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Engineers have more sons, nurses have more daughters: an evolutionary psychological extension of Baron–Cohen's extreme male brain theory of autism

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Abstract

In his extreme male brain theory of autism, Baron-Cohen postulates that having a typically male brain was adaptive for ancestral men and having a typically female brain was adaptive for ancestral women. He also suggests that brain types are substantially heritable. These postulates, combined with the insight from the Trivers–Willard hypothesis regarding parental ability to vary offspring sex ratio, lead to the prediction that people who have strong male brains should have more sons than daughters, and people who have strong female brains should have more daughters than sons. The analysis of the 1994 US General Social Survey data provides support for this prediction. Our results suggest potentially fruitful extensions of both Baron-Cohen's theory and the Trivers–Willard hypothesis.

Keywords: Extreme male brain theory; Trivers–Willard hypothesis; Offspring sex ratio; Testosterone

1. Introduction

In a series of scientific articles and books (Baron-Cohen, 1999, 2002; Baron-Cohen and Hammer, 1997; Baron-Cohen et al., 2004) and in the popular science book *The Essential Difference* (Baron-Cohen, 2003), Simon Baron-Cohen advances the "extreme male brain" theory of autism. In the theory, Baron-Cohen posits the existence of the "male brain," which is particularly designed for "systemizing," and the "female brain," which is especially suited for "empathizing." Both men and women vary in the extent to which they possess the sex-typical brain; some men are more systemizing than others, and some women are more empathizing than others. Baron-Cohen hypothesizes, and amasses substantial evidence, that autism may be the result of some men (and women) possessing extreme male brains, which are especially good at systemizing but poor at empathizing. His theory can simultaneously account for many (though not all) clinical manifestations of autism (the severe deficits in interpersonal domains, such as theory of mind, while maintaining normal or even exceptional abilities in others) as well as the fact that an overwhelming majority of autistics are male.

In this paper, we first present Baron-Cohen's extreme male brain theory of autism systematically (pardon the pun), by enumerating all the key postulates of the theory. We then extend it beyond the explanation of autism, by incorporating one principle from modern evolutionary psychology: The Trivers–Willard hypothesis regarding parents' ability to vary the sex ratio among their offspring. We suggest that the incorporation of the Trivers–Willard hypothesis into

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Baron-Cohen's theory leads to the prediction that men (and women) who possess more systemizing brains should have more sons than daughters, while women (and men) who possess more empathizing brains should have more daughters than sons. We present the analysis of the 1994 US General Social Survey which empirically supports our prediction.

2. The anatomy of the theory

Baron-Cohen's extreme male brain theory of autism consists of a few crucial theoretical statements, which together provide symptomatology and psychometric descriptions of autism. We will first present these postulates and discuss them briefly, before attempting to reformulate and generalize the theory by incorporating evolutionary psychological principles.

2.1. Postulates about the male and female brains and their particular strengths

Baron-Cohen's theory begins with the two crucial concepts of the *male brain* and the *female brain*. The male brain is primarily designed for systemizing, and the female brain is primarily designed for empathizing. What are systemizing and empathizing then?

"Systemizing is the drive to analyse, explore and construct a system. The systemizer intuitively figures out how things work, or extracts the underlying rules that govern the behavior of a system. This is done in order to understand and predict the system, or to invent a new one" (Baron-Cohen, 2003, p. 3). Baron-Cohen (2003, pp. 63–69) enumerates six different types of systems: Technical systems (artifacts, machines); natural systems (ecology, geography); abstract systems (logic, mathematics); social systems (law, economics); organizable systems (classifications, taxonomies); and motoric systems (physical movements such as playing musical instruments or throwing darts). His definition of what constitutes a system is therefore very comprehensive, and seems to include everything that has to do with things, rather than people. "I mean by a system anything which is governed by rules specifying input-operation-output relationships" (p. 63).

In contrast, "empathizing is the drive to identify another person's emotions and thoughts, and to respond to them with an appropriate emotion… . Empathizing occurs when we feel an appropriate emotional reaction, an emotion *triggered by* the other person's emotions, and it is done in order to understand another person, to predict their behavior, and to connect or resonate with them emotionally" (Baron-Cohen, 2003, p. 2). "Empathizing is about spontaneously and naturally tuning into the other persons' thoughts and feelings, whatever these might be… . A good empathizer can immediately sense when an emotional change has occurred in someone, what the causes of this might be, and what might make this particular person feel better or worse. A good empathizer responds intuitively to a change in another person's mood with concern, appreciation, understanding, comforting, or whatever the appropriate emotion might be… . A natural empathizer not only notices others' feelings but also continually thinks about what the other person might be feeling, thinking or intending" (Baron-Cohen, 2003, pp. 23–24). In short, "empathy is a defining feature of human relationships…and also makes real communication possible" (p. 24).

