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Beautiful parents have more daughters: A further implication of the generalized Trivers–Willard hypothesis (gTWH)

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Abstract

The generalized Trivers–Willard hypothesis (gTWH) [Kanazawa, S., 2005. Big and tall parents have more sons: further generalizations of the Trivers–Willard hypothesis. J. Theor. Biol. 235, 583–590) proposes that parents who possess any heritable trait which increases the male reproductive success at a greater rate than female reproductive success in a given environment will have a higher-than-expected offspring sex ratio, and parents who possess any heritable trait which increases the female reproductive success at a greater rate than male reproductive success in a given environment will have a lower-than-expected offspring sex ratio. One heritable trait which increases the reproductive success of daughters much more than that of sons is physical attractiveness. I therefore predict that physically attractive parents have a lower-than-expected offspring sex ratio (more daughters). Further, if beautiful parents have more daughters and physical attractiveness is heritable, then, over evolutionary history, women should gradually become more attractive than men. The analysis of the National Longitudinal Study of Adolescent Health (Add Health) confirm both of these hypotheses. Very attractive individuals are 26% less likely to have a son, and women are significantly more physically attractive than men in the representative American sample.
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1. Introduction

In their classic paper, Trivers and Willard (1973) suggest that parents might under some circumstances be able to vary the sex ratio of their offspring in order to maximize their reproductive success. The Trivers–Willard hypothesis (TWH) proposes that, for all species for which male fitness variance exceeds female fitness variance, male offspring of parents in better material and nutritional condition are expected to have greater reproductive success than their female siblings, because their greater size allows them to outcompete their intrasexual rivals and monopolize available reproductive opportunities. The converse is true of offspring of parents in poorer material and nutritional condition, because the smaller males, who are not intrasexually competitive, are excluded from mating opportunities. Parental condition affects the reproductive prospects 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).

It therefore pays parents in good condition 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 condition should produce more male offspring than female offspring. Their facultative 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). Recent meta-analyses of the TWH and facultative sex ratio manipulation include Ewen et al. (2004) for birds, Sheldon and West (2004) for ungulates specifically, and Cameron (2004) for mammals in general.

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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' status, so that sons from higher-status families are expected to attain much greater reproductive success than sons from lower-status families. This is because sons from higher-status families typically inherit the status from their fathers, and thus are in a position to protect and invest into their offspring. Women prefer to mate with men of higher status and wealth (which has consistently been highly correlated with status since the advent of agriculture), and thus such 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' status or wealth, because it mostly depends on their youth and physical attractiveness. Men in general prefer younger and physically more attractive women for their mates, not women from higher-status families; a potential mate's status or wealth is far less important for men than her youth and physical attractiveness (Buss, 1989; Kanazawa, 2003). The TWH in both of its specifications (secondary sex ratio and facultative 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 Leimar (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 nonhuman primate literature. For the human populations, Koziel and Ulijaszek (2001) provide only qualified support, and Freese and Powell (1999); Keller et al. (2001); Ellis and Bonin (2002) find no support for the TWH for contemporary North America.

2. Generalized Trivers–Willard hypothesis (gTWH)

While the TWH in its original formulation has specifically to do with material and economic condition of parents and their ability to vary the sex ratio of their offspring in response to such condition, the basic insight behind it may be more general. The fundamental assumption underlying the TWH is that, if males are expected to attain greater reproductive success than females, *for whatever reason,* then parents may have more sons than daughters. If, in contrast, females are expected to attain greater reproductive success than males, *for whatever*

reason, then parents may have more daughters than sons. While female fitness variance is much smaller than male fitness variance among mammalian species, there is still variance among females, and some women do better than others, in terms of the quality, if not quantity, of their offspring.

Kanazawa (2005) thus proposes the gTWH:

gTWH: Parents who possess any heritable trait which increases male reproductive success at a greater rate (or decreases male reproductive success at a smaller rate) than female reproductive success in a given environment will have a higher-than-expected offspring sex ratio (more males). Parents who possess any heritable trait which increases female reproductive success at a greater rate (or decreases female reproductive success at a smaller rate) than male reproductive success in a given environment will have a lower-than-expected offspring sex ratio (more females).

