

## Sex Differences in Intellectual Functioning: How Much of a Difference Do Genes Make?<sup>1</sup>

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*An X-linkage theory of inheritance of genes controlling sex differences in major intellectual traits is critically examined. A review of the research suggests that the mechanism of inheritance of differences in spatial visualization ability is X-linked recessive and its expression is probably testosterone-limited. However, the evidence concerning inheritance of differences in IQ does not support an X-linkage theory. Several characteristics of heritability estimates are discussed, including their specificity to a particular population at a certain point in time, their fluctuation with changes in amount of environmental variation, and the necessity of unconfounding sex and treatment in order to better determine the relationship between heritability and changeability of sex differences in specific intellectual trait expression.*

"Why are there so few women of genius?" This question is really asking why there are fewer women who have attained levels of outstanding achievement in such fields as science, the arts and literature, as compared to men. Some writers have emphasized that women as a group have not been as free as men to pursue careers due to their traditional roles as childbearers and child-rearers (Bernard, 1966; Rossi, 1964), they have not had equal access to the graduate institutions in which great numbers of persons who achieve in such fields are trained (Colson & Scott, 1970), and, regardless of level of achievement, their works are devalued because of their sex (Goldberg, 1968). Others have provided empirical support for questioning whether women do achieve objectively less than men when matched on such factors as education (Simon, Clark & Galway, 1967). A third

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view is that, as a group, fewer women than men should be expected to achieve genius level intellectually because they are genetically less suited to intellectual achievement (Lehrke, 1972). This paper addresses only the last issue.

Belief in the inherent inferiority of women in terms of intellectual potential is not new. Aristotle (1941) was among the first Western Philosophers to espouse this view. Some have cited scientific evidence in support of such a claim (Lang, 1971). But it is unusual for such a theory to be published in a reputable professional journal, as Lehrke's theory has been.

The main purpose of this paper is to critically examine Lehrke's theory of inheritance of genes controlling sex differences in major intellectual traits. Problems of interpretation of findings concerning the mechanisms by which genetic factors control sex differences in intellectual functioning will be discussed, and evidence relative to the theory will be cited. Finally, consideration will be given to current changes in child-rearing practices which will afford psychologists an opportunity to study the determinants of psychological sex differences more fruitfully.

## AN X-LINKAGE THEORY OF SEX DIFFERENCES IN INTELLECT

In Lehrke's paper, entitled "A Theory of X-Linkage of Major Intellectual Traits," the author presents an X-linkage explanation for the finding that males show a greater variability in the distribution of IQ test scores than do females (Penrose, 1963; Childs, 1965); that is, that males tend to score at the extremes more often than females. In order to better understand the arguments Lehrke employs in support of his viewpoint it will be helpful to review the concept of X-linked inheritance. Modern genetics texts such as Cavalli-Sforza and Bodmer's (1971) *The Genetics of Human Populations* describe the rules for sex-linked inheritance as follows:

1. Any gene on the Y chromosome is present only in males and is therefore transmitted only from father to son. (It is believed that the Y chromosome, one of the smallest chromosomes, carries little else than the genetic instruction for male sex characteristics.)
2. Males have only one copy of the X-linked genes, which of course, always come from their mothers.
3. Females have two copies of X-linked genes, one of which is paternal and the other of maternal origin.
4. In females, the inheritance of sex-linked genes is the same as that of autosomal genes.
5. In males, the inheritance of X-linked genes is different from that of autosomal genes.

Another concept which is essential to an understanding of Lehrke's theory is the Lyon hypothesis. According to the Lyon hypothesis, (cf. Stern, 1973, pp. 322-323), at some stage early in embryogenesis, one of the X chromosomes of each cell of the female is inactivated at random and the same X remains inactive in all the descendants of any given cell. Lehrke has presented a model to illustrate why the laws of X-linkage together with the Lyon hypothesis predict greater variability of IQ test scores among males than among females. This model rests upon Lehrke's interpretation of the Lyon hypothesis to mean that "in females the expression of any deviant member of a gene pair on one X chromosome is likely to be offset or modified toward the mean by one on the other. Males on the other hand would tend to show full expression of X-linkage traits since there are few, if any, homologous genes on the Y chromosome" (Lehrke, 1972, pp. 613-614).