2.2. Postulates about the sex distributions of systemizing and empathizing skills

Having defined what systemizing and empathizing are, Baron-Cohen then describes the distribution of systemizing and empathizing skills among men and women. He postulates that: (1) both systemizing and empathizing skills are distributed normally among the general populations of men and women; (2) men have a higher mean on systemizing skills than women; (3) women have a higher mean on empathizing skills than men; but (4) the sex distributions of systemizing and empathizing skills are substantially overlapping. The last postulate means that, while men on average are better at systemizing and women on average are better at empathizing, there are many men who are better empathizers than women and there are many women who are better systemizers than men (Baron-Cohen, 2003, p. 60, Fig. 5, p. 85, Fig. 7).

Baron-Cohen (2003, pp. 6–8) defines the brain of someone who is better at systemizing than empathizing as the "Type S" brain or the male brain (even though not everyone who possesses the male brain is male), and the brain of someone who is better at empathizing than systemizing as the "Type E" brain or the female brain (even though not everyone who possesses the female brain is female). Baron-Cohen then explains autism (and other autism spectrum syndromes such as Asperger's Syndrome) as a result of possessing the "extreme male brain," which is exceedingly good at systemizing but correspondingly poor at empathizing. Not only does Baron-Cohen's conceptualization of autism as a manifestation of the extreme male brain explain many of the clinical features of autism, but it also explains why it is so much more prevalent among men than among women.

2.3. Postulates about the evolutionary adaptiveness of brain types

Baron-Cohen (2003) devotes an entire chapter (Chapter 9) in his book to the discussion of the possible evolutionary origins of the male and female brains. He suggests that it might have been highly adaptive for ancestral men to possess the Type S brain, and for ancestral women to possess the Type E brain. For example, given that hunting large game was an almost entirely male activity (Murdock, 1967), ancestral men with the Type S brain might have had advantage in tolerating solitude during long hunting and tracking trips, during which the male hunter has very little human contact and which would have been intolerable for anyone with high need for human contact. High systemizing skills might have helped in making tools and weapons, and inventing new ones, also exclusively male activities in Murdock's (1967) ethnographic atlas. Having low empathy associated with the Type S brain is probably conducive to aggression and pursuit of status in dominance hierarchies, allowing ancestral men to eliminate their rivals physically and ruthlessly without regard to their pain and suffering (de Waal, 1996) and to exercising leadership, with the ability to make decisive, if impersonal, decisions for the sake of the collectivity without regard to consequences for individual members (Rubin, 2002; de Waal, 1982).

Similarly, the Type E brain might have been advantageous for ancestral women. For example, high empathy skills associated with the Type E brain would have helped in making friends in a new environment, because, due to female exogamy, ancestral women often had to migrate to and marry into new groups upon reaching puberty (Murdock, 1967; Oota et al., 2001). Empathy would help in various aspects of mothering, such as anticipating and understanding the needs of infants who cannot yet communicate verbally (Bowlby, 1969; MacLean, 1985). Empathy would also allow women to read a (potential) partner's mind, so as not to make the wrong mating choice in light of the much higher reproductive costs of such mistakes for women (Trivers, 1972) or to gather information through gossiping (Barkow, 1992).

2.4. Postulates about the heritability of brain types

While Baron-Cohen devotes an entire chapter (Chapter 7) of his book on the cultural influences on the brain types such as gender socialization, to dispel any misconception that the individual brain types are entirely "genetically determined," it is nevertheless obvious from his subsequent chapter on biological influences that the brain types are substantially heritable. Perhaps the best evidence for the heritability of brain types is the large heritability of autism and Asperger's syndrome (Bailey et al., 1995; Folstein and Rutter, 1988); the concordance of autism among monozygotic twins in one British twin study is 60% whereas the concordance among dizygotic twins is 0% (Bailey et al., 1995). Another indication that the brain types (Type S vs. E) might be heritable is the observation that families of autistics often contain a disproportionate number of physicists, engineers and mathematicians, all of whom must possess very high systemizing skills (Baron-Cohen, 2003, Chapter 11; Baron-Cohen et al., 1997, 1998).

