Why Are So Few Women in Math-Intensive Fields?

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Harvard University Math 55: Honors Advanced Calculus and Linear Algebra

“probably the most difficult undergraduate math class in the country.”

It is legendary among high school math prodigies, who hear terrifying stories about it in their computer camps and at the Math Olympiads. Some go to Harvard just to enroll in it. The year-long freshman course meets for three hours a week but, as the catalog says, homework takes between 24 and 60 hours each week.

“Math 55 does not look like America. Each year as many as 50 students sign up, but at least half drop out within a few weeks. As one former student told The *Crimson* in 2006, “We had 51 students the first day, 31 students the second day, 24 for the next four days, 23 for two more weeks, and then 21 for the rest of the first semester.” Said another student, ‘I guess you can say it’s an episode of *Survivor* with people voting themselves off.” The final class roster: 45 percent Jewish, 18 percent Asian, 100 percent male.” (Christine Hoff Sommers, 2008)

Why Are Women Underrepresented in Math-Intensive Fields?

I. Gender Ability Gap in Math and Spatial Reasoning?
   - Depends on where and when one looks

II. Gender-Related Differences in Interests?
   - Values, family issues, work life

III. Gender Biases and Sex Discrimination?
   - Proximal factors, sexism

IV. Five Unwarranted Assumptions

V. Interventions

VI. Conclusions

It’s Not All Bleak: NSF Survey of Earned Doctorates (2007)

- 2006 was the 5th year in a row in which the majority of research Ph.D.s awarded to U.S. citizens went to women.
- Women earn more Ph.D.s than men in the humanities, social sciences, education, and life sciences.

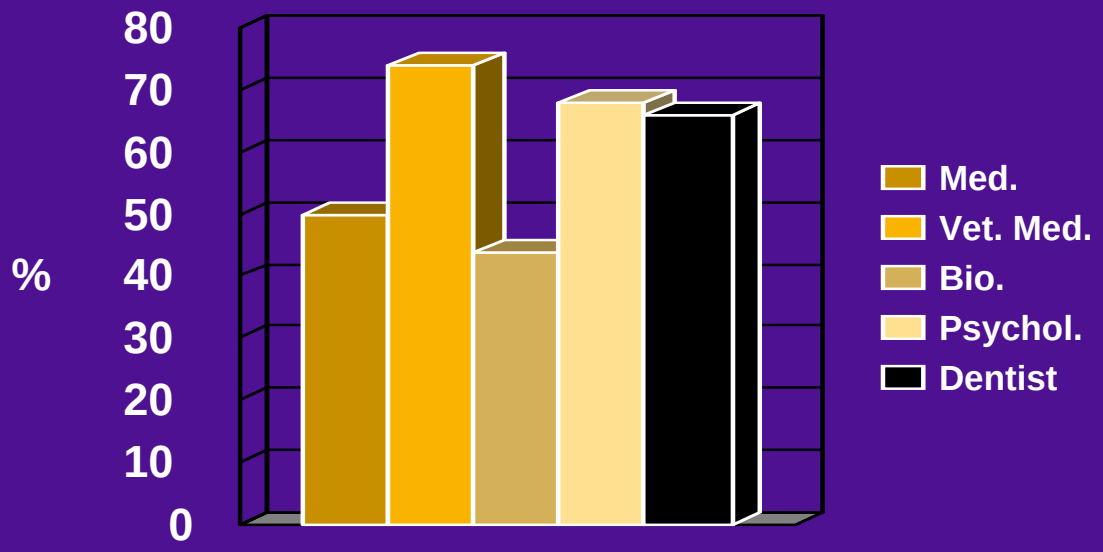
Growth in Female Ph.D.s in Science, Technology, Engineering & Math (STEM)

1966 - 8%

2001 - 36.6%

Growth disproportionately in Social Sciences and Biomedical Sciences

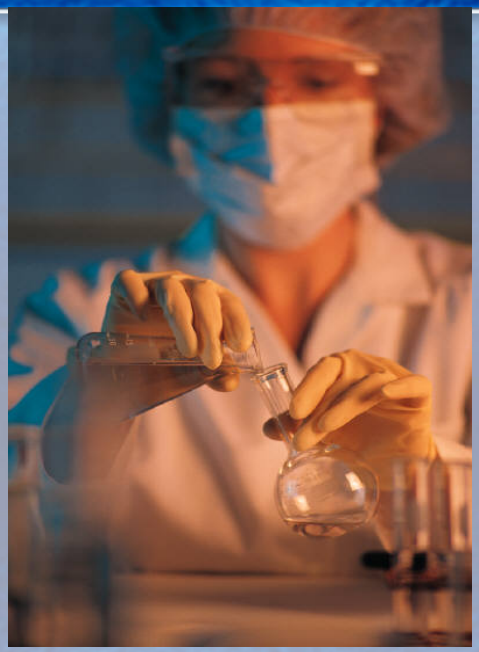
Women Now Dominate New Doctorates in Some STEM Fields



5-to10-Fold Increases Since Early 1970s

- Medicine
- Biological Sciences
- Psychology
- Dentistry
- Veterinary Medicine

Women Ph.D.s in Biology



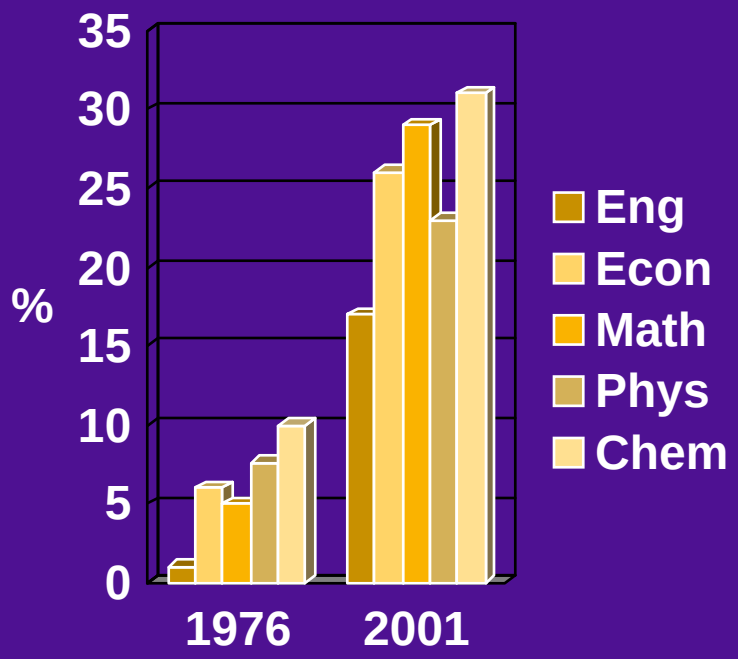
1976 - 8%

2006 - 48%

Women MDs/DMDs

- 50% MD recipients
- 74% of DVM recipients
- 76% of current vet students

Growth in Female Ph.D.s in Math-Intensive Fields

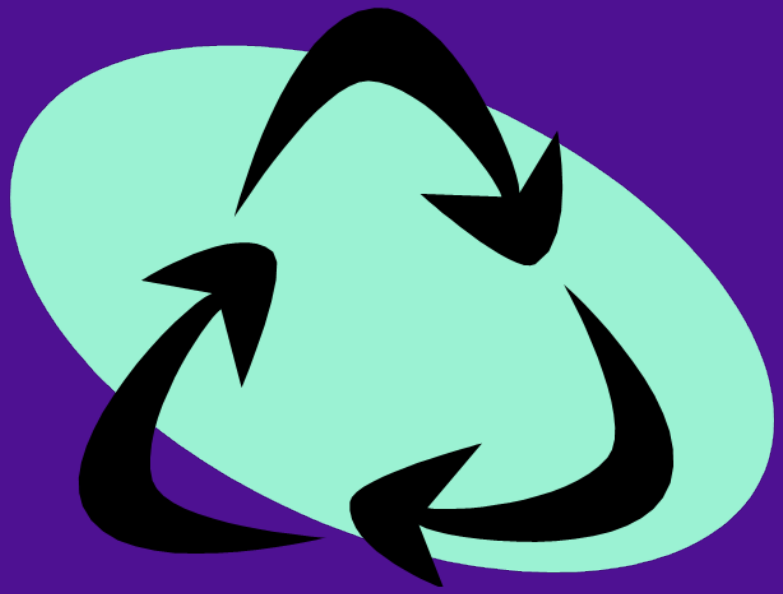


- Despite impressive growth in Ph.D.s, (women have tripled or quadrupled their representation in 25 years), women are still only 17%-31% of new doctorates.

