Correlation Study between Second/Fourth Digit Ratio, Number of Older Brothers and Mathematics Inclination in Female Pre-service Teachers

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***Abstract*--Prenatal hormones have been shown to influence individual characteristics. The ratio of the lengths of the index finger and ring finger (2D:4D) is commonly used as an indicator of prenatal testosterone exposure. This study examines the possibility that prenatal hormones, as measured by the 2D:4D finger length ratio, may influence female pre-service teaching students' mathematics inclination, as indicated by their choice of major and minor concentrations. Also studied was the possible correlation between the number of older brothers and this mathematics inclination. The results point to a statistically significant link between the right 2D:4D ratio and the choice of a mathematics major or minor in female pre-service education students. However, a link between the number of older brothers and the choice of mathematics major or minor was not determined.**

***Index Terms*—Androgens, Digit Ratio, Finger length, Mathematics Inclination, Testosterone**

I. INTRODUCTION

The ratio of index finger to ring finger length (2D:4D) and its links to human characteristics has been the focus of much research in recent years. Digit ratio has been shown to be related to several traits [1]. High levels of prenatal testosterone are associated with low 2D:4D ratios [2], [3]. Also males usually have a lower 2D:4D digit ratio than females [3]. Mixed results have been found as to the digit ratios differing between the right and left hand [4]. The "masculinizing" effect of prenatal testosterone on the brain has been shown to result in higher spatial ability [5]. A negative correlation has been found between right hand 2D:4D ratios (lower ratios are more masculine) and higher numerical intelligence [6]. Higher spatial ability and numerical intelligence are indicative of higher mathematical abilities. Fink, Brookes, Neave, Manning and Geary [7] found that lower digit ratios in boys aged 6-11 were associated with higher numerical performance. Girls were not found to have this correlation. Higher testosterone levels may influence abilities that give males advantages on mental rotation tasks [8]. However, Putz, Gaulin, Sporter and McBurney [9] found significantly better Mental Rotation Test scores in females with higher (less masculine) 2D:4D left hand ratios. Brosnan [10] found, in an academic sample, that the Social Science Faculty of both sexes had a digit ratio consistent with the male norm of 0.98, yet the Science Faculty had a more female norm of 1.00. Photocopies of the fingers have been found to yield lower digit ratios [11] than direct finger measurements do, so the testing herein used direct measurements. Internet self-reported measurements were found to have large measurement error [12], so trained measurers were used herein.

The connection between 2D:4D digit ratio and birth order has also been the focus of recent research. The digit ratios for females varied with neither number of older brothers or sisters nor birth order [13]. Dominant women have been found more likely to conceive sons [14].

In this study, the possibility that prenatal hormones may positively correlate with mathematics inclination was investigated. Prenatal hormones levels were determined using the right-hand 2D:4D finger length measurement ratios of female pre-service teaching students. Mathematics inclination was indicated by the students' choice of major and minor concentrations, mathematics versus non-mathematics. Also studied was a possible connection between the numbers of older brothers that the students have and this mathematics inclination.

II. METHODS

A sample of 69 female pre-service teaching students was studied within several mathematics courses at the researcher's college. Within this sample, 46 of the students were not mathematics majors or minors, while 23 of them were. The study was conducted from 2005 to 2009. This admittedly small study is to be expanded upon in the future. Male students were studied; however, there was not a large enough sample size to show statistical significance (1 male student with a mathematics major and 4 non-mathematics majors), and hence were not included in the analysis.

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The palm-side of the index and ring fingers of the subjects' right hands were measured with digital calipers. Actual measurements, not photocopies of the hands, were used. The estimated error in measurements was ± 0.5 mm.

The first claim to be submitted to hypothesis testing was as follows:

The 2D:4D ratio of the pre-service teacher program students that exhibit mathematics inclination [population 1] as indicated by their choice of a mathematics major or minor is less than the 2D:4D ratio of the pre-service teacher program students that do not exhibit mathematics inclination [population 2] as indicated by their choice of a non-mathematics major or minor.

The hypothesis test was a one-sided test, using the means of the 2D:4D ratios.

The sample means of the 2D:4D ratios of the two population samples were compared. The level of significance was chosen to be 5% corresponding to a left tailed test. The variance was assumed to be different for the population of students who exhibit mathematics inclination than for the population of people who do not exhibit mathematics inclination. The test was a "t" test since the population variances were unknown. A "pooled" or combined estimate of the common variance was not used. Data analysis determined the sample variances.

The null hypothesis for this test was that the population means were equal. The alternate hypothesis was that the mean of population 1 was less than that of population 2. The criterion for rejection of the null hypothesis was if the test statistic was less than the critical value with the appropriate degrees of freedom in accordance with the sample.

The second claim to be submitted to hypothesis testing was as follows:

The number of males previous to the subject in birth order of the pre-service teacher program students that exhibit mathematics inclination [population 1] as indicated by their choice of a mathematics major or minor is greater than the number of males previous to the subject in birth order of the pre-service teacher program students that do not exhibit mathematics inclination [population 2] as indicated by their choice of a non-mathematics major or minor.

The hypothesis test was a one-sided right tailed test, using the means of the number of males previous to the subject in birth order. The sample means of the number of males previous to the subject in birth order of the two population samples were compared.

The level of significance of the "t" test with unknown population variances was again chosen to be 5%. The null hypothesis for this test was that the population means are equal. The alternate hypothesis was that the mean of population 1 was greater than that of population 2. The criterion for rejection of the null hypothesis was if the test statistic was greater than the critical value with the appropriate degrees of freedom in accordance with the sample. Statistical parameters were calculated using Microsoft Excel® and Texas Instruments® software.