Evidence related to red-green color blindness, for example, is consistent with the Lyon hypothesis. Males who inherit the defective form of the X-linked gene which controls this aspect of color vision will be red-green color blind, while females will be so only if they inherit two such genes. Although there are quantitatively ordered degrees of red-green color blindness, for purposes of medical classification and X-linkage determination, categorization of the trait is usually limited to occurrence and nonoccurrence. To the extent that red-green color blindness is viewed as a qualitative category, an X-linkage theory of inheritance of such color blindness predicts precise differences in frequency of occurrence between the sexes. Unlike relatively qualitative traits such as red-green color blindness or the lack of it, intellectual traits have been quantitatively valued from low to high. The usual measure employed to quantify intellectual functioning is the IQ test, which has itself been criticized (e.g., Ryan, 1972). According to Lehrke, then, an X-linkage theory of major intellectual traits would predict differences in the average variability of trait expression between the sexes rather than sex differences in frequency of occurrence of such traits.

## DEVELOPMENT AND CHARACTERISTICS OF THE DEBATE

Two papers discussing Lehrke's view appeared in the same issue of the *American Journal of Mental Deficiency*. Nance and Engel (1972), in their response to Lehrke, questioned both the finding of a sex difference in variability of IQ scores and the X-linkage explanation of such a finding. With regard to the latter, they pointed out that Lehrke did not present the type of evidence necessary to test his theory. In her paper, Anastasi (1972) expressed the belief that the difference in variability, when it appears, is an artifact resulting from different criteria for mental retardation by sex. She did not question one of Lehrke's basic

assumptions, namely that greater variability of IQ test scores among males provides evidence for a theory of X-linkage of major intellectual traits, even if environmental explanations were to be set aside.

In this respect, the X-linkage-theory debate as presented in the *American Journal of Mental Deficiency* bears some similarity to what occurred following the publication of Arthur Jensen's (1969) paper on the heritability of IQ and its implications for explaining the origins of the race difference in IQ test scores. In the case of the Jensen controversy nearly all of his respondents emphasized the importance of the 20% variation in IQ test scores which even Jensen concluded could be attributed to environmental factors. By doing so, they inadvertently conceded several points to Jensen which many geneticists do not.<sup>3</sup> In general the geneticists and behavior geneticists have concluded that Jensen's basic statistic was calculated and applied inappropriately. Hence debating less fundamental points is somewhat superfluous and can be misleading.

Lehrke's paper bears three striking similarities to Jensen's writing. Like Jensen, Lehrke acknowledges that some people might interpret his theory as being derogatory toward one societal group. In Lehrke's case, it is women if one concentrates on the upper end of the IQ score distribution, since his theory predicts that women will achieve these levels less often than men. Second, Lehrke abdicates responsibility for his theory. He states simply that "Like Topsy, the theory 'just grew'," as if out of objective, value-free data. Finally, in a manner similar to Jensen, Lehrke assumes that the evidence he presents competitively supports the explanation offered, when in fact it does not. Each of these three points will be considered in turn.

First, is the theory derogatory toward women? Each of us must decide this for himself or herself. It is clear that Lehrke is saying that women, as a group, and because of their genes, are not as likely to score at the extremes of the distribution of IQ as are men as a group. Lehrke has allowed that, nevertheless, we should expect a few women geniuses and idiots, although fewer of each type than we would expect of males.