While there are currently no studies that examine the heritability of systemizing skills per se, there have been twin studies which examine the heritability of empathizing skills, and they show moderate to high degrees of heritability of empathizing skills (Constantino and Todd, 2000; Zahn-Waxler et al., 1992).[1] The estimate of heritability (h^2) of reciprocal social behavior among male twins is .72 (Constantino and Todd, 2000, p. 2044). The estimates of heritability of various components of empathy (such as prosocial acts and empathetic concern) among 14-month-old twins range from .20 to 1.15 (even though true heritability cannot exceed 1.0) (Zahn-Waxler et al., 1992, p. 1044, Table 4). The evidence presented by Baron-Cohen and his colleagues as well as other researchers therefore strongly suggests that the brain type might be heritable, such that individuals with Type S brains are more likely to have children with Type S brains, and individuals with Type E brains are more likely to have children with Type E brains.

To recap, Baron-Cohen's extreme male brain theory of autism consists of the following four postulates:

1. There are Type S brains, good at systemizing, and Type E brains, good at empathizing.
2. Men on average are more likely to possess the Type S brains, and women on average are more likely to possess the Type E brain.
3. Possessing the Type S brain was highly adaptive for ancestral men, and possessing the Type E brain was highly adaptive for ancestral women.
4. Brain types are substantially heritable.

3. An evolutionary psychological extension of the theory: Enter the Trivers–Willard Hypothesis

To these four postulates from Baron-Cohen's theory, we add another one, borrowed from modern evolutionary psychology: the Trivers–Willard hypothesis. In its original formulation, the Trivers–Willard hypothesis (TWH: Trivers and Willard, 1973) states that, for all species for which male fitness variance exceeds female fitness variance, male offspring of parents in better material and nutritional conditions are expected to have greater reproductive success than their female siblings, because their greater size allows them to outcompete

[1]We thank one anonymous reviewer for bringing our attention to these studies of heritability of empathy skills.

their intrasexual rivals and monopolize available reproductive opportunities. The converse is true of offspring of parents in poorer material and nutritional conditions, because the smaller males, who are not intrasexually competitive, are excluded from mating opportunities. Parental conditions affect the reproductive prospect of female offspring to a much lesser extent. Almost all females get to reproduce some offspring, even though no female can produce a large number due to their greater obligatory parental investment into each offspring (Trivers, 1972).

Thus, it pays parents in good conditions to bet on male rather than female offspring. Since females have much lower variance in reproductive success, parents in poor material and nutritional condition should prefer to produce females as a safe bet. Trivers and Willard (1973) thus hypothesize that parents in better conditions should produce more male than female offspring and those in poorer conditions should produce more female than male offspring. Their parental investment into male and female offspring should be similarly biased. These predictions have been supported by data from a large number of experiments with a wide array of species (Venezuelan opossum: Austad and Sunquist, 1986; Red deer: Clutton-Brock et al., 1986; Spider monkey: Symington, 1987).

Evolutionary psychologists have since applied the original formulation of the TWH to modern humans and derived further hypotheses. Sons' expected reproductive success depends largely on the parents' wealth, so that sons from wealthy families are expected to attain much greater reproductive success than sons from poor families. This is because sons from wealthy families typically inherit the wealth from their fathers, and can in turn invest the resources into their offspring. Women prefer men with greater resources, and thus wealthy men throughout human evolutionary history have been able to attract a large number of high-quality mates (Betzig, 1986).

In contrast, daughters' expected reproductive success is largely orthogonal to parents' wealth, because it mostly depends on their youth and physical attractiveness. Men in general prefer younger and physically more attractive women, not wealthy women, for their mates (Buss, 1989; Kanazawa, 2003). The TWH in both of its specifications (offspring sex ratio and biased parental investment) has been supported with data from a wide variety of human societies, including the contemporary United States (Betzig and Weber, 1995; Gaulin and Robbins, 1991; Kanazawa, 2001; Mueller, 1993). Cronk (1991) provides a comprehensive review of the empirical evidence in support of the hypothesis, and Trivers (2002, pp. 120–122) adds a brief update on the status of the TWH.

While the TWH is one of the most celebrated principles in evolutionary biology and the preponderance of empirical evidence supports it, it has nonetheless received some criticisms. Myers (1978) and Leimer (1996) provide analytical critiques of the TWH's predictions. A comprehensive review (Brown, 2001) and a meta-analysis (Brown and Silk, 2002) find no consistent evidence for the TWH in the non-human primate literature. For the human populations, Koziel and Ulijaszek (2001) provide only qualified support, and Freese and Powell (1999) and Keller et al. (2001) offer counterevidence for the contemporary United States.