Representation of women among tenure-track faculty in elite universities in physical science, mathematics, and engineering (Halpern et al. 2007)

Mathematics:	**8.3%**
Chemistry:	**12.1%**
Chemical Engineering	**10.5%**
Physics:	**6.6%**
Mechanical Engineering	**6.7%**
Electrical Engineering:	**6.5%**
Civil Engineering:	**9.8%**
Computer Science:	**10.6%**
Astronomy:	**12.6%**

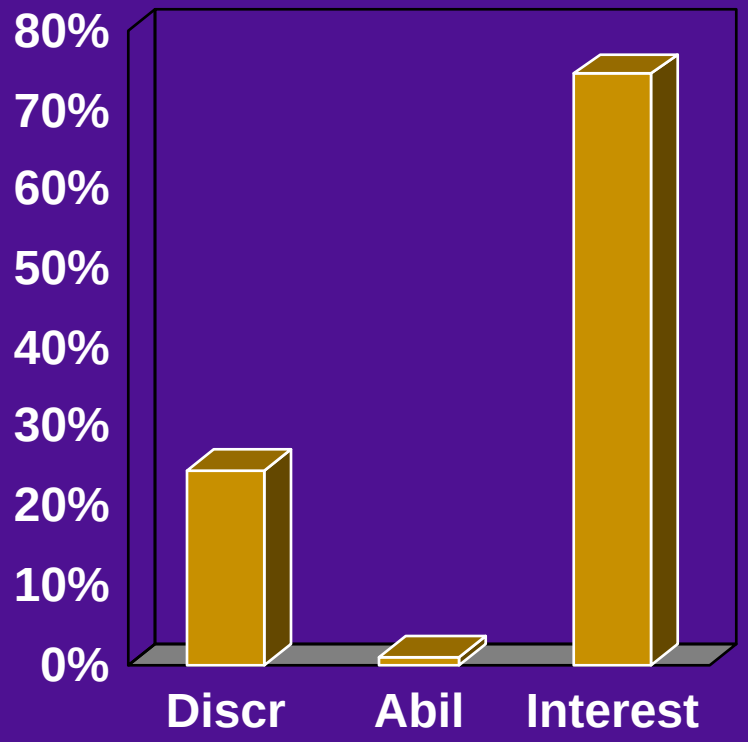
What Explains Women's Underrepresentation? Three Alleged Classes of Factors



I. Interests
II. Abilities
III. Biases

Ability vs. Interests vs. Bias

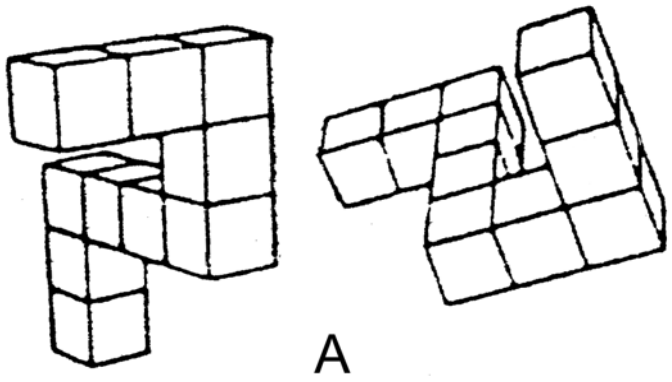
Gross & Simmons (2007) surveyed 1,414 full-time professors. Only 1 % support differences of ability hypothesis. And only 25% blame discrimination, with the rest citing sex differences in interests. (Women are twice as likely to blame discrimination as men-- 33.8 % vs. 17.1 %.)



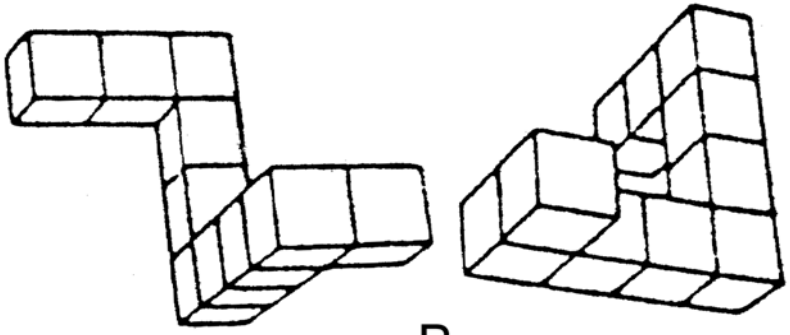
I. Abilities

Do Ability Differences Explain the Gender Gap?

- What is known about Math ability at the extreme right tail?
- What is known about spatial ability?



A



B

Hyde (2005)

- synthesized 128 effect sizes from 47 published metaanalyses
- somewhat large effects for mental rotation and mechanical reasoning favoring males (*d*'s between 0.56 and .76)

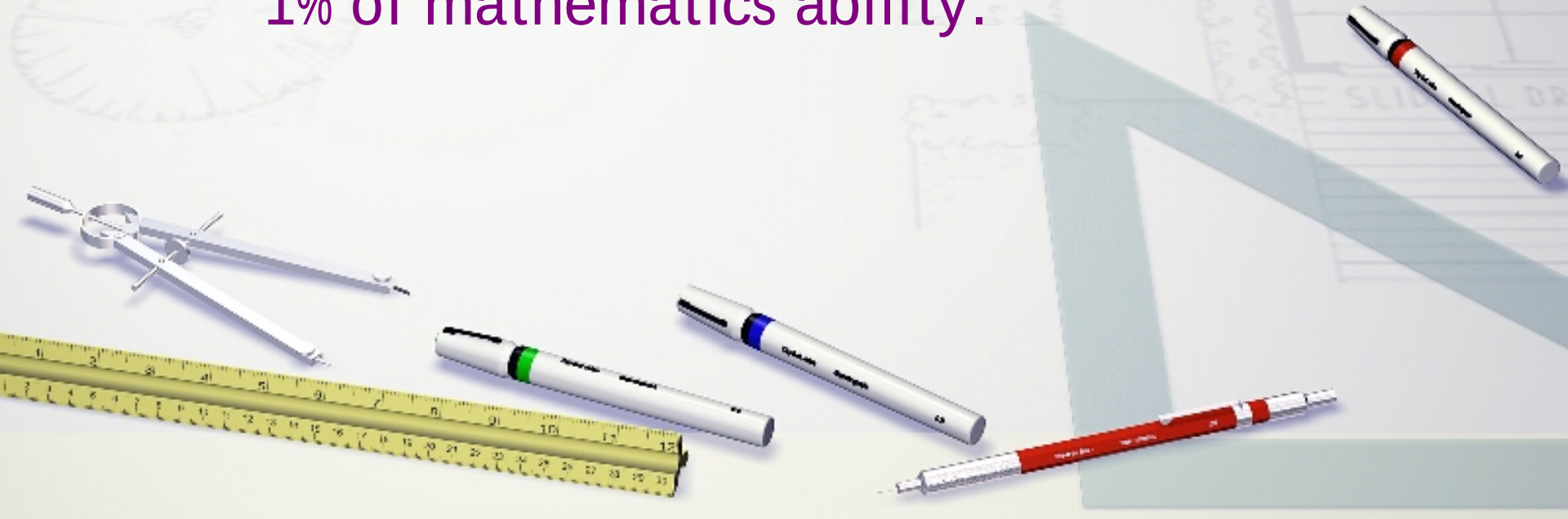
Mixed Evidence for Spatial Differences Among Preschoolers

Casey and her colleagues have provided evidence of sex differences in 3-D mental rotation among kindergarteners (Casey, Andrews, Schindler, Kersh, & Samper, 2008).

