Research Article

Sex Differences in Intellectual Performance

Analysis of a Large Cohort of Competitive Chess Players

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ABSTRACT—*Only 1% of the world's chess grandmasters are women. This underrepresentation is unlikely to be caused by discrimination, because chess ratings objectively reflect competitive results. Using data on the ratings of more than 250,000 tournament players over 13 years, we investigated several potential explanations for the male domination of elite chess. We found that (a) the ratings of men are higher on average than those of women, but no more variable; (b) matched boys and girls improve and drop out at equal rates, but boys begin chess competition in greater numbers and at higher performance levels than girls; and (c) in locales where at least 50% of the new young players are girls, their initial ratings are not lower than those of boys. We conclude that the greater number of men at the highest levels in chess can be explained by the greater number of boys who enter chess at the lowest levels.*

The game of chess has been studied by computer scientists and cognitive psychologists as a model arena of human intellectual performance. Research on computer chess has culminated in programs that can defeat the best human players (e.g., Hsu, 2002), and research on chess masters has yielded seminal discoveries, such as the chunk structure of short-term memory (Chase & Simon, 1973), and has contributed to debates on the importance of pattern recognition and deliberate thought in expertise (Burns, 2004; Chabris & Hearst, 2003; Gobet & Simon, 1996). But one of the most striking facts about chess competition has received little study: the dramatic lack of women among the game's elite performers. None of the official world champions has been a woman, no champion of a major country is a woman, and as of January 2004, only 9 of the world's 894 chess grandmasters—1%—were women (according to data in Howard, 2005).

Analyzing possible explanations for the underrepresentation of women among the chess elite may help explain the underrepresentation of women at the highest levels in other fields, such as tenured professorships in mathematics, science, and engineering. It has been suggested (e.g., Pinker, 2005; Summers, 2005) that differences between men and women in the distribution of cognitive abilities required for success in these fields can partly account for the disparity (the *ability-distribution hypothesis*). In particular, men and women may differ in mean performance levels, variability of performance, or both; evidence suggests that in cognitive abilities, both types of differences are found (Halpern, 2000; Hedges & Nowell, 1995).

However, the possibility of "old boys networks" of men who function as gatekeepers to high positions in these fields, coupled with the subjective nature of assessing achievement, makes it difficult to distinguish between an objective lack of achievement or credentials and discrimination by the existing social system as causes. In chess, there are neither gatekeepers nor subjective assessments; in particular, the rating system invented by Elo (1986) objectively measures individual skill solely on the basis of results of tournament games. The U.S. Chess Federation (USCF) applies this system to rate tens of thousands of players who participate in events that are open to all. Therefore, the overrepresentation of men at the highest levels in chess is, at first glance, more consistent with an ability-distribution hypothesis than with a social-system account. (Note that a difference in mean, variance, or both could explain the observed differences at the upper tail of the distribution.)

However, other explanations are possible. One is that men and women may have differential dropout rates over time. Men and women may start out with equal endowments of the abilities

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necessary for an endeavor, but women may be less likely than men to study and practice intensively or to devote obsessive amounts of time to it (the *differential-dropout hypothesis*). Indeed, some people argue that it is precisely the amount of deliberate practice that predicts success in fields like chess (Ericsson, Krampe, & Tesch-Römer, 1993). Thus, perhaps more potential female than male grandmasters leave organized competition, resulting in an imbalance at the top levels.

Anyone who visits an open chess tournament will be struck less by the lack of women at the top of the results table than by their near absence at all levels. Only 9.7% of all USCF-rated games in 2004 were played by women. It is possible that the lack of women at the top is an artifact of their lower overall participation rate (Charness & Gerchak, 1996): Even if men and women have the same underlying ability distribution, a larger number of top-rated players will be men if the overall number of men competing is greater (the *participation-rate hypothesis*). That is, if fewer women than men even begin to participate in organized competition, dropout rates (and cognitive endowments) could be equal, but women would still be relatively absent at the top.

In the present study, we asked whether these three hypotheses explain the enormous imbalance between men and women among the best chess players. Previous research on sex differences in chess performance (Charness & Gerchak, 1996; Howard, 2005) has considered only players at the top end of the rating spectrum. In this study, we analyzed the annual ratings of nearly all of the chess players who participated in USCF-rated games over 13 years, from 1992 through 2004. This is the broadest and largest sample of chess performance data ever analyzed, and one of the best data sets on sex differences in intellectual performance in any domain.