There has been some emerging evidence for the gTWH with respect to a variety of heritable traits, which increase the reproductive success of offspring of one sex or the other.

2.1. Brain types

Kanazawa and Vandermassen (2005) synthesize the TWH with Baron-Cohen's extreme male brain theory of autism. Baron-Cohen (1999, 2002, 2003; Baron-Cohen and Hammer, 1997; Baron-Cohen et al., 2004) proposes that there are "male (or Type S) brains," which are good at systemizing (figuring things out) and were adaptive for our ancestral men, and "female (or Type E) brains," which are good at empathizing (relating to people) and were adaptive for our ancestral women. Baron-Cohen further suggests that brain types are substantially heritable. Kanazawa and Vandermassen then derive logical implications of the convergence of Baron-Cohen's theory and the TWH, and predict that, if Type S brain increases male reproductive success in the ancestral environment (mostly African savanna during the Pleistocene Epoch when our ancestors lived as hunter-gatherers) and Type E brain increases female reproductive success in the ancestral environment, then individuals with strong Type S brains (such as engineers and mathematicians) should have more sons than daughters, and individuals with strong Type E brains (such as nurses and school teachers) should have more daughters than sons. Their analysis of the 1994 US General Social Surveys confirms their predictions.

2.2. Body size

Humans were mildly polygynous during most of their evolutionary history (Alexander, 1979; Leutenegger and Kelly, 1977). By allowing some men to monopolize all women, polygyny intensifies male intrasexual competition

for mates. In the ancestral environment, where such competition was largely if not entirely physical in character, big and tall men had particular advantages over smaller and shorter men. In contrast, large body size was not particularly adaptive for ancestral women; in fact, some argue that females have been selected to be small, either to mature early sexually in order to start reproducing in polygynous breeding systems (Harvey and Bennett, 1985; Kanazawa and Novak, 2005) or to conserve energy and satisfy the somatic needs of physical maintenance while pregnant or lactating (Pickford, 1986). Probably for this reason, taller men to this day have greater reproductive success than shorter men (Nettle, 2002a; Pawlowski et al., 2000), but shorter women have greater reproductive success than taller women (Nettle, 2002b). And body size (height and weight) is substantially heritable (Chambers et al., 2001; Silventoinen et al., 2001). Kanazawa (2005) therefore predicts that taller and heavier parents have a higher-than-expected number of sons, and shorter and lighter parents have a lower-than-expected number of sons (or a higher-than-expected number of daughters). His analysis of both lifetime number of children and recent pregnancies from the National Child Development Study and the British Cohort Study largely supports his predictions.

2.3. Tendency toward violence

Another heritable trait, which helps men, but not women, in their (often physical and fierce) intrasexual competition for mates in the ancestral environment is the tendency toward violence. Even today violent and aggressive men in contemporary hunter-gatherer societies tend to have more wives and greater reproductive success (Chagnon, 1997; Redmond, 1994). Men's baseline testosterone levels on the one hand predict aggression and violence (Booth and Osgood, 1993; Dabbs and Morris, 1990; Soler et al., 2000) and on the other predict their dominance rank (Mueller and Mazer, 1996). And they are highly heritable (Harris et al., 1998; Rushton et al., 1986). In contrast, as Campbell's (1999) "staying alive hypothesis" predicts, women's first reproductive priority is to stay alive in order to take care of her children because their survival and wellbeing depend more heavily on maternal than on paternal care, and the tendency toward violence is clearly detrimental to this priority, as it might result in the mother's injury of death. Consistent with this logic, Kanazawa (2006) shows that violent men both in American and British samples are more likely to have sons.

2.4. Language impairment

Tallal et al. (1989) show that mothers (but not fathers) with a developmental language impairment have an exceedingly high sex ratio (2.5000: 25 boys vs. 10 girls). Women normally have greater language and communica-

tion skills than men, and thus language impairment is relatively more problematic and maladaptive for girls than for boys. There is some evidence to suggest that our ancestors, like our great ape cousins, may have practiced female exogamy (Maryanski and Turner, 1992, pp. 21–23; Smuts, 1995), where pubescent females leave their natal group and marry into a neighboring one. Females under such circumstances would therefore have particular difficulty making friends and creating networks in the new environment. This is an example of a heritable trait that would decrease female reproductive success to a much greater extent than it decreases male reproductive success, and thus the gTWH would predict that language-impaired parents should have more sons than daughters.