The second issue concerns the degree to which any theorist has a responsibility to anticipate false conclusions which might be drawn from his or her theorizing, especially when such conclusions may have ramifications for social policy, and to refute such false conclusions. Lehrke has failed to do this. One

<sup>3</sup> In fact, geneticists and behavior geneticists have raised a number of questions concerning the very suitability of Jensen's use of heritability estimates. For example, they have questioned the suitability of calculating heritability estimates based on correlations of IQ test scores of individuals of varying degrees of kinship. Such estimates were originally designed to be used to analyze the results of breeding experiments. Some have raised questions concerning the suitability of calculating heritability estimates on data for which there is a tendency for the environments of genetic relatives to be similar, since degree of genetic similarity and degree of environmental similarity are confounded in such data. Third, they have questioned the suitability of using a heritability estimate of a trait calculated on one population (whites) at one point in time as an estimate of the heritability of an average difference between two populations (whites vs. blacks) on that trait.

conclusion which might be incorrectly drawn from a theory of X-linkage of major intellectual traits is that the theory, if true, justifies differential treatment of the sexes. It should be pointed out that any such theory, even if true, is quite devoid of any implications for the treatment of persons by sex. There are a number of reasons for this. First, there is a great deal of overlap in phenotypic expression of traits by sex, making it impossible to predict to any appreciable degree a person's score on a test of intellectual ability from a person's sex. Second, even if there were little or no overlap in expression of intellectual abilities by sex, in principle our society is committed to equal educational and social opportunity for all and to the tenet that people are to be judged on their individual merits rather than their group membership. Furthermore, and perhaps most importantly, there is ample evidence to show that IQ scores vary tremendously as a result of differing situational and motivational determinants (Watson, 1972).

### TYPES OF EVIDENCE RELEVANT TO AN X-LINKAGE EXPLANATION OF SEX DIFFERENCES IN INTELLECT

The third consideration is: to what extent do sex differences in variability of IQ constitute compelling evidence for a theory of X-linkage of major intellectual traits? Interestingly enough, most geneticists do not accept the simple fact of greater variability in the expression of a quantitative trait in one sex than in the other as evidence for X-linkage of genes controlling expression of that trait. Instead evidence for X-linkage is based on within-family comparisons, such as correlations of scores between persons of varying degrees of kinship. Observed values are then compared to theoretical values which would be expected from a theory of X-linkage. Based on the considerations of Fuller and Thompson (1960) it can be predicted that any contributions of sex-linked genes to the observed variance in quantitative traits will tend to result in the following:

a) father-son correlations should be approximately zero because males do not receive an X chromosome from their fathers;

b) father-daughter and mother-daughter correlations will be greater than zero because females receive one X chromosome from each parent;

c) father-daughter correlations will be higher than mother-daughter correlations because females always receive their father's only X chromosome, but may receive either of their mother's X chromosomes;

d) mother-son correlations should be about equal to father-daughter correlations because in both cases, half of the X chromosomal inheritance of the female member of the pair is identical to the X chromosomal inheritance of the male member of the pair.

Thus the predictions are:  $(\text{mother-son} \approx \text{father-daughter}) > (\text{mother-daughter}) > (\text{father-son} \approx 0)$ .

One study which found a pattern of intrafamily correlations consistent with an X-linkage interpretation has been published by Stafford (1961), who gave 104 fathers and mothers and their 58 teen-aged sons and 70 daughters the Identical Blocks Test, a measure of one's ability to visualize space. The pattern of intrafamily correlations of scores on this test was what would be expected on the assumption that aptitude for visualizing space is an X-linked recessive trait. Close approximation of observed values to theoretical values, assuming a 20% frequency of genes controlling this trait, was found. This study has been replicated by Hartlage (1970) using a different measure of spatial ability, the space section of the Differential Aptitude test. Corah (1965) reported the same pattern of correlations between children and their cross-sex or same-sex parents for performance on an embedded-figures test. Finally, Bock and Kolakowski (1973), using a revision of the Guilford-Zimmerman Spatial Visualization test, Form B, obtained the expected pattern of correlations from a sample of 167 families. In addition they identified two components of spatial ability, only one of which was due to X-linked recessive genes.

