Gender Differences in Mathematical Ability

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December 1, 1998
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ABSTRACT

This paper examines the existence of differences in mathematical ability between men and women. The issue of whether such a difference exists is discussed and evidence for both sides of this argument are presented and criticized. Both innate and environmental causes for such a difference are examined, and evidence for both of these possibilities are discussed. The final conclusion is drawn, based on the evidence presented for all sides, that there do exist some gender differences in mathematical ability, however further research is sought to determine the exact cause for this difference.

INTRODUCTION

Gender has always been a line along which to separate people. Women in many societies have historically played different roles than men: They took care of the children and cooked food while men hunted. Women stayed at home when men went to war; they didn't participate in religious ceremonies or were restricted and separated from men when worshipping. Women were referred to as the "weaker sex." To a large extent (perhaps more than our current society would like to admit), women still are seen in a different light than men, even though they have successfully performed roles that were once the domain of men only.

In modern society, in light of the change in societal perception of the woman from subservient companion to equal, we must ask why women were traditionally cast in such an inferior role. Is there actually a difference in women's abilities as compared men's? This question has been asked in reference to many topics, and the results of experiments to root out the answer are contradictory. To more closely examine the arguments for and against gender equality, this paper looks at a single domain: Mathematics. Are women different than men in terms of mathematical ability? If so, what are the possible reasons for this difference? Do these differences stem from innate or environmental factors?

There are differing viewpoints on this subject, each with research to back up its claim. Doreen Kimura supports the view that gender differences in mathematical ability are due to an innate difference in the physiology of the female versus male brain. Jeffrey Foss rebuts Kimura's claims of innate gender difference. Experiments supporting his viewpoint show that males and females are equal in innate ability. There are also experiments that show no real difference between the performance of men and women in mathematical tests. Each of these claims will be reviewed and evaluated and their justification clarified, in an attempt to resolve the opposing viewpoints.

PERCEIVED DIFFERENCES

The question of whether men and women actually differ in mathematical ability is still up for debate. It is not altogether clear that men are more able than women in this domain. Indeed, there are studies that claim that there are no differences. These studies, including those performed throughout the 1970's by Norman Freed, state directly that men and women are equivalent in mathematical ability. Even as recently as 1996, studies have shown equivalent competency between genders on standardized mathematics tests.

Why should there even be any question as to whether there are gender differences in mathematical ability? Women hold the same mentally challenging jobs as men. No one would claim that women are less capable than men in any of these jobs due to their proven competence (as well as a fear of being a male chauvinist). It is clear from real-world experience that men and women are similarly capable at any mental task.

Yet there are fewer women in almost all of these mentally challenging jobs as there are men. Most people, especially women, would claim that such an inequality is due to the still recent prejudices against women performing in these jobs. Such prejudices prevented many women from entering the workforce and holding mentally challenging jobs, though they were cognitively capable of doing so. The Women's Liberation movement began in the 1960s to destroy this prejudice, and although prejudice still exists to some extent today, women have risen to high ranks in this country's workforce. However, since it has only been thirty years since this mass migration from the home to the workplace began, there presumably has not been enough time to allow an equal number of women as men to overcome these prejudices—which were held by both sexes—to be employed in mentally challenging jobs.[1] (Phillips 1997)

The possibility still exists, however unpopular, that gender disparity in the workplace is due, in part, to an actual difference in mental ability. Tests of mathematical ability that pit men against women show that there is no real difference in ability between sexes. The position of supporters of this belief is that men and women are fundamentally equal in ability. Any disparity seen is due not to an underlying inequality in aptitude, but rather due to the prejudices of the test. A number of studies argue this point using the same data that opposing studies use to claim male superiority in mathematics tests.

An early proponent of the theory that men and women are on equal footing when it comes to mathematical ability is Norman Freed, a psychologist, who in 1983 questioned the validity of a study that showed men superior to women in mathematical achievement. He claimed that "the same data [as in the study] actually show girls to be catching up with boys in mathematical skills as measured by three interrelated indices across two separate grade levels." (Freed 1983) He claims that there will exist "future if not present equivalent mathematical aptitude by gender." By showing that women were catching up to men in mathematical ability, Freed shows that any difference in measured ability is due not to a difference in actual ability, but rather due to the analysis of the results of mathematical tests.

Re-analyzing data to come to a completely opposite conclusion should be suspect. Which analysis is correct, the original interpretation of the data or Freed's interpretation? It is not clear in this case that either is definitively correct; both analyses were conducted according to proper statistical methods. The choice of which result is more significant is a subjective one. Further research should be done, discarding this data, since its interpretation is not clear. Furthermore, this study deals solely with seventh graders; a more complete study across many grades would yield more complete results. However, the ability to reanalyze this data, and data like it, to reach a completely different conclusion brings into question the validity of the conclusions of the studies 'proving' male superiority.