Lubinski & Benbow's 30-Yr. Program

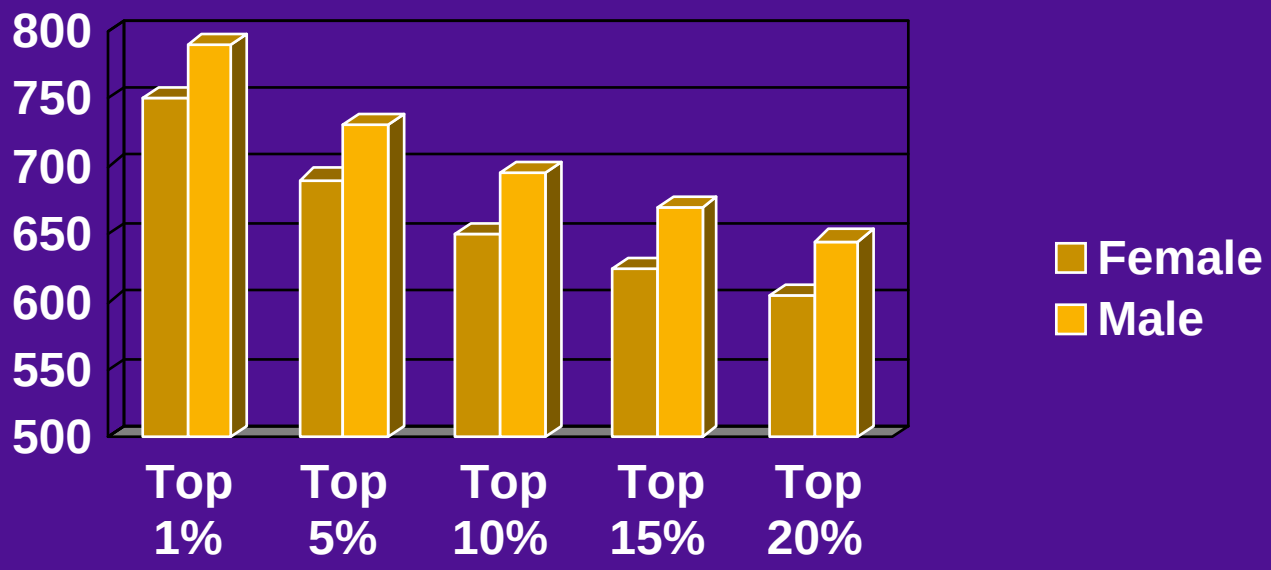
- SMPY longitudinal studies
- Studies of spatial ability

Web, Lubinski, and Benbow (2007) have shown that more than half of the top 1% of spatially gifted students are not identified when screening is conditioned on the top 1% of mathematics ability.



Casey, Nuttal, & Pezaris, 1997 (see also Casey, Nuttal & Pezaris, 2001) using the top third of the college-bound sample, found that the gender-SAT-Math relationship was explained roughly two-thirds by mental rotation ability and one-third by mathematics self-confidence, suggesting both are highly important.

SAT-M Percentile Ranks for College Bound Seniors, 2006



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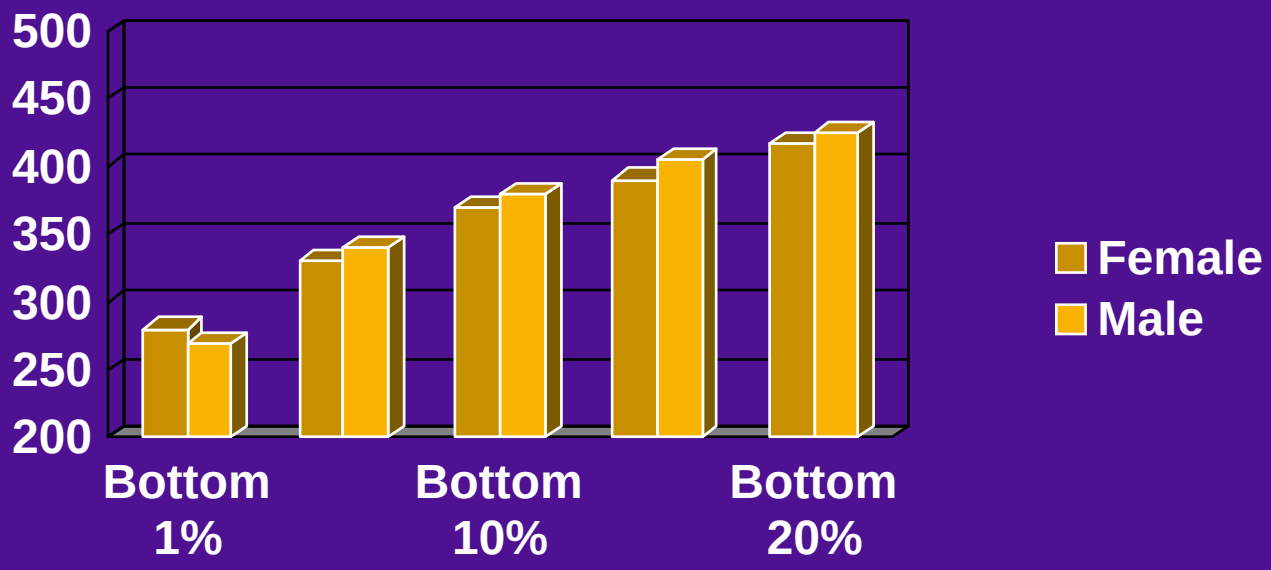
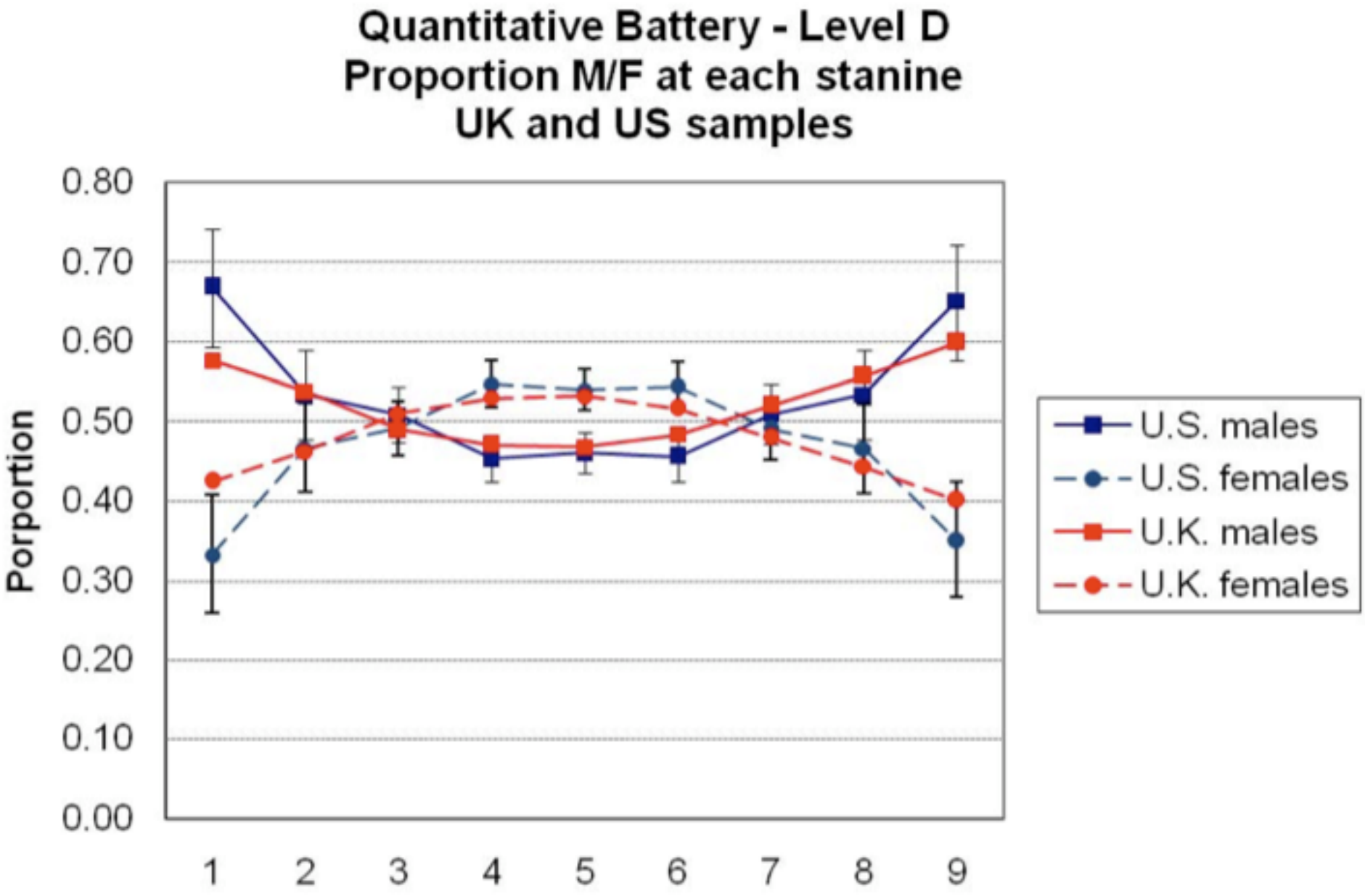



Quantitative Battery - Level D
Proportion M/F at each stanine
UK and US samples
Porportion
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
1
2
3
4
5
6
7
8
9
U.S. males
U.S. females
U.K. males
U.K. females

Environmental Effects on Ability

- Correlation between replicating Lego structure and MR
- Computer videogame experience (Quaiser-Pohl, Geiser, & Lehmann, 2006; Terlecki & Newcombe, 2005) is related to differences in mathematical and spatial abilities

Sex differences in ability depend on *where* one looks. Findings show male overrepresentation but very large trans-national variability

- Physical Science
- Engineering
- Mathematics
- Computer Science
- Chemistry

TIMSS Data

- Netherlands *d* = .63
- Denmark *d* = .62
- Norway *d* = .60
- Israel *d* = .25
- U. S. *d* = .13
- Hungary *d* = .05

Odds Ratio of Being Female at Right and Left Tails

	TOP 10%	BOTTOM 10%
Netherlands	.34	6.25
Canada	.29	2.16
Sweden	.22	1.69
Denmark	.25	3.27
Norway	.22	2.65
Israel	.63	1.35
U. S.	.58	.95
Hungary	.54	.74

Large Transnational Variability

- Magnitude of *d's* is constant across the distribution for 11 countries, favoring males
- In several countries *d*'s are greater at left tail (Lithuania, Netherlands)
- In several countries *d*'s are greater at right tail (Sweden)
- In some countries girls do as well as or better than boys at the left tail but worse at the right tail (U.S., Hungary)
- In some countries sex differences are most pronounced in the middle of the distribution (Russia, Austria)

Transnational Variability (cont.)