GENERAL METHOD

The data for our study included rating information on all USCF members who were active between 1992 and 2004 and had both birth date and sex recorded in the USCF database, a total population of 256,741 tournament players. Table 1 shows the sex distribution by players' ages; 10.6% of the sample was female.

For each player, we recorded birth date, sex, most recent ZIP code (if available), and year-end rating on each annual rating list from 1992 through 2004. A rating appears on the annual list only if the player played at least one rated game that year. For the years of our study, most players had some missing rating information because either they were inactive during 1 or more years or they started playing in USCF tournaments after 1992. We also recorded the number of tournament games played per year by each player, and whether the rating was "provisional" or "established." Provisional ratings are based on fewer games than established ratings, and are generally less reliable measures of playing strength. Once a player's rating becomes established, it remains established.

TABLE 1

Percentage of Females Within 10-Year Age Groups and Distribution of Ages in the Study Population

Age (years)	Percentage female	Percentage of study population
5–15	17.0	26.4
15+–25	11.9	43.5
25+–35	4.9	11.5
35+–45	2.2	6.4
45+–55	2.0	6.8
55+–65	2.2	3.3
65+–75	2.0	1.3
75+–85	2.1	0.7
85+–95	2.5	0.1

A player's USCF rating is an estimate of his or her current playing strength on a scale that ranges generally from 100 to 3000; higher ratings are associated with better playing ability. The principles underlying the rating computations are explained by Elo (1986) and Glickman (1995).[1] Average tournament players are usually rated between 1400 and 1600, chess masters are rated above 2200, and world-class players tend to be rated above 2500. USCF ratings are essentially estimates of merit parameters from Bradley and Terry's (1952) model for paired comparisons, calculated using an approximately Bayesian filtering algorithm to update ratings over time (Glickman, 1999). Although ratings are only estimates of unknown parameters and are therefore subject to variability, they can be treated as data in statistical modeling, recognizing that the extra uncertainty may lead to conservative inferences.

CROSS-SECTIONAL ANALYSES OF SEX DIFFERENCES

We began by asking whether male and female tournament competitors differ in mean chess ability, whether any such difference depends on age, and whether observed differences persisted over time. We calculated the mean difference between males' and females' ratings for each year of the study, restricting the sample to players with established ratings who played at least one rated game in the given year (see Fig. 1, left panel).

On average, mean ratings were higher for males by 450 to 500 points, a very large difference: The expected outcome of a game between opponents having this rating difference is between .93 and .95 (counting a win by the higher-rated player as 1, a loss by this player as 0, and a draw as 0.5). We adjusted these simple sex differences by incorporating covariates in linear regression models. For rating lists from 1995 through 2004, we examined the subsample of players with established ratings in the given year and modeled current rating as a function of sex, current age, number of games played in the current year, and number of

[1]For complete details of the USCF rating system, see www.uschess.org.

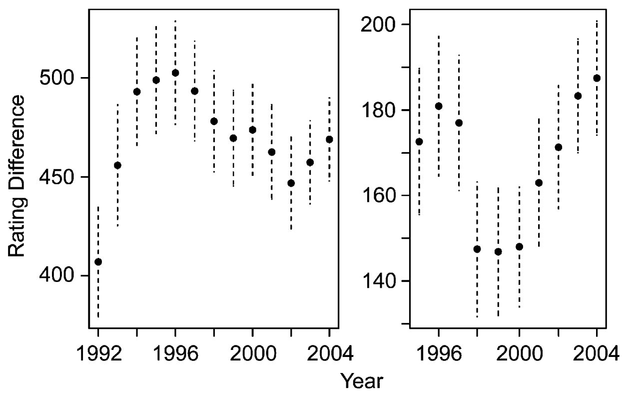

Fig. 1. Sex differences in chess ratings (male minus female) as a function of year, with 95% confidence intervals. The graph on the left shows mean rating differences, and the graph on the right shows regression-adjusted estimates of those differences.

games played in the previous 3 years. Prior to model fitting, the latter three explanatory variables were categorized into groups because we did not want to assume a priori that they related to ratings via a simple parametric function (Charness, Krampe, & Mayr, 1996; Elo, 1986). The break points for the three numerical predictor variables were chosen by fitting regression trees (Breiman, Friedman, Olshen, & Stone, 1984) to the 2004 data, regressing current rating on each variable separately. This procedure resulted in the following categories:

- Age (years): < 12.8, 12.8+–17.5, 17.5+–19.5, ≥ 19.5
- Number of games in current year: 0–9, 10–50, ≥ 51
- Number of games in prior 3 years: 0–74, 75–151, ≥ 151

The choice of these break points was supported by similar analyses of data from the earlier years.