There is therefore converging and accumulating evidence that parental ability to vary the offspring sex ratio, first recognized by Trivers and Willard in 1973, may be more general than originally thought. What triggers a biased sex ratio may not be limited to the parents' material and economic condition, but may extend to all factors that affect the sex-specific reproductive success in a given environment, so long as such factors are heritable.

One heritable characteristic which increases the daughters' reproductive success much more than son's reproductive success is physical attractiveness, which is defined by the geometric concept of bilateral symmetry, the mathematical concept of averageness, and the biological concept of secondary sexual characteristics (Langlois et al., 1987; Langlois and Roggman, 1990; Rhodes and Zebrowitz, 2002). Men universally seek women who are physically attractive for both long- and short-term mating (Buss, 1989) because physical attractiveness is a phenotypic marker of genetic and developmental health (Thornhill and Møller, 1997). In contrast, while women may prefer physically attractive men for short-term mating (extra-pair copulations) (Gangestad and Simpson, 2000; Li and Kenrick, 2006), they often place greater emphasis on other traits, such as wealth and status, for long-term mating (Buss, 1989).

And physical attractiveness is heritable. While there has not been a study whose *principal* purpose is to demonstrate the heritability of physical attractiveness (perhaps because everybody takes it for granted that beautiful parents beget beautiful children without any need for empirical demonstration), one twin study (McGovern et al., 1996) suggests that the heritability of physical attractiveness $h^2 = 0.64$ (Kanazawa and Kovar, 2004). Rowe et al. (1989) show that the correlation in physical attractiveness between MZ twins, corrected for measurement errors, is $r = 0.94$, which would suggest a very high h^2.

The logic of the gTWH would therefore suggest that physically attractive parents should have a higher-than-expected number of daughters, and, conversely, lower than expected number of sons. I put this hypothesis to an empirical test below.

3. Empirical analysis

3.1. Data

I use the National Longitudinal Study of Adolescent Health (Add Health). A sample of 80 high schools and 52 middle schools from the US was selected with unequal probability of selection. Incorporating systematic sampling methods and implicit stratification into the Add Health study design ensures this sample is representative of US schools with respect to region of country, urbanicity, school size, school type, and ethnicity. A sample of 20,745 adolescents were personally interviewed in their homes in 1994–1995 (Wave I), and again in 1996 (Wave II; $n = 14,738$). In 2001–2002, 15,197 of the original Wave I respondents, now age 18–28, were interviewed in their homes. My sample consists of Wave III respondents who have had at least one biological child ($n = 2972$).

3.2. Dependent variable

I use the sex of the first child (0 = female, 1 = male) as the binary dependent variable. In previous empirical tests of the gTWH (Kanazawa, 2005, 2006; Kanazawa and Vandermassen, 2005), I use the total number of children of one sex, while controlling for the total number of children of the other sex, as a measure of offspring sex ratio. However, the use of the total numbers of boys and girls in the family is susceptible to the influence of "stopping rules" (when couples choose to stop having children or when they choose to continue to have more).[1] Different couples might use different stopping rules; for example, there is some evidence that couples with two boys or two girls are more likely to have a third child than couples with a boy and a girl (Yamaguchi and Ferguson, 1995). In order to eliminate the influence of idiosyncratic and systematic stopping rules that couples may adopt, I use the sex of the first child as the measure of parents' propensity to have a boy or a girl in this paper.

3.3. Independent variable

The primary independent variable of interest is physical attractiveness. Unlike most social science survey data, Add Health has a direct measure of respondents' physical attractiveness. At the conclusion of each in-home interview, the interviewer is asked to rate the respondent's physical attractiveness on a five-point ordinal scale (1 = very unattractive, 2 = unattractive, 3 = about average; 4 = attractive; 5 = very attractive). I use this five-point scale as a measure of respondents' physical attractiveness.