One of the theoretical competitors of the TWH is Grant's (1998, 2003) maternal dominance hypothesis. Grant maintains that it is not the material or economic conditions of the parents that influence the sex ratio of the offspring, as the TWH predicts, but the mother's personality trait known as dominance; more dominant mothers produce more sons, less dominant mothers produce more daughters. Grant (1998, pp. 29–38) specifically argues, and empirically finds, that father's dominance has no effect on the sex ratio of the offspring. Grant and France's (2001) study finds that the level of serum testosterone is the *proximate* (hormonal) determinant of women's dominance; however, unlike the TWH, Grant's maternal dominance hypothesis does not specify the *ultimate* (evolutionary) reason why more dominant mothers should have more sons than daughters.

While the TWH has specifically to do with material and economic conditions of parents and their ability to vary the sex ratio of their offspring in response to such conditions, the basic insight behind it is more general. The fundamental assumption underlying the TWH is that whenever males in a particular environment are expected to attain greater reproductive success than females (or vice versa), the potential exists for a species to evolve a mechanism for varying the offspring sex ratio in response. If males in a particular environment are expected to attain greater reproductive success than females, *for whatever reason,* then parents may have more sons than daughters. In an environment where females are expected to attain greater reproductive success than males, *for whatever reason,* then parents may have more daughters than sons.

This fundamental assumption behind the TWH, combined with Postulate 3 (adaptiveness of Type S brain for men and of Type E brain for women in the ancestral environment) and Postulate 4 (heritability of brain types) from Baron-Cohen's extreme male brain theory of autism leads us to the following novel prediction: *individuals who have Type S brains should have more sons than daughters, while individuals who have Type E brains should have more daughters than sons.*

Because men are more likely to have Type S brains and women are more likely to have Type E brains, our prediction above appears to have a seemingly absurd logical implication that men are more likely to have sons and women are more likely to have daughters. This is part of our logic, however. A mateship between an average man (with the average Type S brain) and an average woman (with the average Type E brain) is expected to produce a roughly equal number of sons and daughters (with the precise sex ratio of 1.05; Grant, 1998). When one or the other or both parents between them have an excess of systemizing skills (by having a strong Type S brain), then *the couple* is expected to produce more sons than daughters; when one or the other or both parents between them have an excess of empathizing skills (by having a strong Type E brain), then *the couple* is expected to produce more daughters than sons. Unlike Grant (1998), we are agnostic about which parent (mother or father) determines the sex of the offspring.

In the next section, we analyze data from the 1994 US General Social Survey to test our prediction that parents who have Type S brains should have more sons than daughters, whereas parents who have Type E brains should have more daughters than sons.

4. Empirical analysis

4.1. Data

The National Opinion Research Center at the University of Chicago has administered the General Social Surveys (GSS) either annually or biennially since 1972. Personal interviews are conducted with a nationally representative sample of non-institutionalized adults in the US. The sample size is about 1,500 for each annual survey, and about 3000 for each biennial one. The exact questions asked in the survey vary by the year.

As is common with social science data sets, for which biological information about the respondents is assumed unimportant, however, the GSS normally do not make distinctions between biological and non-biological (adopted, step, foster) children of the respondents. Further, they normally do not even measure the sex of their children, treating boys and girls interchangeably. In 1994 (and only in 1994), however, the GSS assesses the respondents' precise relationship with each of their children, and measures their sex.

In addition, the 1994 GSS measures the number of siblings that the respondents have, their precise biological relationship with each of their siblings (full, half, step), and the sibling's sex. From these variables, we can further determine how many biological sons and daughters the respondents' *parents* had. We use information on both generations from the 1994 GSS data to assess: (1) the effect of the GSS respondents' brain types on the number of sons and daughters they have (Generations t and $t+1$); and (2) the effect of the GSS respondents' parents' brain types on the number of sons and daughters that they had, one of whom is the GSS respondent (Generations $t-1$ and t).

4.2. Dependent variables

We use the number of biological sons and daughters that the respondents have, and the number of biological sons and daughters that the respondents' parents had, as our dependent variables. The number of biological sons and daughters are measured as an interval variable up to nine.

We use this count measure of our dependent variable, rather than ratio measures (such as Number of sons/Number of daughters) because ratio measures have a couple of undesirable features at the individual level. First, when the denominator is zero (for instance, if the individual has no daughters), the ratio is mathematically undefined. However, one can get around this problem by adding an epsilon to the denominator (so that the dependent measure becomes Number of sons/Number of daughters + .001, for example). More importantly, however, ratio measures cannot distinguish between two sonless individuals with different numbers of daughters. If someone has no sons and one daughter (0/1), and someone else has no sons and five daughters (0/5), both of them would have zero as a dependent measure, even though the latter individual is much more prone to producing daughters than the former individual. Because of these problems, we have chosen to use the number of sons or daughters as the dependent variable, while controlling for the number of children of the opposite sex. (See below.)