A regression of current rating on sex, adjusted by the full interaction of the three other predictor variables, resulted in the average adjusted sex differences shown in the right panel of Figure 1. Although accounting for current and past frequency of play (both of which were related positively to rating) and age decreased the sex difference by a factor of about 3, the mean difference each year was still a highly significant 150 to 200 points (corresponding to an expected game outcome of .70–.76). Similar analyses using alternative break points, or keeping the variables untransformed, yielded similar results.

We also examined sex differences for the model in which sex and the three other variables fully interacted. Fitting this model is analogous to examining sex differences in rating separately within strata formed by all combinations of the categorized variables (age, number of games in the current year, and number of games in the prior 3 years). We performed this analysis separately for each year from 1995 to 2004. In strata with more than 25 females, males always had higher ratings (and significantly so, with very few exceptions). Although the mean difference dropped as low as 62.8 (in 2002, for 12.8- to 17.5-year-old players who played the fewest games in the current year and prior years), there was no clear pattern to the effect of age and playing frequency on sex differences.

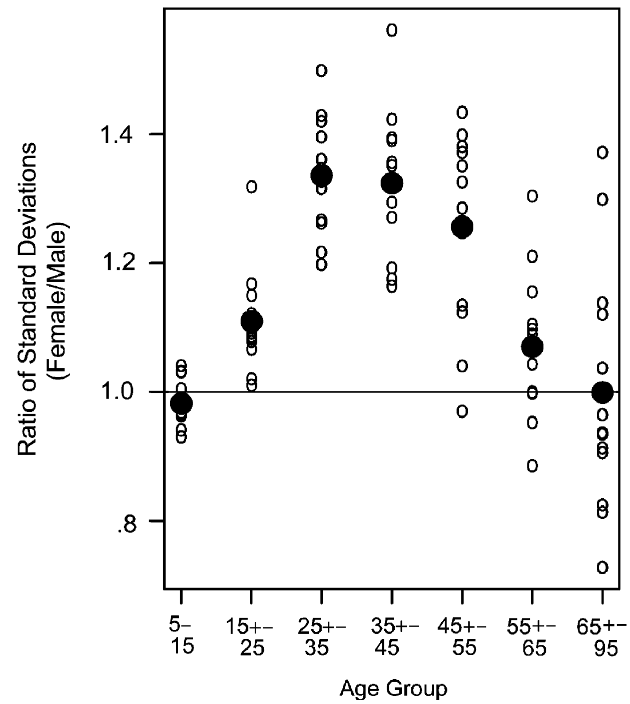

Fig. 2. Ratios of female:male standard deviations in chess ratings among chess players with established ratings in 1992 through 2004. Results are shown as a function of age group. Each open circle represents the ratio for the indicated age group in 1 year, and the solid circles are the mean ratios across the 13 years.

SEX DIFFERENCES IN RATING VARIATION

Regardless of any difference in mean ratings, the disproportionate number of men at the top in chess could result from their abilities being more variable than women's in the general population. This larger male variation would also imply a larger proportion of men at the bottom of the ratings. Greater male variation in ability has been observed in data on cognitive test scores (Hedges & Nowell, 1995), and it has been offered to explain the high male:female faculty ratios in academic disciplines (e.g., Pinker, 2005; Summers, 2005). Because only individuals in the upper tail of the distribution of chess players self-select to compete in tournaments, this hypothesis would not necessarily predict that the lowest rated players are male (because the lower tail is truncated as a result of self-selection), but the rating variation should still be larger for men than for women (because the upper tail would be occupied disproportionately by males).