A more complete timeline study was conducted by the *NAEP 1996 Mathematics Report Card for the Nation and the States*. It looked at fourth, eighth, and twelfth-grade students, and found that "average scores…for males and females did not show any significant differences." (Manning 1998) Though this study did not factor out socioeconomic or genetic factors in mathematical performance, the mere breadth of the sample size evens out these differences.

A similar report from the National Research Council, conducted in 1989, "maintain[s] that as girls and boys progress through the mathematics curriculum, they show little difference in ability, effort or interest through adolescence." (Manning 1998) The details of this experiment show that student background was not factored into the conclusions drawn, so the results may be skewed. However, again, the breadth of the experiment would seem to cancel out any inter-student discrepancy. The results of both of these studies are difficult to ignore.

INNATE DIFFERENCES

The idea that men and women possess different mathematical ability is one that is believed to be true by many people. Studies have shown that girls believe they are less able to perform on mathematical tests than boys in the same class. (Stipek 1984) Such a belief is supported by many studies of male versus female performance on such tests. (Englehard 1990) In such studies, females more often than males, report that they would do poorly on the subsequent mathematics test.

Such a belief commonly held. There are fewer females than males in higher-level mathematics classes. (Manning 1998) This belief is well founded: Yee et. al. have shown that women do worse than men in tests of mathematical ability. (1988) Others have shown similar results. (Englehard 1990, Kimball 1989) Most of the studies that look for gender differences in mathematical ability do find such differences.

Assuming that such gender differences do exist, the question that arises is: To what are these differences in ability attributable? Kimura suggests that such differences arise due to innate differences in mathematical ability between men and women: "Differing patterns of ability between men and women most probably reflect different hormonal influences on their own developing brains." (Kimura 1992) Kimura believes that such hormones act during the prenatal and early postnatal stages of infant development:

> The lifelong effects of early exposure to hormones are characterized as organizational, because they appear to alter brain function permanently during a critical period. Administering the same hormones at later stages has no such effect. (Kimura 1992)

It is Kimura's belief that the brains of men and women are fundamentally different at the earliest stages of life, and it is these differences that are the cause of any difference in mathematical ability that is evident at any point during their lives.

The belief that men and women are innately different is one that is as old as history. The earliest records of human activity show men and women performing different tasks. Many religions segregate—and in some cases subjugate—women from men. It is not a stretch to imagine that such a separation of the sexes arose due to innate differences. After all, women are biologically distinct from men.

It is difficult to test whether an attribute is innate versus environmental. To be absolutely sure, an experiment must remove all innate factors to show that a difference in ability is due solely to environmental causes. The reverse is true as well: to be sure that the environment plays no role, genotypically distinct individuals must be tested for a difference in ability in exactly the same environmental setting. It would seem that the latter situation is more easily accomplished; however this is untrue. As soon as a child is born, it interacts with its environment. Infants only minutes old have been shown to be responsive to external stimuli, and the earliest years of life are believed to be the ones that are most filled with learning on the child's part. (Pinker 1997)

To definitively rule in favor of innate differences, infants as young as possible must be tested in their mathematical ability. This clearly presents a problem, since language is not available on the infant's part to do such testing. Testing for the presence of mathematical ability, and more specifically the ability to count the number of objects in small groups, has been done on infants as young as a few months old. (Baillargeon 1993) Experimenters are unable to elicit accurate and stable responses from younger infants, when experience has not played as much of a role in the development of the cognitive structure of the child.

One of the basic experiments Kimura uses to back up her thesis is the measurement of androgen levels in women and men during mathematical reasoning. Men are shown to have higher baseline levels of androgens than women. During these mathematical tests, women who scored higher relative to other women were also shown to have a higher level of androgen concentration in their bodies. (Kimura 1992) Kimura claims that such results suggest men are more capable of mathematics than women.

A major argument against such a conclusion is that the results point to correlation, not causation. Kimura does touch on this topic briefly: "The relation between natural hormonal levels and problem solving is based on correlational data. Some form of connection between the two measures exists, but how this association is determined or what its causal basis may be is unknown." (Kimura 1992) Caution prevents her from claiming outright that innate differences are the cause of differences in mathematical ability; however, the belief that such is true is still present in her analysis.

A further argument against this study is that by the time these subjects were tested, the environment could already have changed the biochemical state of their brains, altering their structure in such a way as to make it seem that the differences are innate. It

is difficult to separate out the innate from the environmental causes in any study; however, by the time males and females are adults, environmental effects on the internal state of the brain (due to memory formation and other ongoing processes) are so entrenched that it can be impossible to separate from the innate form. This is true especially in mathematics, where a child, especially those of First-World nations where these experiments were performed, is exposed from a very young age to learning mathematics.