4.3. Independent variables

Our primary independent variables of interest are the respondents' and their parents' brain types (Type S vs. Type E). Baron-Cohen and his colleagues have developed a battery of tests precisely to measure an individual's systemizing quotient (SQ) and empathy quotient (EQ) (Baron-Cohen et al., 2003; Baron-Cohen and Wheelwright, 2004). The individuals' SQ measures the extent to which they have the Type S brain, and their EQ measures the extent to which they have the Type E brain. However, these tests have only been conducted in their own studies, and they have not been administered to a nationally representative sample of any population. We therefore need a proxy measure of brain types.

We assume that, in a free market economy like the United States, individuals more or less choose to have jobs that best suit their temperaments and natural inclinations. Those who have the Type S brains choose to have occupations that require systemizing skills, and those who have the Type E brains choose to have occupations that require empathizing skills. In the GSS data, we therefore measure the individuals' brain types by the occupations they hold. While this proxy measure is far less accurate and precise than Baron-Cohen's SQ and EQ tests, all the random measurement errors should cancel out, and a consistent pattern should emerge, at the aggregate in a large data set like the GSS.

Admittedly, however, our assumption of free occupational choice to suit individual temperaments and inclinations is probably truer today among the GSS respondents (in Generation t) than in the past among the respondents' parents (in Generation $t-1$). Sex-typing and sex segregation of occupations were stronger in the past than it is now, so that, for example, men felt less free to become a nurse and women felt less free to become an engineer (even though that is what best suited their temperaments) in the parents' generation. For this reason, we expect our measure of brain types to be more accurate in Generation t than in Generation $t-1$.

Baron-Cohen does not provide a list of occupations which attract Type S or Type E brains, other than that physicists, engineers, and mathematicians have predominantly Type S brains (Baron-Cohen, 2003, Chapter 11; Baron-Cohen et al., 1997, 1998). We have gone through the entire list of occupations in the 1980 US Census Occupation Code (used by the 1994 GSS), and selected those occupations that we believe require particularly high systemizing skills and those that we believe require particularly high empathizing skills. These occupations are listed in the Appendix.

In our lists, the systemizing occupations mostly consist of scientists (including professors of science), engineers, mathematicians, statisticians, and other quantitative occupations. The empathizing occupations consist of nurses, therapists, and kindergarten, primary and secondary school teachers. Most occupations in the 1980 Census Occupation Code are neutral and are not on either the systemizing or empathizing list in the appendix. For instance, we have chosen not to include doctors and physicians in either list. On the one hand, doctors require extensive training in the sciences, pushing them into the systemizing directions. On the other hand, unlike medical researchers and scientists, they need good bedside manners and sensitivity to deal with patients, pushing them into the empathizing directions. Many female-dominated occupations, such as secretaries, sales clerks, and librarians, are also neutral in our classification. We do not claim that these are the definitive lists of Type S and Type E occupations, only that these are close enough approximations and thus possibly a good place to start. Future researchers can no doubt improve on our lists.

Each respondent has two dummy variables: systemizing occupation = 1 if the respondent has one of the systemizing occupations in the appendix, = 0 otherwise; empathizing occupation = 1 if the respondent has one of the empathizing occupations in the appendix, = 0 otherwise. Among the respondents (Generation t), 5.9% have one of the systemizing occupations (and are thus assumed to have Type S brains), and 6.1% have one of the empathizing occupations (and are thus assumed to have Type E brains). Among the respondents' parents (Generation $t-1$), 5.9% of the fathers have a systemizing occupation, and 1.2% of them have an empathizing occupation; 1.9% of the mothers have a systemizing occupation, and 13.1% of them have an empathizing occupation.

4.4. Control variables

4.4.1. Trivers– Willard controls

Because the TWH in its original formulation explains the offspring sex ratio in terms of the material wealth of the parents, we need to control for parental social status, in order to estimate the *partial* effects of parent's brain types on the offspring sex ratio, net of the effects of parental social status. We therefore include controls for respondents' and respondents' parents' education (measured in years of formal education) and income (measured in 23 relatively equidistant ordinal scale). Controlling for education and income is also important because holders of both systemizing and empathizing occupations have significantly higher education and income than holders of other, neutral occupations (education: systemizing vs. non-systemizing, 15.66 vs. 13.10, $t = 11.23$, $p < .0001$; empathizing vs. non-empathizing, 16.39 vs. 13.05, $t = 15.15$, $p < .0001$; income: systemizing vs. non-systemizing, 16.08 vs. 12.10, $t = 8.70$, $p < .0001$; empathizing vs. non-empathizing, 13.63 vs. 12.29, $t = 2.78$, $p < .01$). We therefore control for education and income in both Generations t and $t-1$.