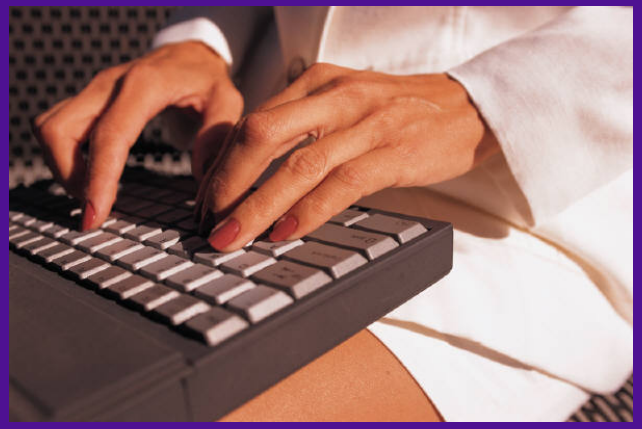
- National samples of 9-year-olds found the *d's* for sex differences in mathematics ranged from -0.06 in Ireland (female superiority) to +0.28 in Korea
- Icelandic high school girls outperform boys on spatially-loaded subtests

Inconsistent Sex Differences, Despite General Pattern of Increases of Male Advantage with Age

- In Korea, the effect size decreases with age
- In Ireland and Spain it increases with age

Overrepresentations of Males Among Computer Science Graduates

- Turkey 1.76
- Czech Republic 6.42 (3.59 times more)
- United States 2.10



II. Does Bias Explain the Underrepresentation of Women in Math-Intensive Careers?

Major Evidence of Dsicrimination

- Wenneras & Wold (1997)
- M.I.T. study
- Steinpress et al. (1999)

Wenneras, C. & Wold, A. (1997): "Nepotism and sexism in peer-review". *Nature, 387*, 341-343.

Scores given by reviewers were compared with objective data (e.g., total publications, first-authored articles, citations). The authors found that the translation of objective data into subjective scores was highly biased against women.

Wenneras & Wold analyzed 114 applications for postdoctoral fellowships in biomedical sciences

62 submitted by men; 52 by women

16 men were funded (25.8%) and 4 women (7.7%)

Wenneras & Wold reported that the most productive female applicants--those with 100 impact points or more (measure of number of publications adjusted for citation frequency)--was the only group judged as competent as men, although only as competent as the least productive male applicants who had fewer than 20 total impact points.

“a female applicant had to be 2.5 times more productive than the average male applicant to receive the same competence score” (Wenneras & Wold,1997, p. 342).

Counterevidence

- RAND (2005) analysis
- Marsh et al. (2003, 2006, 2008)
- Wenneras & Wold's data lost
- Leboy (2007)
- Ginther & Kahn (2006, forthcoming)

Marsh et al. (2008)

- 15.3% of the applicants for grants were female, their success rate was 15.2%.
- When gender of only the first-named investigator was considered, the success rate was 21% for both males and females.

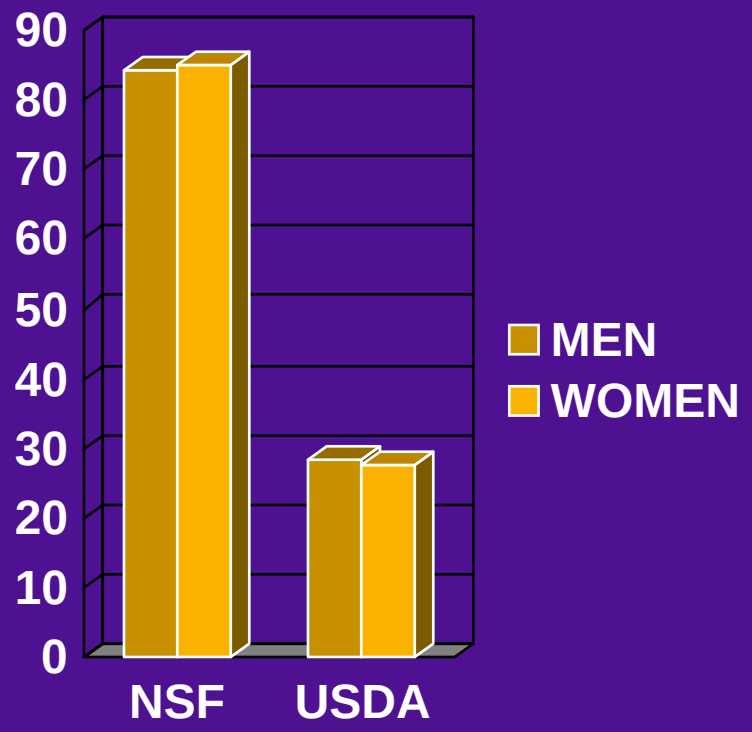
Leboy (2007)

- Success rates at NIH for grants reveals identical success rates for new submissions (18% women vs. 18% men)
- Similar success rates for competing renewals (33% women vs. 34% men)

RAND (2005)

Assessed gender bias in grant awards at NSF, NIH, and U.S. Department of Agriculture.

RAND (2005)



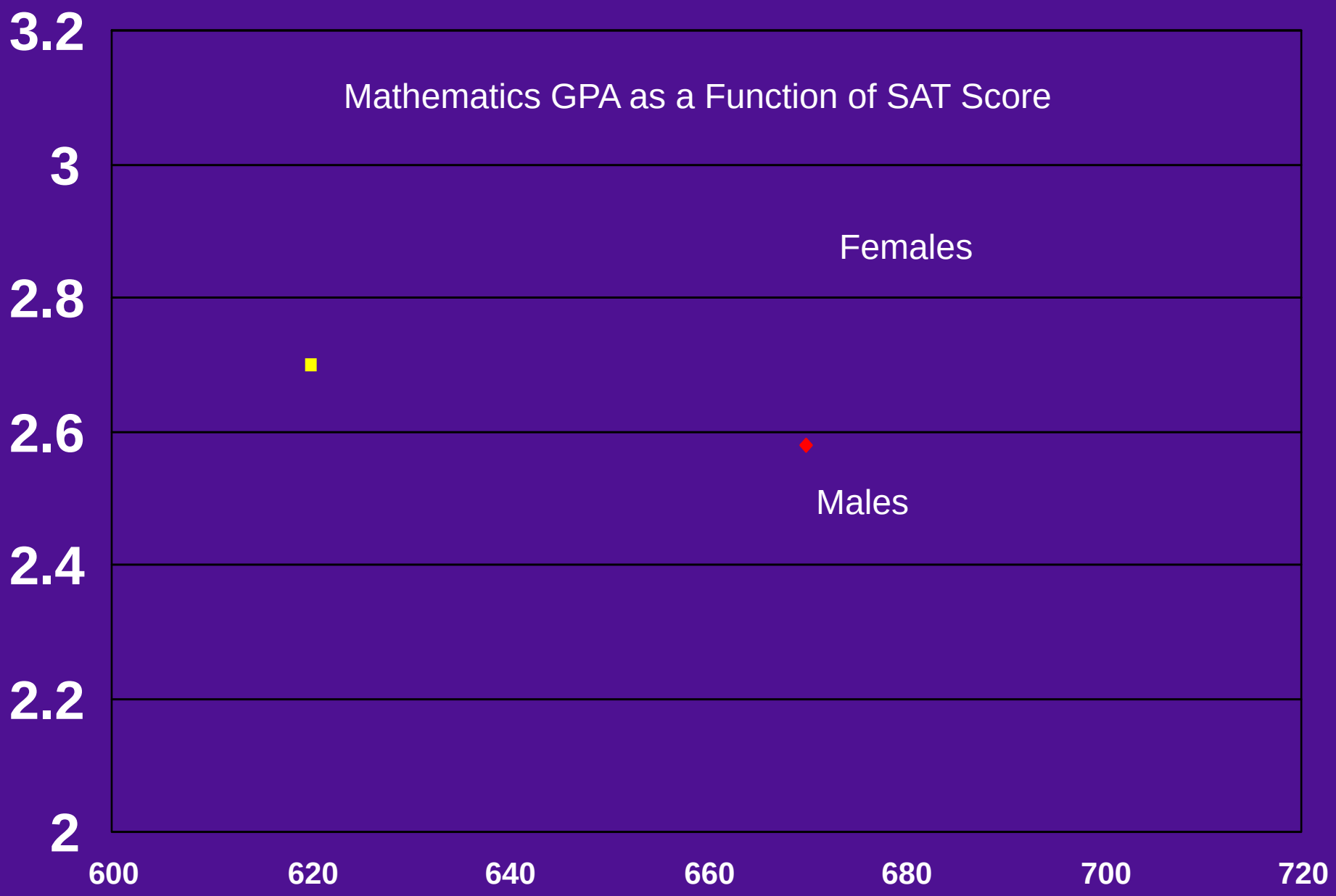
No consistent evidence of gender bias in either funding rates or amount of funding