These studies taken together support the predictions of Fuller and Thompson. It is important to note that the required pattern of correlations is not obtained on the Mental Arithmetic Test of quantitative reasoning (Stafford, 1965), nor on any but the spatial subtest of Raven's Progressive Matrices (Guttman, 1974). One is thus led to the conclusion that for a variety of tests of spatial ability, a pattern of family correlations consistent with an X-linkage recessive gene hypothesis has been obtained. Such a pattern is difficult to explain via experiential hypotheses, since, as Garron (1970) has pointed out, such theories would predict that like-sex parent-child pairs should be more similar than unlike-sex parent-child pairs, and the opposite is true.

A second line of evidence regarding X-linked recessive gene determinants of differences in spatial ability is based on Stern's (1973) prediction that, for qualitative traits which are determined by recessive alleles on the X chromosome, the proportion of females showing the trait will be the square of the proportion of males showing the trait. This is because females must get the recessive allele from both parents, while males must get it from their mothers only. Extrapolating to quantitative traits such as scores on spatial ability tests, the prediction is that the mean spatial ability score for males should be higher than for females. This result was obtained by Stafford (1961), Hartlage (1970), and Bock and Kolakowski (1973), although not by Corah (1965). Of course, this result is also consistent with environmental hypotheses.

Two lines of evidence appear to be inconsistent with an X-linkage recessive gene hypothesis for the determination of differences in spatial ability. The first is Bock's (1967) report that females who excel in spatial ability do not always have fathers who excel. They should if it is true that the daughters excel because

they have received one recessive allele from each of their parents and the fathers must therefore have the recessive allele on their one X chromosome. On the other hand, Bock explains that the lack of high spatial scores on the part of the fathers could be due to poor motivation. Thus the finding may not actually contradict the hypothesis of an X-linked recessive gene mechanism.

The second line of evidence which appears to bring Stafford's (1961) hypothesis into question is the data from women with Turner's syndrome who have an XO sex chromosomal complement. Such females are similar in genetic inheritance to normal males insofar as they have only one allele of each gene located on the X chromosomes, and have only a single X chromosome. Such women should, therefore, show a similar distribution of spatial ability test scores to normal males and equally superior to normal females. But several studies (Ferguson-Smith, 1965; Money & Granoff, 1965; Shaffer, 1962) have shown that the spatial ability test scores of women having the XO complement and no other chromosomal abnormalities usually associated with Turner's syndrome nevertheless have spatial ability test scores which are lower even than those of normal females.

Bock and Kolakowski (1973) have discussed an additional mechanism which may need to be posited in order to account for the Turner's syndrome data and related data from males suffering from testicular feminization. This is that the gene determining spatial ability differences is not only X-linked recessive, but is limited in its expression to persons in whom a given threshold of testosterone is operative. This would explain all the data because Turner's XO women do not produce testosterone and testicular-feminized males are insensitive to testosterone, while both normal males and normal females produce testosterone, but males produce more.

The data discussed in this section suggest that spatial visualization ability is X-linked and testosterone-limited in its expression. Of course, the expression of any trait which is under genetic control is dependent upon interaction with the environment. Different environments may certainly affect the expression of the trait differentially. Furthermore, since X chromosomes are virtually the only ones for which even partial mapping has been done and since the X chromosome probably carries about 5% of the genetic material which a person inherits, it is not too surprising that genes controlling some intellectual trait expression will be found on them. While IQ tests do involve items testing spatial visualization, it does not follow that X-linked genes make a significant contribution to IQ test scores. That hypothesis must be tested separately. Three lines of evidence will be presented: data relative to the hypothesis that the effects of inbreeding on IQ test scores should differ by sex in a particular way, data concerning the prediction that the mean IQ for males should be higher than for females, and correlations of IQ scores between opposite-sex fraternal twin pairs and same-sex fraternal twin pairs.