4.4.2. Risk factors

Our dependent variables are the numbers of sons and daughters. Besides the brain types, there are other factors that can increase the number of children that individuals have. First, since the number of biological children can only monotonically increase with age, we must control for the individual's age. Second, since marriage is a particular risk factor for having children, we control for the individual's current marital status (1 if currently married, 0 otherwise) and the age at which the individual first got married. Third, because blacks in the US have significantly more children than non-blacks (2.34 vs. 1.79, $t = 6.02$, $p < .0001$), we control for the respondent's race (1 if black, 0 otherwise), which in Generation $t-1$ also indirectly measures the respondent's parent's race. Finally, because individuals can have more sons or daughters, not necessarily because they are more likely to have children of one sex or the other but because they have more children (both boys and girls), we control for the number of biological children of the opposite sex, to estimate whether the individual's brain types have an effect on the number of biological children of one sex *net* of the number of biological children of the opposite sex. Naturally, the bivariate correlation between the number of boys and the number of girls is significantly positive (Generation t: $r = .4319$, $p < .0001$; Generation $t-1$: $r = .1707$, $p < .0001$) (but see below for their partial correlations).

Controlling for religion as a potential risk factor, by including a set of four dummy variables (Catholic, Protestant, Jewish, and Other, with None as the reference category) does not alter the substantive results presented below. We do not include other risk factors in the equations for Generation $t-1$ because information about the respondents' parents' age at marriage and marital status are not available in the GSS. Entering the father's and the mother's year of birth in the equations does not alter the substantive conclusions.

4.5. Results

4.5.1. The effects of brain types in generation t on the offspring sex ratio in generation t+1

Table 1 presents the results of the OLS regression of the number of boys and girls in Generation $t+1$ on the parental brain types in Generation t. The left column shows that, controlling for social status (education and income) and risk factors (age, age at first marriage, race, and current marital status), individuals who hold systemizing occupations (and are thus assumed to have Type S brains) have significantly ($p < .01$) more biological sons than daughters. Conversely, the right column shows that, controlling for the same variables, individuals who hold empathizing occupations (and are thus assumed to have Type E brains) have significantly ($p < .01$) more biological daughters than sons. The results presented in Table 1 therefore strongly support our prediction, derived from the combination of Baron-Cohen's extreme male brain theory of autism and the Trivers–Willard hypothesis, that parents who have Type S brains are more likely to have sons than daughters and parents who have Type E brains are more likely to have daughters than sons.

Our results in Table 1 provide ambiguous support for the TWH, however. While the strongly significantly ($p < .0001$) negative effect of education on the number of daughters (right column) supports the TWH, education and income also have significantly (albeit weaker) negative effect on the number of sons (left column), in contradiction to the prediction of the original formulation of the TWH. All the risk factors have the predicted effects. Older individuals, those who married at younger ages, and blacks all have more sons and daughters, while those who are currently married have more sons, but not daughters, possibly because the presence of sons decreases the likelihood of divorce (Morgan et al., 1988; Katzev et al., 1994).

Table 1
The effects of respondents' brain types on the sex of their offspring (Generations t and $t+1$)

	Dependent variable	
	Number of sons	Number of daughters
Main predictors		
Systemizing occupation	.3498**	.1357
	(.1326)	(.1341)
Empathizing occupation	.2684	.3981**
	(.1405)	(.1411)
Trivers–Willard controls		
Education	−.0375**	−.0571****
	(.0142)	(.0142)
Income	−.0187*	.0063
	(.0073)	(.0074)
Risk factors		
Age	.0325****	.0278****
	(.0031)	(.0032)
Age at first marriage	−.0519****	−.0415****
	(.0082)	(.0083)
Race (1 = black)	.2979**	.4998****
	(.1150)	(.1149)
Currently married (1 = yes)	.1688*	.1363
	(.0735)	(.0741)
Number of sons/daughters	−.1029**	−.1044**
	(.0366)	(.0371)
Constant	1.4699	1.3036
	(.2633)	(.2665)
R^2	.1952	.1620
n	738	738

Note: Main entries are unstandardized regression coefficients. Numbers in parentheses are standard errors.
*$p < .05$.
**$p < .01$.
***$p < .001$.
****$p < .0001$.