III. RESULTS

The sample statistical results, for the first claim, that of the digit ratio difference within the two populations, were as follows. The sample means, $\overline{\chi}_1$ and $\overline{\chi}_2$, and the sample standard deviations, S_1 and S_2, of the 2D:4D digit ratios of the two population samples, were compared.

Sample Means, Standard Deviations and Sizes

2D:4D Population 1	*2D:4D Population 2*
Math Major or Minor	*Non-Math Mjr/Minor*
$\overline{\chi}_1 = 0.962$	$\overline{\chi}_2 = 0.999$
$S_1 = 0.038$	$S_2 = 0.050$
$n_1 = 23$	$n_2 = 46$

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 < \mu_2$

Using the non-pooled variance $t_0 = -3.405$ [15].

The criterion for rejection of the null hypothesis, $H_0: \mu_1 = \mu_2$, was $t_0 < -t_{\alpha,v}$. Since $t_0 = -3.405$ which was indeed less than the critical value $-t_{\alpha,v} = -1.679$ [16], for 45 degrees of freedom, the null hypothesis was rejected. Also, the p-value of 0.0006 was less than the level of significance, α, of 0.05, alternatively pointing to rejection of the null hypothesis. The population 1 mean was statistically less than the population 2 mean.

The sample data supports the claim that population 1 has a lesser mean than population 2. That is, the sample data support the claim that the 2D:4D ratios are less for the female pre-service teacher program students that exhibit mathematics inclination [population 1] as indicated by their choice of a mathematics major or minor than the 2D:4D ratios of the female pre-service teacher program students that do not exhibit mathematics inclination [population 2] as indicated by their choice of a non-mathematics major or minor.

The second claim that was submitted to hypothesis testing was that of the number of males previous to the subject in birth order being a factor in mathematics inclination. The same samples of students were surveyed to find out the number of males that their natural mother had given birth to, previous to the subjects' birth. Once again, population 1 was the pre-service teacher program students that exhibit mathematics inclination as indicated by their choice of a mathematics major or minor. Population 2 was the pre-service teacher program students that do not exhibit mathematics inclination as indicated by their choice of a non-mathematics major or minor. The sample results were as follows:

Sample Means, Standard Deviations and Sizes

Population 1	*Population 2*
Math Major or Minor	*Non-Math Mjr/Minor*
$\overline{\chi}_1 = 0.556$	$\overline{\chi}_2 = 0.348$
$S_1 = 1.363$	$S_2 = 0.566$
$n_1 = 23$	$n_2 = 46$

$H_0: \mu_1 = \mu_2$

$H_1: \mu_1 > \mu_2$

Using the non-pooled variance $t_0 = 0.701$.

The criterion for rejection of the null hypothesis, $H_0: \mu_1 = \mu_2$, was $t_0 > t_{\alpha,v}$.

Since $t_0 = 0.701$ which is not greater than the critical value of $t_{\alpha,v} = 1.684$ [16]. The p-value of 0.245 is not less than the level of significance, α, of 0.05. Therefore, we cannot reject the null hypothesis H_0: $\mu_1 = \mu_2$. There were approximately 26 degrees of freedom for this non-pooled variance test.

The sample data therefore does not support the claim that population 1 has a greater mean than population 2. The hypothesis that the number of males previous to the subject in birth order of the pre-service teacher program students that exhibit mathematics inclination [population 1] as indicated by their choice of a mathematics major or minor is greater than the number of males previous to the subject in birth order of the pre-service teacher program students that do not exhibit mathematics inclination [population 2] as indicated by their choice of a non-mathematics major or minor is not supported by this study.

Even when using the less conservative pooled estimate of common variance, which assumes that the two population standard deviations are equal, the test would have the same outcome. However, this equality of population standard deviation assumption is not supported by the sample evidence, which shows that the sample standard deviation of population 1 is almost triple that of population 2. To sum up the second part of testing, the hypothesis that the number of males previous to the subject in birth order of the pre-service teacher program students that exhibit mathematics inclination [population 1] as indicated by their choice of a mathematics major or minor is statistically greater than the number of males previous to the subject in birth order of the pre-service teacher program students that do not exhibit mathematics inclination [population 2], as indicated by their choice of a non-mathematics major or minor is not supported by the analysis.

IV. CONCLUSIONS

This study found evidence that female pre-service teaching students who were inclined toward mathematics exhibited smaller, more masculine, digit ratios than those who were not as mathematically inclined. The right-hand 2D:4D ratios of the female pre-service teaching students who had a mathematics major or minor as their chosen field of study were compared to the right-hand 2D:4D ratios of the female pre-service teaching students who did not have a mathematics major or minor as their chosen field of study. The 2D:4D ratios of those with the mathematics major or minor was found to be statistically significantly less than those without. Please note that causality is not claimed, merely correlation.

The masculinizing effect that high prenatal testosterone exposure (low right 2D:4D) has on the brain has been linked to higher numerical intelligence [6]and spatial ability [5]. Seemingly, those with higher numerical intelligence and spatial ability would show more aptitude towards mathematics, and hence be more inclined to focus their studies in those areas which rely more heavily on mathematical ability. In pre-service teaching students, this ability might influence the students' choice of major, either towards a mathematics focus for those with higher mathematics ability, or towards another, non-mathematics focused specialty for those with lower mathematics ability.

Findings herein showed no evidence of linkage between the number of older brothers that a female pre-service teaching student has and her choice of a mathematics focus. The mean number of elder male siblings born to the same mother of the mathematically focused students was not shown to be statistically different than that of the non-mathematics focus.

These findings suggest that prenatal androgens may play an important role in determining mathematics inclinations. The author intends to continue on with the research.

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