To examine this hypothesis, we computed the standard deviation of ratings for males and females, stratified by the age groupings used in Table 1 (collapsing ages 65–95 into one group), for each year in our data. The standard deviations by gender-age-year strata ranged from about 250 to 500. Figure 2

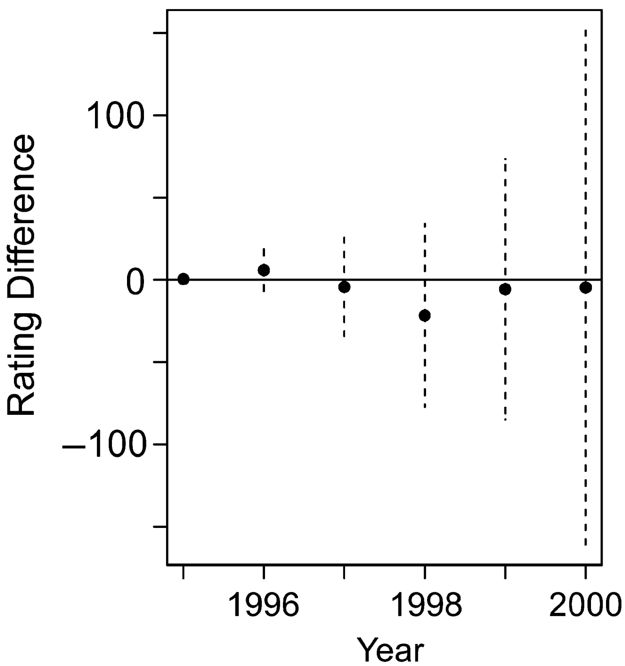

Fig. 3. Sex differences in chess ratings (male minus female) in the matched-pairs analysis. Results are graphed as a function of year; 95% confidence intervals are shown. (The wider confidence intervals for later years reflect the attrition of male-female pairs due to players becoming inactive.)

displays the female:male ratios of standard deviations. Generally, and most particularly for players between 25 and 55, the ratios were greater than 1, meaning that rating variation was typically larger for females than for males. Only in the extreme age groups were the ratios close to 1. The data clearly do not support greater male variation in ratings.

SEX DIFFERENCES IN LONGITUDINAL RATING CHANGES

The consistently higher mean male rating, with no clear sex difference in variability, could be explained by girls beginning on an equal footing with boys, but improving more slowly or dropping out in greater numbers, so that those women who remain in the rating system have a lower mean rating than the men. To test this hypothesis, we performed a case-control study by creating a subsample of our data set in which each female was initially matched as closely as possible to a male, and then following these pairs over time. This analysis focused on players who were 5 to 25 years old in 1995 and who had established ratings. Younger players were used for this analysis because we wanted to examine a group who were recent entrants to tournament chess. For each player, we recorded four variables: 1995 year-end rating, age, number of games played in 1995, and number of games played in the previous 3 years. We formed male-female pairs via caliper matching (Cochran & Rubin, 1973) on these four variables, using a common caliper size of 0.15. That is, within each pair, the male and female values on each variable differed by no more than 0.15 standard deviations of the overall distribution of that variable. This process resulted in 647 matched pairs, which we tracked for 10 years. Figure 3 shows the mean rating difference, with 95% confidence interval, for each year with 10 or more pairs; the difference does not deviate significantly from 0. Similar analyses with different starting years, smaller calipers, and different age ranges yielded the same conclusions.

On the basis of research on cognitive sex differences (reviewed by Kimura, 1999), one might suggest that males should overtake females in chess performance only around puberty. That is, if chess skill relies in part on visual-spatial ability (Frydman & Lynn, 1992; Robbins et al., 1996; but see Waters, Gobet, & Leyden, 2002), and if this ability is influenced by testosterone, then males might benefit from the increase in androgens during the early teen years. Sex differences in spatial-task performance have been observed at ages well before puberty (e.g., before age 5 by Levine, Huttenlocher, Taylor, & Langrock, 1999; at ages 8–9 by Levine, Vasilyeva, Lourenco, Newcombe, & Huttenlocher, 2005), but the magnitude of the male advantage tends to increase during the teenage years (see Table 4 of Voyer, Voyer, & Bryden, 1995). If this phenomenon applied to chess performance, it would appear in the rating comparison of early-teenage males and females who had similar preteen ratings. We investigated this possibility in our matched-pairs sample by examining the within-pair rating difference at the end of 1998 as a function of the players' ages in 1995. These differences were evenly distributed around 0, suggesting that males on average were not overtaking females during the early teen years. Analyzing data from other years yielded the same conclusion.

