Feeling	Being Human
11	Christa Davis Acampora	Agonistic Politics and the War on Terror	Being Human
12	Arun Saldanha	So What <i>Is</i> Race?	Being Human
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14	Robert Hariman	Democratic Stupidity	Being Human
2010 Volume 3			
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3	Maxine Sheets-Johnstone	Strangers, Trust, and Religion: On the Vulnerability of Being Alive	Darwin's Legacy

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5	Eduardo Mendieta	Political Bestiary: On the Uses of Violence	Being Human
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Insights

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