Another unexpected finding in Table 1 is the effect of the number of biological children of the opposite sex. While, as noted above, the number of boys and the number of girls have a positive bivariate correlation ($r = .4319$), both of these variables have significantly ($ps < .01$) *negative* partial effect on the number of biological children of the opposite sex. In other words, when we control for all the variables included in our equations, those who have more biological daughters have *fewer* biological sons, and those who have more biological sons have *fewer* biological daughters. This seems to suggest that parents specialize in producing children of one sex or the other, some producing mostly or exclusive boys, and others producing mostly or exclusively girls. While the partial negative effects of these variables are unexpected from their positive bivariate correlation, they are nonetheless consistent with both the TWH and our prediction in this paper.

4.5.2. The effects of brain types in generation t−1 on the offspring sex ratio in generation t

Table 2 presents the results of the OLS regression of the number of boys and girls in Generation t on the parental brain types in Generation $t-1$. Here the empirical results are more ambiguous. The left column shows that, controlling for father's education and occupational status (the information on respondent's parent's income is not available in the GSS), mother's education and occupational status, race, and the number of sisters, the brain types of the father and the mother, measured by their occupations, do not seem to have any effect on the number of boys that they have in Generation t. In fact, the only significant effect found in this equation is the effect of race: Blacks have significantly more sons than non-blacks. The absence of clear effects of brain types on the offspring sex ratio in Table 2, compared to the clear results presented in Table 1, may be due to the fact, discussed above, that occupational choice was less free in the previous generation ($t-1$) than in the current generation (t), and thus occupations were less valid measures of respondents' parents' brain types.

However, there is partial support for our hypothesis when the dependent variable is the number of daughters. The right column shows that, controlling for the same variables, mothers who have empathizing occupations are significantly ($p<.0001$) more likely to have daughters than sons. So there is at least some support for our prediction among the parents in Generation $t-1$. Consistent with the TWH, the right column in Table 2 shows that both father's and mother's education have significantly ($ps<.05$) negative effect on the number of daughters. The results in Table 2, right column, showing that only the mother's empathizing skills matter for the number of daughters, are also consistent with Grant's (1998, 2003) maternal dominance hypothesis for sex determination, although the results in Table 1, showing the effects of both the father's and the mother's brain types, are inconsistent with it.

Table 2
The effects of respondents' parents' brain types on the sex of respondents' siblings (Generations $t-1$ and t)

	Dependent variables	
	Number of brothers	Number of sisters
Main predictors		
Father's systemizing occupation	−.0148	−.0601
	(.1674)	(.1751)
Father's empathizing occupation	−.2093	.0626
	(.2874)	(.3006)
Mother's systemizing occupation	−.4912	.2201
	(.2554)	(.2675)
Mother's empathizing occupation	.0182	.6816****
	(.1630)	(.1692)
Trivers–Willard controls		
Father's education	−.0203	−.0379*
	(.0147)	(.0154)
Father's occupational status	.0014	−.0058
	(.0041)	(.0042)
Mother's education	−.0319	−.0383*
	(.0173)	(.0181)
Mother's occupational status	.0039	−.0071
	(.0041)	(.0043)
Risk factor		
Race (1 = black)	.5872****	.5118***
	(.1248)	(.1309)
Number of sisters/brothers	.0051	.0056
	(.0289)	(.0316)
R^2	.0396	.0745
n	1108	1108

Note: Main entries are unstandardized regression coefficients. Numbers in parentheses are standard errors.
*$p<.05$.
**$p<.01$.
***$p<.001$.
****$p<.0001$.

5. Conclusions

If the Type S brain, particularly adept at systemizing, was adaptive for ancestral men, and if the Type E brain, especially designed for empathizing, was adaptive for ancestral women, as Baron-Cohen (2003, Chapter 9) argues, and if the brain types are substantially heritable, then, combined with the fundamental insight behind the Trivers–Willard hypothesis (TWH) regarding the parents' ability to vary the sex ratio of offspring in order to maximize inclusive fitness, it follows that people with strong Type S brains should have more sons than daughters and people with strong Type E brains should have more daughters and sons. Our analysis of the 1994 General Social Survey provides support for our prediction. The GSS respondents who have "systemizing" occupations, such as scientists, engineers, and mathematicians, are significantly more likely to have sons than daughters; those who have "empathizing" occupations, such as nurses, therapists, and school teachers, are more likely to have daughters than sons. There is also some evidence for our prediction in the previous generation. Among the parents of the GSS respondents, mothers who had empathizing occupations are significantly more likely to have daughters than sons.