To correct for such environmental effects, young infants must be tested, which involves surmounting the problems outlined above. At the least, young children who have not had any mathematics teaching should be tested for such a divergence of mathematical ability. Kimura tests neither infants nor young children. Therefore her conclusions cannot be accepted blindly.

Kimball suggests a slightly different cause of mathematical ability difference in males and females: “A major theoretical explanation of sex related differences in mathematics achievement has proposed that differences in autonomous learning behaviors directly cause sex-related differences in mathematical achievement.” (1989) According to Kimura’s theory, males and females differ fundamentally in their learning processes, and therefore exhibit differences in learned mathematical ability when tested.

Much of her evidence for such a theory comes from a study by Peterson and Fennema, who in 1985 found that boys and girls performed comparably on low-level problems, but boys did better on high-level problems. (Kimura 1989) Such a study is subject to criticism in two areas. Most important is the characterization of math problems as low- or high-level. Though it is commonly agreed that addition and subtraction are

low-level operations, performing such operations on large numbers can stress the capacities of young children. Furthermore, it is unclear whether multiplication and division are low- or high-level operations. Further complicating this issue is the ability to transform a problem from low- to high-level just by changing its presentation. A straightforward addition can be made more complex when presented as a word problem. Problems based on concrete versus abstract objects also can have an effect on the rating of a problem.

Another argument against these findings is that high-level problems depend on more teaching, and girls' abilities versus boys' may be affected by the way such abilities are taught. Changing the subject of problems used to teach such high-level abilities can change how interesting a problem appears to a boy relative to how interesting the same problem appears to a girl. (Stipek 1984) The study did not attempt to correct for biases caused by the teacher in instances where high-level mathematical abilities were tested.

Sociological Differences

Much like the argument for innate causes of mathematical differences in ability between sexes, the theory that any difference that exists between men and women in the psychological domain presumes that there actually are differences in mathematical performance. Such a belief is well founded; many studies of standardized test scores have found that women perform worse than men do. Some of these same studies show that women perform better in a classroom setting than men. (Wentzel 1988)

All of these studies, however, find that this difference in performance arises later in school. Measured from sixth grade through twelfth grade, girls seem to decrease in ability in standardized tests as compared to boys. (Wentzel 1988) This finding points to a social cause for mathematical differences between sexes.

The basic argument for social causes for this disparity in ability is that men and women, when born, posses brains which are biologically the same. Jeffrey Foss states this belief clearly in terms of evolution:

> Natural selection tends to find the simpler solutions where they exist, and a single genotypic plan for a brain with multipurpose intelligence is simpler to achieve than two genotypically different sorts of brain. Of course, this sort of simpler solution is not always available, notably in the case of the brain structures underlying sexual preference and behavior as such, where differentiation is the very thing nature must achieve. Still, it is available for the design of the heart, kidney, muscle, eye, ear…and the brain structures underlying human intelligence. Evolution favors but two primary sexual orientations, but the main evolutionary advantage of human beings, as in the case (to a lesser extent) of other primates, is an intelligence that can adapt to countless circumstances.

His argument is that evolution would have favored a single type of brain, and that men and women share this single brain design. Therefore, differences we see in mathematical ability are due not to innate biological differences between the brains of the two sexes, but rather to some other, external cause.

Attributing ability differences between sexes to non-innate causes is a stance taken by many psychologists. Doing the same when discussing mathematical abilities should follow naturally. Indeed, the attribution of many behavioral differences to social causes would lead to the logical conclusion that the brains of men and women are not biologically different—at least for the most part. It would be the odd disparity in ability that must be proved to be based on innate differences. As such, different mathematical abilities, in the absence of concrete evidence to the contrary, should be attributed to social causes, and not innate ones (at least according to this line of reasoning).

Proving such a cause for the disparity of test scores is more difficult than just following a logical conclusion based on previous findings. To show that the cause of the disparity in mathematical ability between men and women is due to social causes requires studies to factor out all innate differences. This is impossible, since it would require that a person be tested both as a male and as a female. Even fraternal twins would not prove this

conclusion absolutely, since they are from two different egg cells, and therefore have slightly different genotypes. Thus, any proof of this conclusion must be carefully examined in order to be sure that the true causes of the differences are non-innate and external.