Interestingly, the males and females in our matched-pairs group had remarkably similar attrition rates. The percentage of females among the active players in this sample in any given year was no less than 47.7% (in 1996) and no higher than 55.1% (in 2004). Not surprisingly, however, attrition in the larger group from which our matched sample was drawn was greater among females than among males. On average, females in this group continued playing beyond 1995 for 1.74 years until becoming inactive, whereas males continued for 1.95 years ($p < .0001$). These figures are consistent with the disproportionately fewer women in the older age groups (Table 1). The greater attrition of females than males in the larger group could result simply from lower-rated players, regardless of sex, tending to become inactive more quickly than higher-rated players because they lose interest, become discouraged, and so forth. In fact, this hypothesis is supported by our data. Using the group of players from which we drew our matched-pairs sample, we performed a Poisson regression of the number of years until a player first becomes inactive on 1995 rating, age group (using the categories determined by the regression-tree analysis), and sex. Both 1995 rating and age group were highly significant (lower rating and older ages predicted attrition), but sex was not ($p = .54$, likelihood ratio test).

Thus, although in general men have a higher average rating than women, matched samples of boys and girls are equally likely to drop out, and improve their ratings at the same rate, without diverging at puberty. The tendency for women to drop out more frequently than males overall appears to be related to age and playing strength, but not sex.

SEX DIFFERENCES IN INITIAL RATINGS OF NEW TOURNAMENT PLAYERS

If males have higher mean ratings, but there are no sex differences in rating change over time, then males must start out in tournaments with higher ratings than females. To confirm that this is the case, we examined for each year from 1998 through 2004 the set of players of ages 6 through 12 who had established ratings at year end and who did not have a rating in any year before the previous one. We excluded older players because they could have been playing chess frequently before beginning tournaments. We chose to restrict our analysis to 1998 and later because it was difficult to determine whether a player had competed in tournaments previously (specifically, prior to the start of our cohort in 1992). On average, the sex difference in ratings for these groups was 110 to 200 points in favor of the males, and was always highly significant ($p \ll .0001$). Linearly adjusting for age (which had an effect of 20 to 45 rating points per year for this age group) did not change the significance or magnitude of the sex difference.

Finally, we addressed the participation-rate hypothesis. If in the general population the number of boys who play chess is substantially larger than the number of girls, the best ones ultimately becoming USCF members and playing competitively, then it follows statistically that the average boys' ratings will be higher than the average girls' ratings (among competitive players) even if the distribution of abilities in the general population is the same (Charness & Gerchak, 1996; Glickman & Chabris, 1996). In fact, far fewer girls than boys enter competitive chess, which suggests that the general population of chess-playing girls is much smaller than that of boys. External factors like the relative lack of female role models among the world's top players and the prospect of playing a game dominated by boys may be discouraging to girls (or their parents), either directly reducing their likelihood of learning how to play in the first place or indirectly reducing their initial performance in competitive play via test anxiety or stereotype threat (Steele, 1997). Thus, it is possible that, on average, girls have the chess-relevant cognitive abilities, but the larger number of boys playing chess leads to significantly higher male ratings in the USCF population.

To test this possibility, we examined the relationship between the sex difference in initial ratings and the female participation rate separately for geographic locales with varying female participation rates. We assumed that in places where girls play competitive chess as commonly as boys, the social factors ordinarily discouraging girls from playing chess may be minimal. The participation-rate hypothesis predicts that if this is true, there will be no difference between boys' and girls' ratings (in such places).

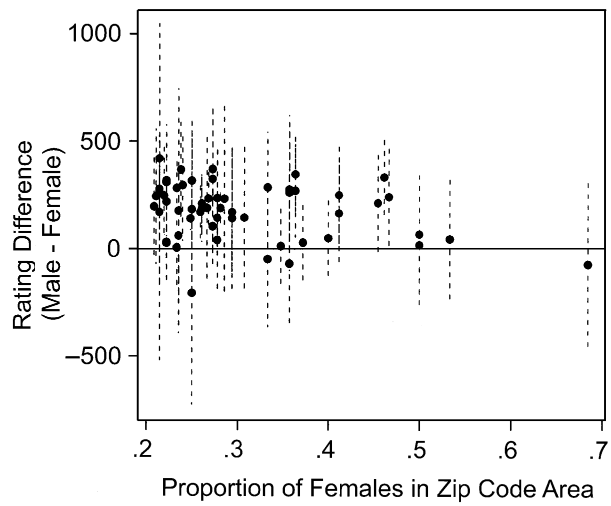

Fig. 4. Mean sex difference in chess ratings (male minus female) for young established players in 2002 through 2004, as a function of the proportion of female chess players in the ZIP-code area, with 95% confidence intervals.