It is interesting to note that, across the entire sample, the objective measure of physical attractiveness that I use in

the analysis below is very weakly, albeit statistically significantly (due to the large sample size) correlated with the self-rated 4-point scale of physical attractiveness (1 = not at all, 2 = slightly, 3 = moderately, 4 = very) ($r = 0.0973$, $p < 0.0001$, $n = 14,760$). More than a quarter (28.2%) of the respondents rate themselves as "very attractive," while only 11.2% of them are so rated by the interviewer.

3.4. Results

3.4.1. Bivariate analysis

Fig. 1 shows the proportion of sons among the first children of Add Health respondents by their physical attractiveness. It is immediately obvious that the proportion of sons among the four lower classes of physical attractiveness (0.50 for "very unattractive," 0.56 for "unattractive," 0.50 for "about average," and 0.53 for "attractive") stay very close to the population average of 0.5122 (105 boys per 100 girls). The proportion among the "very attractive" respondents (0.44), however, appears substantially lower. A one-way analysis of variance shows that the proportion of sons and physical attractiveness are not statistically independent ($F_{(4, 2965)} = 2.55$, $p < 0.05$).

If I dichotomize the respondents into those who are rated "very attractive" and everyone else, the difference in the proportion of sons between the two groups (0.52 vs. 0.44) is statistically significant ($t = 2.44$, $p < 0.05$). There appears to be something qualitatively different about respondents rated "very attractive".

3.4.2. Multiple binary logistic regression analysis

Table 1, Column (1), shows that when the sex of the first child is regressed on the binary variable whether or not the respondent is rated "very attractive" (1 = yes), the
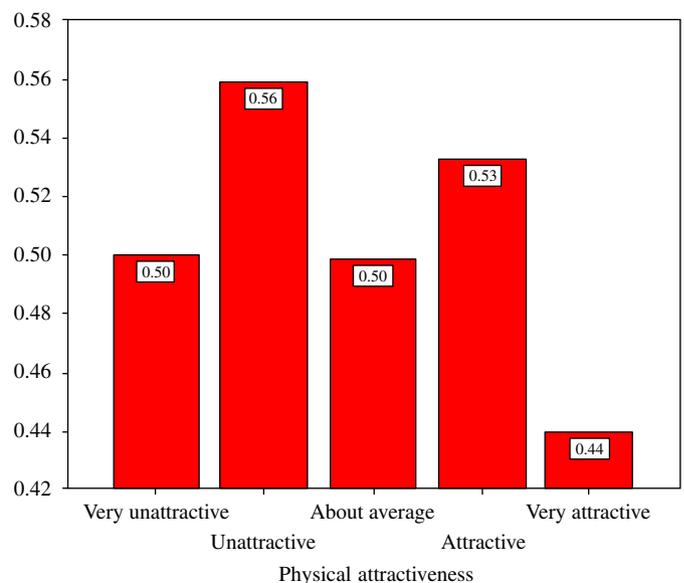

Fig. 1. Proportion of boys among the first child, by parent's physical attractiveness.

Table 1
The sex of the first child

	Sex of the first child (1 = male)		
	(1)	(2)	(3)
Very attractive? (1 = yes)	−0.3063* (0.1260) *0.7362*	−0.3084* (0.1352) *0.7346*	−0.3092* (0.1358) *0.7341*
Trivers–Willard controls			
Education		0.297 (0.0215) *1.0301*	0.0288 (0.0218) *1.0292*
Income		0.0000 (0.0000) *1.0000*	0.0000 (0.0000) *1.0000*
Race (1 = black)		0.0447 (0.0638) *1.0458*	0.0410 (0.0644) *1.0419*
Sex (1 = male)		0.0981 (0.0875) *1.1030*	0.0916 (0.0886) *1.0960*
Age at first sex			−0.0088 (0.0189) *0.9913*
Number of sex partners in last 12 months			0.0072 (0.0253) *1.0072*
Constant	0.0640 (0.0386)	−0.3782 (0.2724)	−0.2344 (0.3805)
−2 Log likelihood	4113.21	3479.67	3429.06
Cox and Snell pseudo-R^2	0.0020	0.0042	0.0040
Number of cases	2972	2518	2481

Note: Main entries are unstandardized regression coefficients.
Numbers in parentheses are standard errors.
Italicized entries are partial effects on odds (e^{b_k}).
*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$; ****$p < 0.0001$.

independent variable has a significantly negative effect ($b = -0.3063$, $p < 0.05$). The associated odds-ratio of 0.7362 means that very attractive respondents are about 26% less likely to have a son as the first child.