Still, the possibility that the environment is the cause of any gender disparity is a completely plausible one. It does not violate any other cause of difference between men and women. We see every day the effect that the outside world can have on the psychological state of individuals. People are affected by their environment, and it is not a stretch to imagine that boys and girls, whose gender roles are learned by the age of three, develop differently in their mathematical abilities because of their surroundings. (Foss 1996)

Some of the strongest evidence for this view comes from studies of women's mathematical performance in a single-sex schooling environment versus their performance in a coeducational environment. Lee and Bryk, in 1996, conducted a study of 1,807 randomly chosen students in 75 Catholic high schools from around the country and found "positive effects associated with [single-sex] schools." (Mael 1998) According to this study, girls enrolled in more math courses and performed better academically in those courses than did girls in coeducational schools. This finding shows that girls are capable of mathematical performance equal to that of boys, and any discrepancy in their performance is due to the social climate of their learning environment.

One problem with this argument is that Catholic schools tend to be more selective in the students they attract. Their students tend to be brighter and from higher socioeconomic backgrounds than students from coeducational schools. (Mael 1998) A similar study done on Australian ninth-graders matched socioeconomic backgrounds of

the students, and found similar results: females performed better. (Mael 1998) Such an argument against Lee and Bryk's study may not be well founded.

Wentzel (1998) performed a study that lends further credence to the argument for a social basis for different mathematical abilities in males and females. She looked at the test scores of 30 males and females from sixth through tenth grade. She found that the average score on math tests dropped for girls over this time. Over the same period of time, the scores for boys stayed fairly constant. By tenth grade, boys were achieving higher average scores on math tests than were girls, whereas in sixth grade, girls were outperforming boys. This study clearly shows that over time, mathematical ability declines in females. Any such change is a result of social effects on the students, since the same study showed comparable performance in tests of English abilities for both sexes over the same time period.

One obvious flaw in this study is the small sample size of the group tested. Thirty students cannot possibly be representative of the performance of each sex as a whole. Yet even though this study's size may prevent it from being considered scientifically exact, the trend it reports is real. If there were biological differences between boys and girls in terms of brain physiology, they should have shown up across all ages, since a hard-wired limitation would cause a person to perform poorly from the start.

Also, this study did not account for the backgrounds of the students being tested. It is commonly accepted that each individual will have a different level of ability based on their genotypic background. When studying innate versus environmental causes in gender differences in abilities, all pertinent genetic factors must be corrected for, with the exception of sex. There is the possibility that in this study, the boys were not as "intelligent"—genetically—across the board as the girls (or vice versa). Such corrections

were not made, and therefore the results of the experiment must be considered in light of the lack of this correction.

CONCLUSION

Whether there actually are differences in the mathematical ability of men and women is still the subject of debate, although it seems that there is more evidence pointing *to* an actual disparity than there is *against*. However, the only concrete conclusion that can be drawn in answer to this question is that the answer depends on how mathematical ability is measured.

> Whereas virtually all IQ and mental aptitude tests are dedicated to mathematics, making manifest the universally assumed link between mathematics and cognitive ability. It is crucial to recognize that these tests are continually adjusted to make the scores square with preconceptions or even social ideals; indeed, when early IQ tests indicated that women were more intelligent than men, the content, including sections on mathematics, was adjusted to correct for this 'anomaly'. (Foss 1996)

It is virtually impossible to create a completely fair and accurate test of any mental ability, including mathematics.

Evidence in favor of a difference in mathematical ability between men and women is more concrete than evidence to the contrary. Furthermore, more recent studies show that such a difference exists. On this basis, it seems clear that there is some reason to believe that men and women differ in their abilities in the domain of mathematics.

Since the majority of evidence points to the existence of a gender disparity (keeping in mind Foss' comments on the validity of the tests studied), the question that must be addressed is: What is the cause of this disparity? Is it an innate difference between men and women, manifesting itself in a biological difference in the brains of the two sexes? Or is the social environment in which people learn and grow the cause for the disparity?

While the evidence is not conclusive, much of it does seem to point to a social cause for the gender differences in mathematical ability. Studies that claim to show that such a difference is innate do not do so acceptably, according to scientific standards. They leave too much of the environment uncorrected for to be believed completely. However, there is no absolute evidence that gender differences are not caused in some part by innate factors. In both cases, it is very difficult, if not impossible, to separate the two causes into mutually exclusive, testable criteria.

The evidence for an environmental basis for differences between sexes in mathematical ability is more powerful, and thus it seems that this is the cause for the disparity seen in experiments. The evidence for innate differences is in some cases difficult to ignore, and the conclusion that must be drawn is that there are both innate and environmental factors that play a role in gender differences in mathematical ability. Such a conclusion must be tested more thoroughly. Further experiments must show that in the presence of *only* innate or environmental factors, a gender difference still exists.

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