## THE CONTRIBUTION OF X-LINKED GENES TO SEX DIFFERENCES IN FULL-SCALE IQ

The first line of evidence relevant to a theory of X-linkage of genes determining differences in IQ concerns the difference in amount of X chromosomal material by sex on which inbreeding might have an effect. According to Jensen (1971) the effects of inbreeding on IQ test scores should be greater in girls than in boys if X chromosomal genes influence IQ differences. This hypothesis is based on the fact that such inbreeding depression can occur in 23/23 chromosome pairs in girls and only 22/23 chromosome pairs in boys. Thus, according to Jensen's hypothesis, boys should show 96% of the inbreeding effect which girls show. Schull and Neel (1965, p. 293), in their study of the effects of inbreeding on nearly 2,000 children of consanguineous parents in Hiroshima report this percentage difference in full-scale scores on the Japanese version of the WISC, but the difference was not statistically significant ( $\chi^2 = 13.51$ ,  $df = 11$ ). Thus the point estimation is in agreement with Jensen's hypothesis, but the interval of uncertainty is too wide to support it. Because such a small difference is hypothesized, a larger data base is needed on which to adequately test Jensen's hypothesis.

The second line of evidence concerns the extrapolation of Stern's (1973) prediction for qualitative traits to the case of quantitatively scaled traits: the mean score for males should be higher than the mean score for females. This hypothesis was supported for spatial ability, but it is clearly not supported for IQ. The means of the distribution of IQ by sex are equal. Of course this is in part due to the fact that items on which the sexes differed in average performance were eliminated from the tests as far as was possible (Wechsler, 1958). Thus the equal mean IQ by sex is due to an artifact of the test design and tells one little about the extent to which differences in IQ scores are determined by genes on the X chromosomes.

Fortunately a third line of evidence concerning a general theory of X-linkage determination of differences in IQ is available. It is based on the fact that such a theory predicts that IQ score correlations between opposite-sex fraternal twins should be lower than IQ correlations between same-sex fraternal twins. This prediction is based on three considerations. First, siblings share one-half of their genetic inheritance, so that for any trait determined by genes on the autosomes, the prediction is that the correlation between siblings should be .50. Second, X-linkage should lower the correlation below .50 for IQ scores between opposite-sex fraternal twins, since a daughter receives one or the other of her mother's two Xs and one X from her father, while a son receives only one or the other of his mother's two Xs. Third, X-linkage should have no effect on the correlation of IQ scores between male same-sex fraternal twins relative to the .50 correlation predicted for nonsex-linked inheritance because each son in such a pair may get



a different X from his mother. But for female same-sex fraternal twins, X-linkage should raise the correlation of IQ scores above .5 between such pair members because each daughter in such a pair receives the same X from her father. The overall prediction, then, is that correlations of IQ scores between opposite-sex fraternal twins should be significantly lower than such correlations between same-sex fraternal twins if X-linked genes make a significant contribution to IQ scores. But are they?

Erlenmeyer-Kimling and Jarvik (1963), in their summary of 52 studies reporting intelligence test correlations (2/3 of which were derived from IQ tests), found 9 correlation coefficients of IQ scores for opposite-sex fraternal twins and 11 such correlation coefficients for same-sex fraternal twins. There was no tendency for same-sex fraternal twins to be closer in IQ than opposite-sex fraternal twins. The median correlation of IQ for both groups was exactly the same, .53. Such evidence clearly fails to support an X-linkage theory of inheritance of IQ.