Table 1, Column (2), introduces control variables into the binary logistic equation. First, in order to control for the social status of the parents (hypothesized to influence the offspring sex ratio in the original TWH), I enter the respondent's years of education and earnings in dollars in the previous year. In addition, I control for the respondent's race (1 = black, 0 = otherwise) and sex (1 = male). The two status variables have the expected positive effects on the likelihood that the first child is a son, but neither effect is statistically significant. Nor does the race and sex of the respondent have any significant effect on the sex of the first child.

Physical attractiveness is significantly correlated with sexual activity. Better-looking women and especially men start having sex at younger age and have larger numbers of

sex partners (Gangestad and Simpson, 2000). In the Add Health data, physical attractiveness correlates with the age at which the respondent had sex for the first time ($r = -0.0231$, $p < 0.05$, $n = 7907$ among women; $r = -0.0442$, $p < 0.001$, $n = 7041$ among men) and the number of sex partners that the respondent has had in the last 12 months ($r = 0.0054$, *ns*, $n = 7874$ among women; $r = 0.0451$, $p < 0.001$, $n = 6997$ among men). However, controlling for these 2 measures of sexual activities as potential confounds of physical attractiveness does not alter the conclusion at all. As Table 1, Column (3), shows, "very attractive" respondents are still about 26% less likely to have a son as the first child, even after controlling for the respondent's education, income, race, sex, age at first sex, and the number of sex partners in the last 12 months.

3.4.3. Evolutionary consequences of the current hypothesis

If beautiful parents have more daughters, as the current application of the gTWH suggests and the analysis of the

Add Health data demonstrates (Fig. 1 and Table 1), and *if* physical attractiveness is heritable, then it logically follows that, over many generations throughout the evolutionary history, women on average should gradually become more physically attractive than men.

Fig. 2 compares the distributions of physical attractiveness among men and women. The comparison of the top and bottom panels of Fig. 2 shows that there are relatively fewer "about average" women (40.5% vs. 51.8%) , and more "attractive" (38.0% vs. 33.7%) and "very attractive" (14.2% vs. 7.9%) women than men. The distribution of physical attractiveness is statistically significantly different by sex ($\chi^2_{(\text{df}=4)} = 280.85$, $p < 0.0001$).

When I compare the mean physical attractiveness of men and women on the five-point ordinal scale (essentially treating the ordinal scale as interval), women have a significantly higher average level of physical attractiveness than men (3.6 vs. 3.4, $t = 11.25$, $p < 0.0001$). It therefore
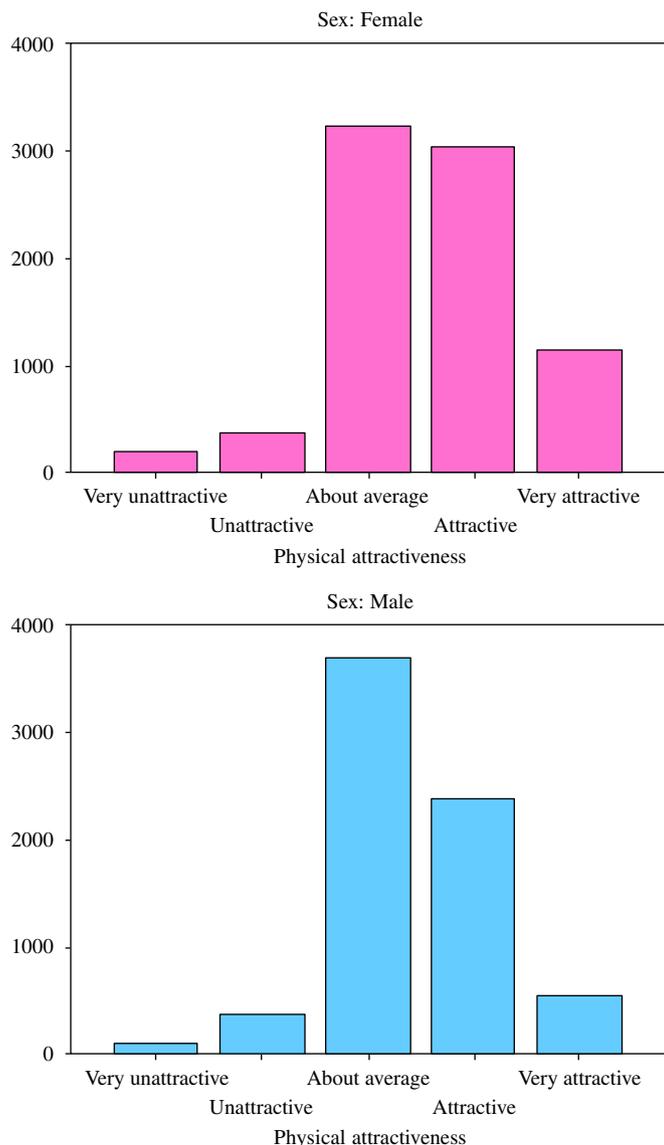
appears that, consistent with the logical implication of the current application of the gTWH, women appear to be significantly more physically attractive than men in this representative sample of American adolescents.