If our findings are robust, what possibly accounts for them? What mechanism is behind the process whereby individuals with strong Type S brains have higher offspring sex ratio (more sons than daughters) than those with strong Type E brains? There is emerging evidence that the biochemical foundation of this process may involve prenatal exposure to testosterone (Baron-Cohen et al., 2004). The 2D:4D ratio (the ratio of the length of the index finger to the length of the ring finger) is an accurate (inverse) indicator of the prenatal exposure to testosterone (Manning, 2002); men have lower 2D:4D ratio than women do. Autistics, who have extreme Type S brains, have lower 2D:4D ratios (Manning et al., 2001), and at the same time those with low 2D:4D ratios have more sons than daughters (Manning et al., 2002).

There appears little doubt that parental hormones affect the sex ratio of offspring. While Grant (1998, 2003; Grant and France, 2001) only emphasizes the dominance and testosterone levels of the mother, James (1980a, b), like us, suggests that the hormones of both parents might influence the sex ratio of the offspring. James (1994, 1996, 2004) reviews the evidence for the influence of parental hormones, in addition to other factors that may also influence the offspring sex ratio, both those that affect all mammalian species (such as parental dominance, day of insemination, and diet) and those that specifically affect humans (such as parental occupations, use of drugs, and wars).

We present our thesis and evidence very cautiously. Baron-Cohen's extreme male brain theory of autism, which has strong validity in the clinical and experimental settings (Baron-Cohen et al., 2001, 2004), has never (to our knowledge) been interpreted in a strong evolutionary psychological framework, as we do in our paper. (For instance, Baron-Cohen does not cite any of his voluminous work in his chapter "Evolution of the Male and Female Brain," probably because he has not extended his clinical theory of autism to evolutionary directions.) Further, the TWH has always been interpreted in terms of the effect of parental conditions (social status and dominance in modern human societies) on the offspring sex ratio; it has never (to our knowledge) been extended to other factors that may influence parents' reproductive success (such as brain types).

If we are right in our extension of the TWH, then other predictions are possible. For instance, there is some evidence that battered women, mated to aggressive and violent men, are more likely to have sons than daughters, because aggression and violence were adaptive for men, but not women, in the ancestral environment (Kanazawa, 2004). Given that taller men have greater reproductive success than shorter men (Mueller and Mazur, 2001; Nettle, 2002a; Pawlowski et al., 2000), and that shorter women have greater reproductive success than taller women (Nettle, 2002b), a similar logic would predict that taller parents should have more sons and shorter parents should have more daughters. Our empirical results presented here suggest that both the evolutionary psychological extension of Baron-Cohen's extreme male brain theory of autism, and reinterpretation of the TWH and its underlying assumption, may be fruitful for further research.

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Appendix. 1980 census occupational classification

Systemizing occupations	Census code	Empathizing occupations	Census code
Executive, administrative, and managerial occupations		*Professional specialty occupations*	
Financial managers	007	Registered nurses	095
Accountants and auditors	023	Dieticians	097
Underwriters	024	Inhalation therapists	098
Other financial officers	025	Occupational therapists	099
Management analysts	026	Physical therapists	103
Professional specialty occupations		Speech therapists	104
Architects	043	Therapists, n.e.c.	105
Aerospace engineers	044	Teachers, prekindergarten and kindergarten	155
Metallurgical and materials engineers	045	Teachers, elementary school	156
Mining engineers	046	Teachers, secondary school	157
Petroleum engineers	047	Teachers, special education	158
Chemical engineers	048	Teachers, n.e.c.	159
Nuclear engineers	049	Counselors, educational and vocational	163

Civil engineers	053
Agricultural engineers	054
Electrical and electronic engineers	055
Industrial engineers	056
Mechanical engineers	057
Marine and naval architects	058
Engineers, n.e.c.	059
Surveyors and mapping scientists	063
Computer systems analysts and scientists	064
Operations and systems researchers and analysts	065
Actuaries	066
Statisticians	067
Mathematical scientists, n.e.c.	068
Physicists and astronomers	069
Chemists, except biochemists	073
Atmospheric and space scientists	074
Geologists and geodesists	075
Physical scientists, n.e.c.	076
Agricultural and food scientists	077
Biological and life scientists	078
Forestry and conservation scientists	079
Medical scientists	083
Earth, environmental, and marine science teachers	113
Biological science teachers	114
Chemistry teachers	115
Physics teachers	116
Natural science teachers, n.e.c.	117
Engineering teachers	127
Mathematical science teachers	128
Computer science teachers	129
Medical science teachers	133
Agriculture and forestry teachers	136
Technicians and related support occupations	
Electrical and electronic technicians	213
Industrial engineering technicians	214
Mechanical engineering technicians	215
Engineering technicians	216

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