Steinpress et al (1999)

They asked 238 psychologists to review fictitious assistant professor candidates and more advanced job seekers who were eligible for tenure. They used the same CV, but varied the sex of the applicant.

“This paper has shown that within science as a whole, even without controls, there are no appreciable gender differences in the probability of receiving tenure track jobs, and only a five percent difference in the probability of promotion to full. Moreover, we can explain what differences that do exist in tenure and promotion to full professor by differences in academic field, demographic and employer characteristics, primary and secondary work activity, government grants, and publications. When broken down into broad fields, with controls there do seem to be some gender differences in promotion to tenure for life sciences only, on the order of approximately 8 percent. No broad fields demonstrate significant gender differences in promotion to full professor.”

Ginther, D. & Kahn, A. (in press). Does Science Promote Women? Evidence from Academia 1973-2001. *NBER*.


Mathematics GPA as a Function of SAT Score
Females
Males
3.2
3
2.8
2.6
2.4
2.2
2
600
620
640
660
680
700
720

Sex differences depend on *when* one looks. Findings show male overrepresentation in ratio of boy-to-girl in top 1%, but large secular variability

- **12-to-1 in the 1983**
- **5.7-to-1 in 1994**
- **4.1-to-1 in 1997**
- **3.0-to-1 in 2005**
- **Ratio of adolescents who scored ≥ 700 in the SAT-M at age 13 shrunk from 13:1 to 2.8-to-1**
- **No child in 2003 scored in the top 10% of the range by 1976 standards (Shayer et al., 2007).**

- **# of women scoring > 700 on the College Board's Mathematics II Achievement test increased by 150%, and the number of women with high scores on the physics test increased by 142%, due to increased female participation**
- **women narrowed the gap in AP-Computer Science between 1984 and 1996 (*d*'s .59 and .16, respectively)**

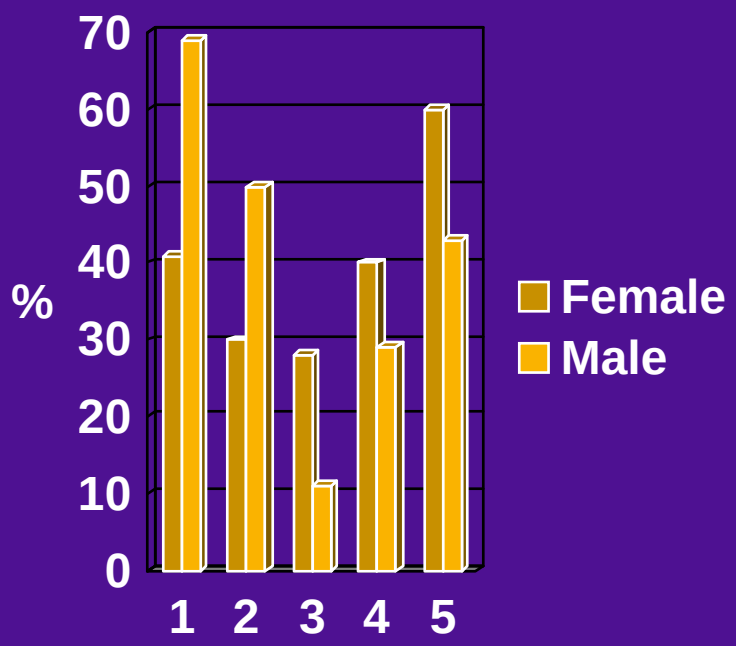
III. Choices/Preferences

- Occupational Preferences
- Hours worked at job
- Fertility decisions

Females Lag in Tenure Track Jobs (Leboy, 2007)

- 45% of Ph.D.s in biomedical sciences (1994-96)
- 29% of tenure track Assistant Profs within ten yrs. (through 2006)

Family-Career Collision Course Among College Professors



1. Married with children
2. Children in first 10 yrs.
3. Unmarried
4. Wish for more children among 40-60 yr. olds
5. Divorced

Sex Differences in Hours Worked Per Week

(From: Jacobs & Winslow, 2004)

WOMEN

- 50% of faculty mothers work > 60 hrs/week
- Work 101 hrs/week across career, housekeeping, and caregiving
- Without children, work 78 hrs/week
- Faculty mothers work 4 hours less per week at their academic jobs than women faculty without children

MEN

- 60% of faculty fathers work > 60 hrs/week
- Work 88 hrs/week across career, housekeeping, and caregiving
- Without children, work 78 hrs/week

Sex Differences in Values

Lubinski (2004) reported data on the amount of time that nearly two thousand 33-year-olds, who during their adolescence were in the top 1% of quantitative ability, say they typically devote to their current jobs and the amount they would devote to their ideal jobs. Roughly twice as many high-aptitude males report working at their jobs 50+ hours per week at the age of 33, and approximately three times more women report working less than 40 hours. Lubinski reported a similar sex difference in another study of nearly 10,000 high-aptitude mathematics scorers.

Sex Differences in Values

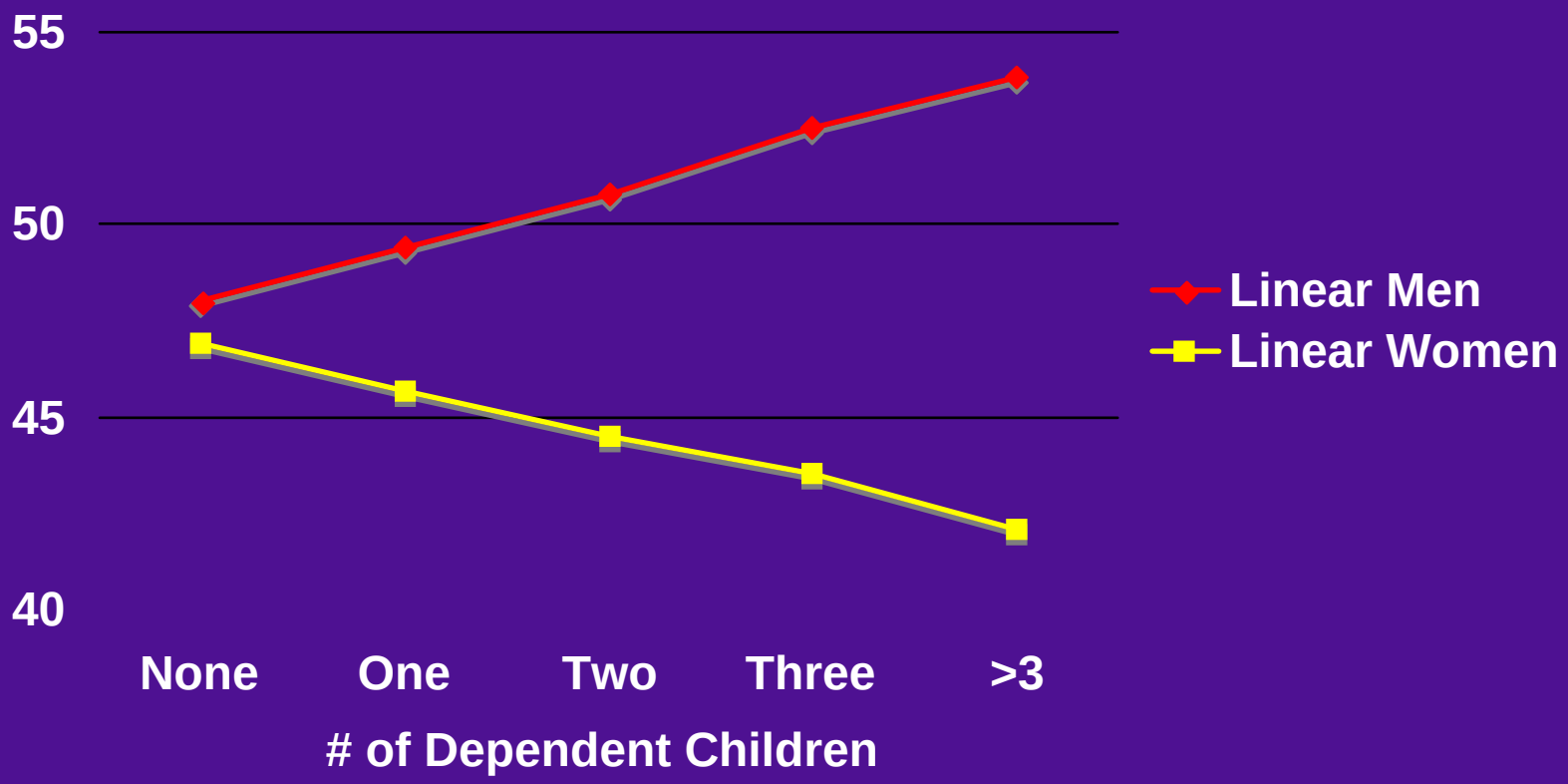
Women exit science and engineering careers at higher rates than men, and this is true at every stage of their career--from starting scientists to senior scientist.