4. Discussion

The analysis of the Longitudinal Study of Adolescent Health (Add Health), the only large representative survey data which contains an objective (i.e. not self-reported) measure of physical attractiveness, suggests that "very attractive" respondents are significantly less likely to have a son for their first child than everyone else. While the proportion of sons among the first children for Add Health respondents not rated "very attractive" is 0.5160, not significantly different from the population mean of 0.5122, the same proportion among the respondents rated "very attractive" is 0.4397. Very attractive Add Health respondents are significantly less likely to have a son than everyone else. Multiple binary logistic regression analysis further shows that these respondents are about 26% less likely to have a son, even when controlling for the respondent's education, income, race, sex, age at first sex, and the number of sex partners in the last 12 months. The Add Health data also show that women on average are significantly more attractive than men.

The logic of the generalized Trivers–Willard hypothesis (gTWH) provides one potential explanation for the significantly lower offspring sex ratio among physically attractive respondents and the significantly higher levels of physical attractiveness among women than men. The gTWH posits that parents with any heritable traits which increases the reproductive success of female offspring much more than that of male offspring have a lower-than-expected number of sons and a higher-than-expected number of daughters. Physical attractiveness is one highly heritable trait, which disproportionately increases the reproductive success of daughters much more than that of sons. Men in all cultures prefer physically attractive women for both long- and short-term mating, whereas women prefer physically attractive men mostly for short-term mating (Buss, 1989; Gangestad and Simpson, 2000; Li and Kenrick, 2006). If physically more attractive parents have more daughters, and if physical attractiveness is heritable, then it logically follows that women over many generations throughout evolutionary history gradually become more physically attractive on average than men.

One puzzle which remains unresolved in the current analysis is why physical attractiveness does not have a linear (or monotonic) negative effect on the likelihood of having a son. As Fig. 1 shows, the proportion of sons among first children is about the same for four lower categories of physical attractiveness. It is only the respondents rated "very attractive" who have a significantly less chance of having a son. Why there is a seeming *qualitative* difference between "very attractive" respon-

Fig. 2. Distribution of physical attractiveness by sex.

dents and merely "attractive" respondents is not at all clear.

Together with the earlier studies, which suggest that parents' brain types biases the offspring sex ratios (Kanazawa and Vandermassen, 2005), that taller and bigger parents have more sons (Kanazawa, 2005), violent men have more sons (Kanazawa, 2006), and mothers with a language impairment have more sons (Tallal et al., 1989), the current study provides further support for the gTWH. However, more research is necessary to investigate the empirical status of gTWH before firmly establishing it as a biological principle. On the other hand, given how completely different the current environment of contemporary American society is compared to the ancestral environment, to which our entire body is adapted, it is nonetheless remarkable that *any* effect is detectable in the contemporary American data, and the uncovered effect of physical attractiveness in the present analysis is relatively large.

Acknowledgments

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