We examined a subsample of the players who were between 6 and 12 years old, who had an established rating at year end, and who did not have a rating in any year before the previous one. We included only players for whom we had 2004 ZIP-code information, and excluded years prior to 2002 because the 2004 ZIP codes became less reliable indicators of place of residence as we moved further back in time. For the 3 years analyzed, we measured sex differences in rating within ZIP code (excluding ZIP codes with fewer than 10 players).[2] Figure 4 shows the mean rating difference as a function of the proportion of females in the sample in the ZIP-code area (truncated at .2 from below).

Boys generally had higher ratings than girls, particularly in the male-dominated ZIP codes. However, in the four ZIP codes with at least 50% girls (areas in Oakland, CA; Bakersfield, CA; Lexington, KY; and Pierre, SD), boys did not have higher ratings. In Oakland, with the greatest proportion (68%) of girls in the sample, the average rating of girls was higher than that of boys, though not significantly so. Combining all ZIP-code areas where the proportion of girls was at least 50%, the sex difference was only 35.2 points in favor of males, which was not significant ($p = .59$). The same result was obtained in an age-adjusted analysis, which yielded a sex difference of 40.8 points ($p = .53$).

[2]In other analyses not reported here, we grouped players by larger geographic regions (metropolitan statistical area, Federal Information Processing Standards code, and urban area code), but these groupings combined locales with high proportions of females with many locales with low proportions, leaving little variation in female proportion across the resulting regions.

The fairly constant mean male advantage until the 50% female participation rate was reached suggests a threshold effect: Factors limiting girls' performance levels may depend on their being in the minority, but not on the relative size of the male majority (in other words, 50% girls may constitute a "critical mass"). Further study of this effect is warranted, perhaps by searching for chess rating data from larger social-geographic regions, such as nations, across which the female participation rate varies; it would be especially instructive to examine cases (if any) in which competitive chess is significantly *more* popular among girls than boys.

DISCUSSION

This study analyzed 13 years of chess rating data to discover the reason for the vast overrepresentation of men among elite players, exemplified by the 99:1 male:female ratio of international grandmasters. We found that men were rated an average of 150 to 200 points higher than women on the Elo (1986) scale, even after controlling for age and frequency of play—a highly significant male advantage. A longitudinal analysis of matched male-female pairs showed that girls and boys of equal strength did not diverge in playing ability or likelihood of dropping out; instead, boys and girls entered competitive chess with different average ability levels, and this difference propagated throughout the rating pool. However, this initial difference was not found in locales where boys and girls entered the rating system in equal proportions. Taken together, our results support the hypothesis that there are far fewer women than men at the highest level in chess because fewer women enter competitive chess at the lowest level (a hypothesis consistent with men and women having equal chess-relevant cognitive abilities).

In a study consistent with our overall findings, Charness and Gerchak (1996) showed that the rating difference between the world's top male and female players in the mid-1990s (Gary Kasparov of Russia and Judit Polgar of Hungary) could be explained by men and women having equal means but different participation rates.[3] By contrast, Howard (2005) argued that social factors are unlikely to explain the sex difference observed among top international players, because the difference has persisted over the past 30 years despite presumed worldwide increases in opportunity and encouragement for women to enter competitive chess. However, Howard's argument does not take into account the vastly different numbers of men and women in even the current international rating lists; moreover, his own data show that since the international rating rules were changed so that the minimum rating was the same for men and women, the average male rating has drifted down toward the average female rating (while the gap between the top 100 men and top 100 women has remained constant).

We have shown that sex differences in participation rates in the population of rated chess players can explain the vast overrepresentation of men among the game's elite. This finding is somewhat surprising given the relative objectivity in how chess skill is measured and the lack of subjective judgment in determining competitive achievements. Thus, significant male-female differences can arise in elite performance even in the absence of gatekeeping mechanisms and advancement standards controlled or developed by men. Beyond the domain of competitive chess, our results show how male-female differences in factors other than cognitive abilities may account for sex differences in observed performance. Understanding the causes of these factors—in our case, why more boys than girls enter competitive chess—is a challenge in itself.

Acknowledgments—We thank Carole K. Hooven and Joel Reisman for helpful discussions, and we especially thank Michael Nolan of the U.S. Chess Federation for generously providing the data analyzed here.

[3]Note, however, that an analysis of extremes in a distribution is a very low-power method of inferring differences in the sample means (Glickman & Chabris, 1996). In the present study, we analyzed the entire distribution, rather than just the extreme performers.

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(RECEIVED 12/23/05; REVISION ACCEPTED 2/28/06; FINAL MATERIALS RECEIVED 3/6/06)