Interestingly, it is also true among women without children, so the reason women exit STEM careers cannot solely be attributed to family needs, although some portion of it can.

Women are far more likely to abandon STEM careers than both men and women in less mathematically-intensive careers: women are 2.8 times more likely than men to exit STEM careers for other occupations, and 13 times more likely to quit the labor force completely.

Number of Children & Hrs. Worked Per Week by Academic Women

(Linear trends, adapted from Leslie, 2007)

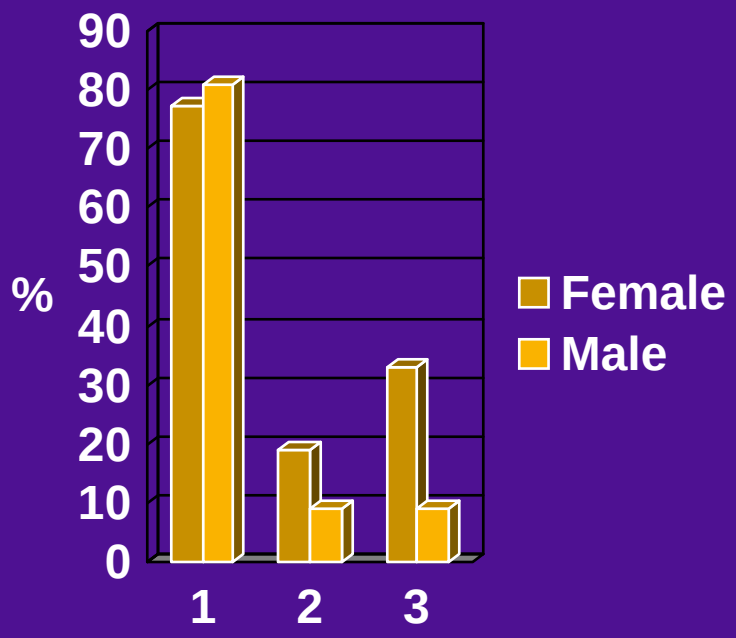


“It is increasingly clear that having children has a particularly serious effect on women’s careers”

Leslie, D. W. (2007, March). The reshaping of America’s academic workforce. TIAA-CREF Institute, #87, at www.tiaa-crefinstitute.org., p. 11

Sex Differences in Lifecourse Preferences

(Lubinski, Benbow, Shea, Eftekhari-Sanjani, and Halvorson, 2001)



1. Grad students reporting full-time career was important or extremely important
2. Subsequent group reporting prefer permanent part-time
3. Preferring part-time for limited period of time

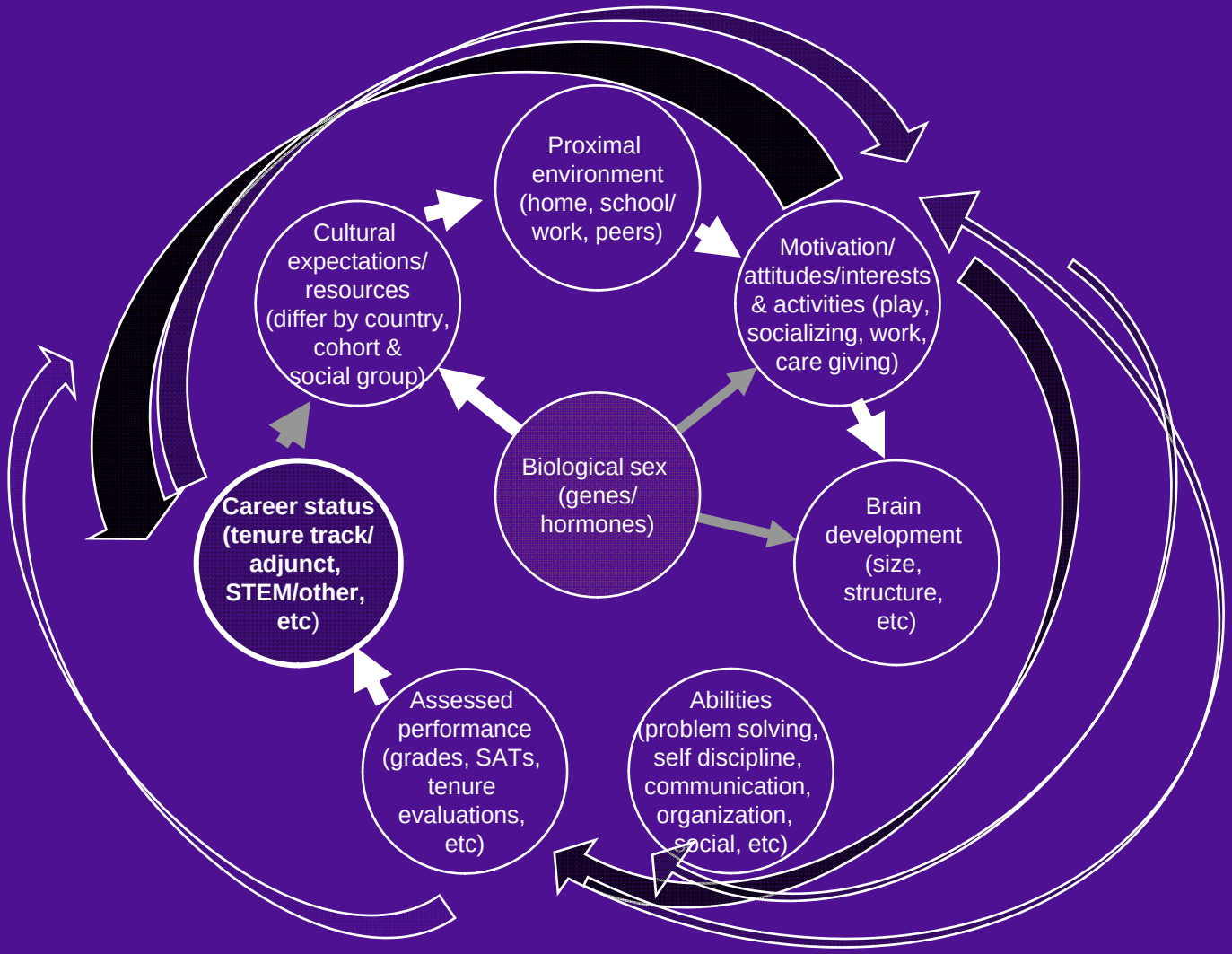
Among mathematically talented students expecting to major in the math/sciences, the specific fields of the expected undergraduate major. (Webb, Lubinski, & Benbow, 2005)