#### IMPLICATIONS FOR THE GENERAL QUESTION OF THE ORIGINS OF SEX DIFFERENCES IN INTELLECT

What conclusions can be drawn from the interpretive and empirical considerations just cited? First, the finding of greater variability in expression of IQ among males than among females follows from any number of hypotheses concerning genetic determinants of differences in IQ test scores, and it would be difficult to view such a fact as enabling one to choose among competing genetic theories. Second, when put to the test, a pattern of intrafamily correlations predicted by X-linkage for IQ fails to emerge. It is important to specify the limits of use to which such correlations are subject. While patterns of intrafamily correlations are useful for testing the X-linkage hypothesis, they are relatively useless for finding an answer to the question of the relative importance of genetic and environmental determinants of psychological sex differences. This is because there is a tendency for the environmental similarity of genetic relatives to vary directly with the degree of kinship, so that the two determinants are confounded and accurate estimates of heritability are thus difficult to obtain. Furthermore, there is no reason to assume that the underlying causes of sex differences in variability of IQ scores are identical at both the lower and upper ends of the distribution. Freire-Maia, Freire-Maia and Morton (1974) recently reported analyses supporting an explanation for the excess of mentally retarded males relative to females in both noninstitutionalized and institutionalized populations based on any one of three sex-modified threshold models. These models are similar to the one elaborated for spatial ability differences by Bock and Kolakowski (1973) discussed earlier. Several lines of evidence presented by partici-

pants in a symposium on intelligence held at the University of Illinois (in Cancro, 1971) suggest that, while alleles involved in mental retardation tend to be recessive, those involved in superior levels of intelligence tend to be dominant. Thus if dominance were complete, X-chromosome involvement in the causes of sex differences in variability of IQ scores would lead to the expectation of an excess of low scores by males relative to females, but not to an excess of high scores by either sex relative to the other. The question concerning the causes of the excess of high-IQ males would thus remain open.<sup>4</sup>

From the foregoing it should now be clear that there is no one general answer to the question of "the heritability of sex differences in intellectual functioning" because so much is left unspecified. Heritability refers to that fraction of the observed variation in expression of a particular trait which can be attributed to differences in heredity. Any question concerning heritability must therefore specify the differences in trait expression under consideration, the particular population concerning which the question is being asked, and the particular environmental conditions obtaining at that time. Estimates of its value can be made larger or smaller merely by altering the amount of environmental variation present in the population under study. This is why estimates of heritability such as those based on intrafamily correlations tell one nothing about how similar two persons' IQ scores might have been had they been reared under more diverse or less diverse environmental conditions.

This is an important point precisely because there is growing evidence to support the hypothesis that the environment to which boys are exposed is different from the environment to which girls are exposed in terms of role models in books (Key, 1971), mother-infant interactions (Lewis, 1972), father-infant interactions (Rebelsky & Hanks, 1972), and punishment and other pressures to avoid "sex-inappropriate" behavior (Maccoby & Jacklin, 1974). Certainly environmental variation between the sexes continues to be as likely a source of sex differences on psychological tests of intellectual functioning as is the obvious genetic variation between them. As long as the sexes continue to be treated differently, it will continue to be impossible to give one correct, general answer to the question of whether heredity or environment is more important in determining variations in mental trait expression by sex. The best procedure for determining the fraction of variability in mental traits by sex due to genetic factors is to remove the difference in environmental variation between them. This does *not* require that every child be exposed to the same environmental treatment as every other child, but merely that as little as possible of the variation in child-rearing practices be based on sex.

As Hirsch (1967) has pointed out, even if accurate estimates of the heritability of differences in behavioral trait expression were known, the degree to

<sup>4</sup>The author gratefully acknowledges the comments of the consulting editor on this issue.

which behaviors are subject to change could *not* be inferred from the magnitude of such estimates. The relationship between the heritability of differences in behavioral trait expression and the degree to which behaviors can be changed can only be assessed ad hoc. Increasing the variation in child-rearing experiences to which boys are exposed and to which girls are exposed while minimizing the differences in environmental variation *between* the sexes provides one way in which to explore the answer to the question concerning the environmental conditions under which particular genetic codes will be expressed. In other words, only when we are willing to allow boys and girls equal opportunity to express their individual genetic predispositions, independently of the child's sex, will we begin to have a clearer idea of how much of a difference genes really do make in determining psychological sex differences in intellectual functioning. Until then, the role of genes will continue to be obscured by differences in treatment by sex with which they are confounded.

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