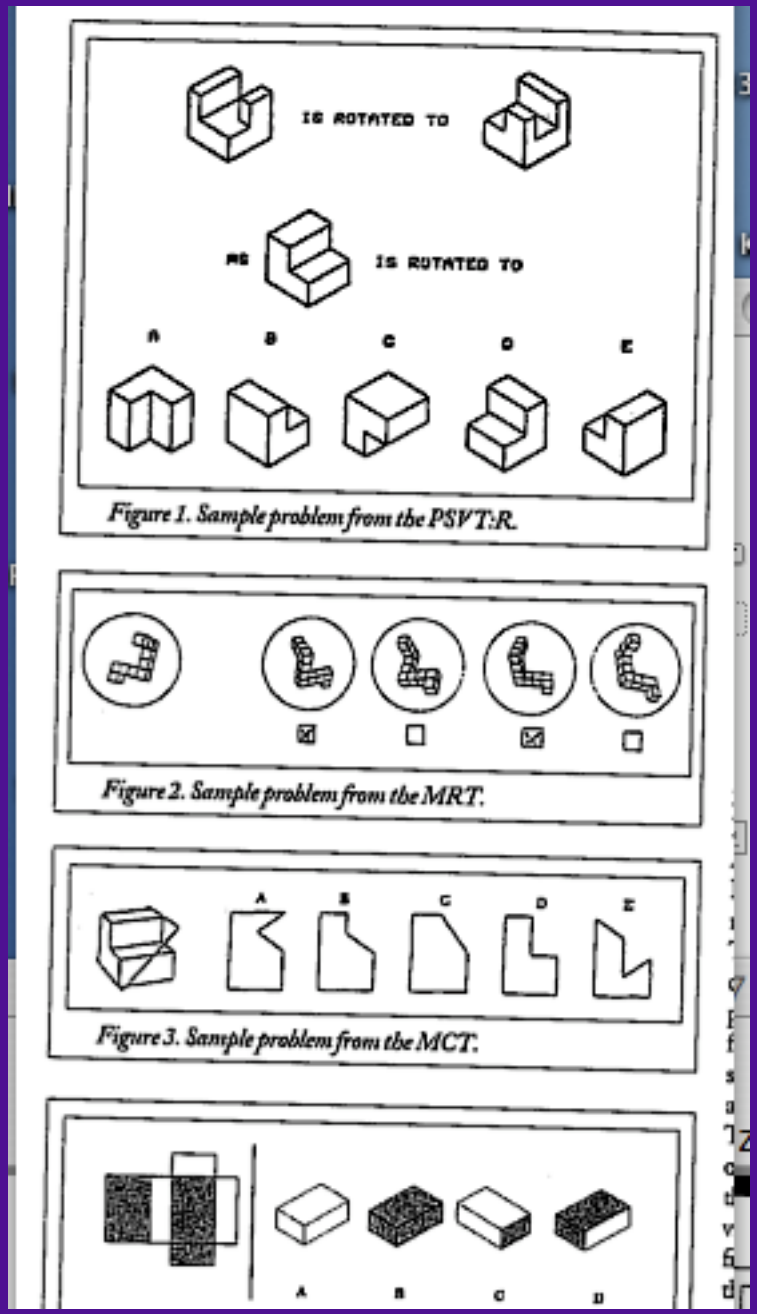
Field	Men	Women	*d*
Engineering	43.4	22.9	0.43
Mathematics	15.9	21.1	- 0.13
Biological science	13.4	23.4	- 0.26
Computer science	8.3	6.0	0.08
Medical science	3.6	12.9	-0.34
Physical science	8.8	1.4	0.41
Chemistry	5.0	8.0	-0.12
Earth science	1.2	2.3	0.08
Agricultural science	0.4	2.0	0.10

Biggest Leaks Occur After First Semester

- Engineering
- Economics

Evidence-based causal model





418 male freshmen; mean PSVT-R = 79.6
117 female freshmen; mean PSVT-R = 68.1

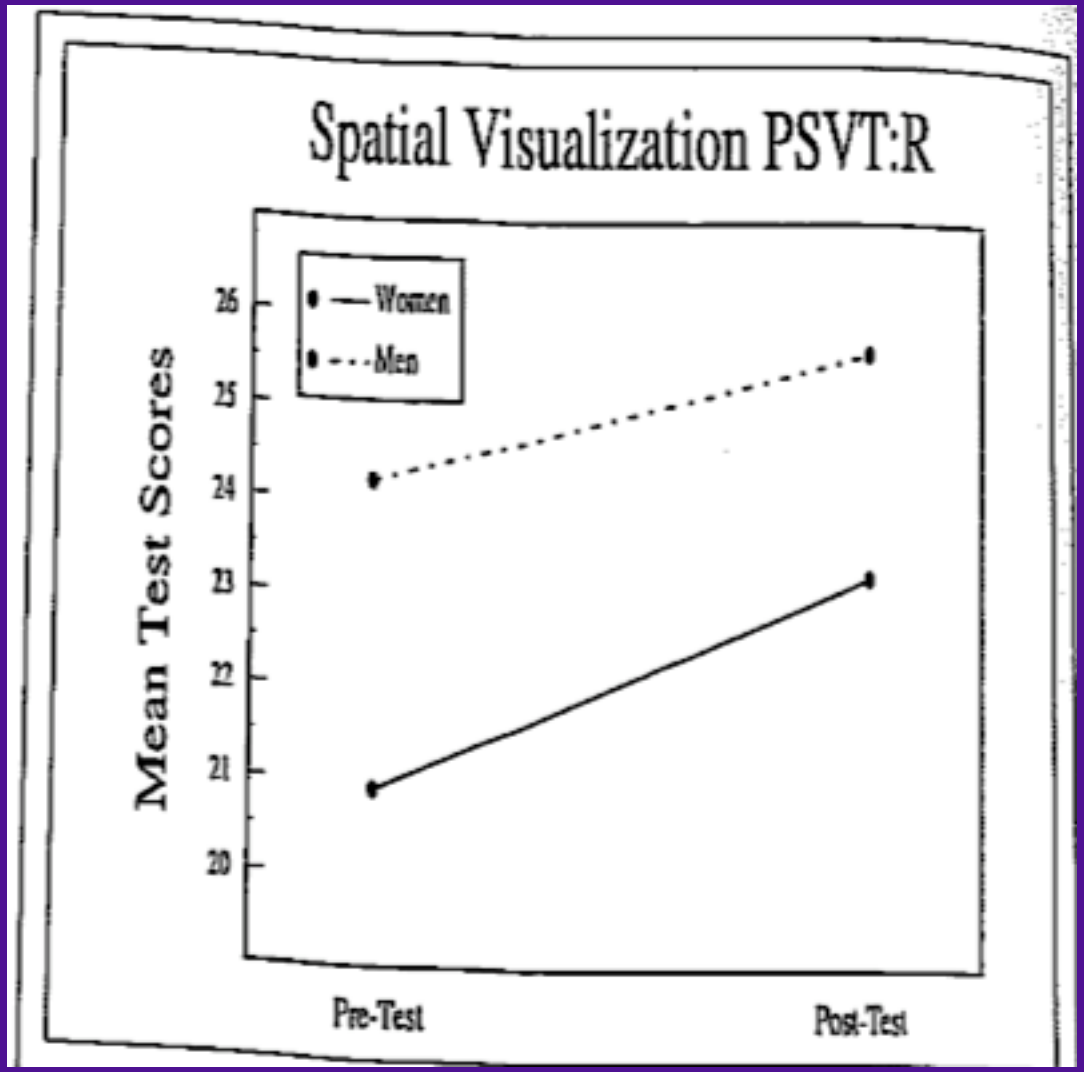
10% males perfect scores
2.6% females perfect scores

12% males failed
39.3% females failed

Legos, Erector sets, Lincoln logs
Prior experience design/drafting
(Math ACT equal predictor for both sex)

Insignificant predictors:
Handedness, videogames,sports,
Prior work experiences, geometry

PSVT-R best predictor of grades of 11 Studied. (Math and prior drafting/shop also significant predictors)


Spatial Visualization PSVT:R
Mean Test Scores
26
25
24
23
22
21
20
Women
Men
Pre-Test
Post-Test

Interventions

Spatial Training Was Effective

- Women and Men elevated their spatial scores over the semester
- Got better grades in gateway courses
- Retained engineering major
- Effect most pronounced for women

Sex Differences in the Academy are complex; there is no single, simple answer

As a rule, women dominate in fields such as education, English, psychology, biology, veterinary medicine, dentistry, and art history, where they comprise large proportions of the professoriate.

Men are much more numerous in physics, mathematics, computer science, chemistry, operations research, economics, and engineering. Men comprise 81 % of tenure-track professors in math, 89 % in physics, and 90 % in electrical engineering.

Unwarranted Assumptions

I. STEM scientists are unexceptional
II. Hormone-spatial-mathematical-STEM
III. Lack of role models/mentoring
IV. Stereotypes
V. Lack of parental encouragement
VI. Explicit Discrimination

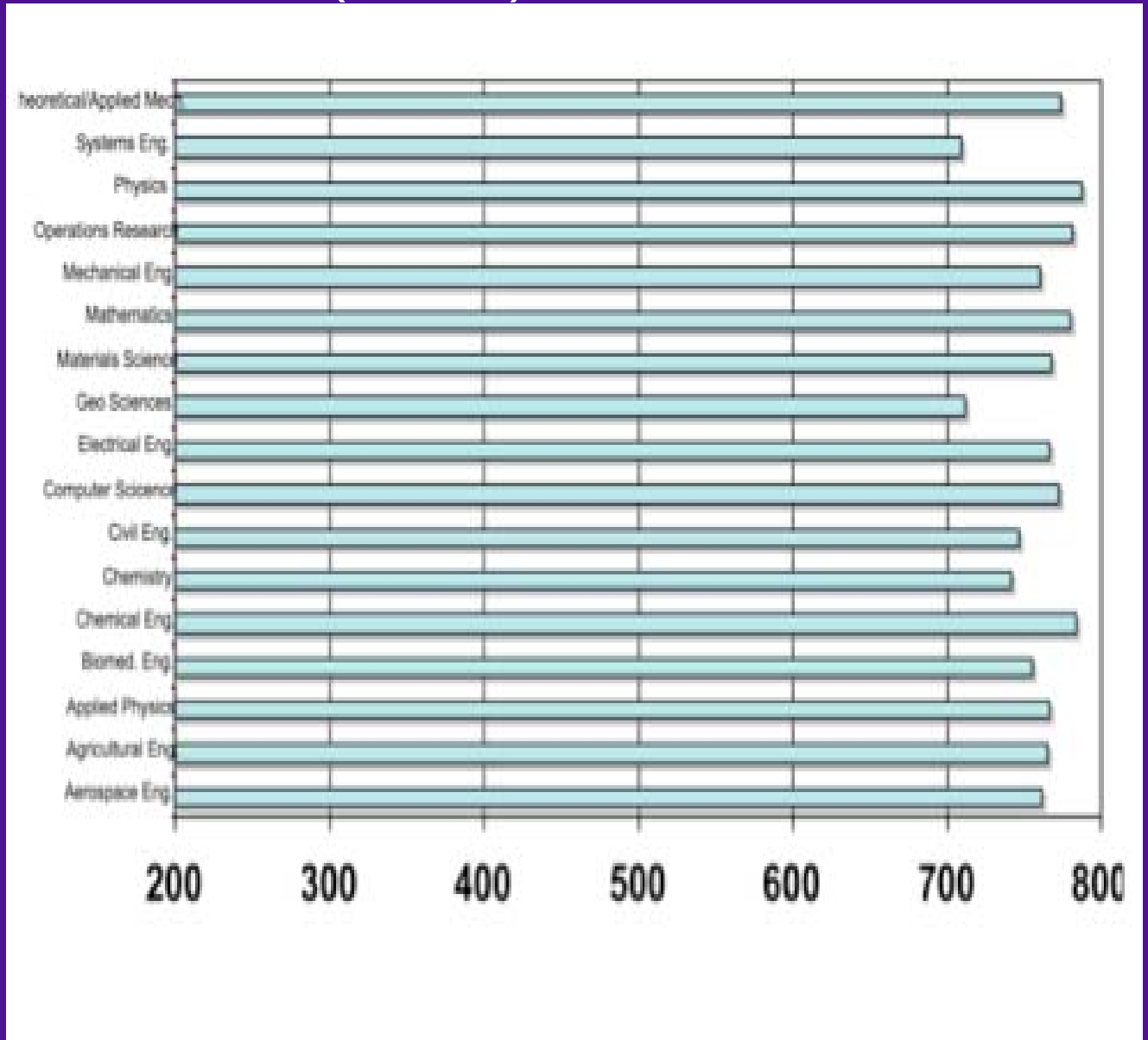
I. Are STEM scientists unexceptional?

"Notably, it is not just the top SAT scorers who continue on to successful careers; of the college-educated professional workforce in mathematics, science, and engineering, fewer than one-third of the men had SAT-M scores above 650, the lower end of the threshold typically presumed to be required for success in these fields. The differing social pressures and influences on boys and girls appear to have more influence than their underlying abilities." (Shalala et al., 2006, p. 24)

Counterevidence

- Benbow & Lubinski’s data
- Wise et al.’s Project Talent

Average GRE-Quantitative Scores for Cornell University Graduate Students in Mathematics-Intensive Fields (N=480)



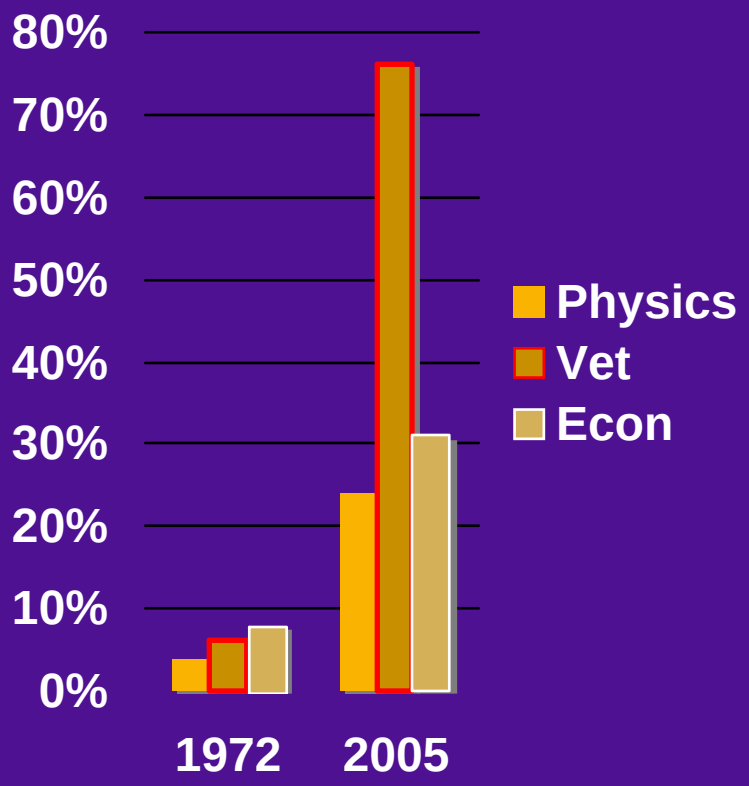
II. Do Sex Differences in Hormones Explain Underrepresentation?

- Highly inconsistent
- Few right tail samples

  (see review by Ceci, Williams, & Barnett)

III. Does Lack of Role Models Explain Dearth of Women Earning Doctorates?

- Role models?



IV. Stereotype Threat

Females who marked the box corresponding to their gender *after* completing the SAT Advanced Calculus test scored significantly higher than those who checked their gender *before* starting it. Identifying their gender *after* the AP-Calculus exam would add nearly 3,000 women eligible to begin college with advanced credit for calculus (Davies & Spencer, 2005)

- Doesn’t explain how girls excel in achievement tests, grades, etc.
- Male overrepresentation in mathematics and science ought to be greater in countries not known for their egalitarian gender beliefs, such as Turkey and Korea, than in the U.S. and U.K. However, there are proportionately twice as many female computer science majors in Turkey as in the U.S.
- Odds ratio of being female at the right tail of the math distribution is greater (by a factor of > 2) in countries not viewed as egalitarian, such as Hungary, and Russia, than in egalitarian countries such as Norway, Denmark, and Sweden

- Why don't women at a young age when they are first sensitive to ST (see Good et al, 2008) "disidentify" with the domain of mathematics—i.e., reconceptualize their values and identity to avoid ST by removing mathematics-like activities as a basis for self-assessment
- If women and African-Americans score higher when ST conditions are removed from the SAT-M context, then they must have mastered the material prior to the administration of the SAT-M, but suffered when the testing context interfered with the retrieval of this learning. If retrieval-time interference is the causal mechanism, then why does the SAT-M overpredict African-American's college mathematics performance but underpredict female mathematics performance? Does the mechanism operate differently when activated by gender vs. racial stereotypes?

V. Lack of Parental Encouragement?

- Penner (2008) found that the students whose parents said that mathematics achievement was important to them actually exhibit larger sex differences at the right tail than at the left tail: girls in the top 5% of mathematics achievement score 3% worse than boys among those who say that mathematics achievement is unimportant to their parents, but they score 6% worse than boys among those who say their achievement in mathematics is important to their parents.
- Catsambis (2004)

VI. Does Explicit Discrimination Explain Women's Underepresentation?

- Ginther & Kahn (2006)
- Marsh et al (2008); RAND (2005)

In Sum: Confluence of Multiple Small Effects

- Proximal Childhood Experiences
  - Legos, Erector Sets, Lincoln Logs, videogames
- Cultural Expectations
- Gender Expectations
- Ability Differences
- Sex Differences in Interests/Values
  - Hrs. per week worked
  - Higher exit rates from STEM
  - Prefer organic fields
  - Want children