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# The relationship between digit ratio and personality: 4D:5D digit ratio, sex, and the trait of conscientiousness

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## SUMMARY

**Sex differences cause differences in hormone levels, impacting many aspects of humans, including the digit ratio and personality. Due to this impact, we decided to investigate the effect of the 4D:5D digit ratio in influencing the personality trait of conscientiousness in female participants. Because research has suggested that a larger 4D:5D digit ratio could indicate more feminine characteristics, we hypothesized that greater conscientiousness would be expressed in females as compared to males. We performed this study by using two methods of data collection, which included quantitative digit ratio measurements and an online survey assessing personality traits. By looking at the relationship between sex and level of conscientiousness through the responses from our survey and the relationship between sex and 4D:5D digit ratio through measurements, we discovered that these findings support our hypothesis that there is a relationship between female sex and increased level of conscientiousness. However, we did not discover a direct relationship between right 4D:5D digit ratio and conscientiousness. Noting that this is an association rather than a causal factor, this suggests that sex-hormone driven differences are influencing the physical attributes of the digit ratio and the personality traits, including conscientiousness.**

## INTRODUCTION

Individual differences refer to a range of variable characteristics in each person. A major factor that plays a role in physical and psychological individual differences is sex differentiation (1). Sex differentiation occurs as a result of a combination of genetics, hormones, environmental factors, and epigenetics. Males typically have the XY genotype and females have the XX genotype, leading to gonadal differentiation and the release of different sex hormones (1). Thus, the degree of an individual's masculinity and femininity, physically and psychologically, is partly influenced by the levels of sex hormones, estrogen and testosterone, that he or she was exposed to during the time in the mother's uterus (2). For example, the level of prenatal exposure to the hormone testosterone influences the mindset and preferences of a child for certain gendered activities, possibly further developing interests during childhood that correlate with their sex-typed behaviors (2). Sex differentiation is, therefore, a complex biological process that influences factors such as digit ratio and personality traits, allowing such factors to provide further insight into the process of sex differentiation. There have been a small number of studies that have directly measured the level of sex hormones and their relation to the 2D:4D digit ratio, in which they have obtained some significant results regarding a negative correlation between increased prenatal testosterone exposure and decreased left 2D:4D digit ratio (3). Literature, however, has broadly pointed to a negative association between testosterone exposure and digit ratio. To receive a better understanding of the relative level of sex hormones that individuals may have been exposed to in the uterus, psychologists can calculate their digit ratios (4).

People's digit lengths change during the developmental stages of their lives, but the digit ratio is a measure that remains proportionally constant since the ratio of the digit lengths changes proportionally (7). There are different digit ratios that scientists study, but the most frequently studied and established digit ratio measure is the 2D:4D digit ratio. We reviewed and cited studies that examined the 2D:4D digit ratio, which led to our investigation of the 4D:5D digit ratio. The 4D:5D digit ratio is defined as the ratio between the fourth digit of the hand and the fifth digit of the hand. Digit ratio can vary between the left and right hands due to a difference in the levels of estrogen and androgen activity that are present on different digits (4). Researchers have found that the right-hand digit ratios are better indicators of prenatal androgen exposure as compared to left hand digit ratios when they are measured ventrally (5). The 4D:5D digit ratio is an emerging area of interest and has only began to be studied recently, thus we decided to focus on this ratio as opposed to the other studied ratios, including the 2D:4D digit ratio. Recent studies found that the 4D:5D digit ratio actually provides a stronger correlation to sex differences than does the 2D:4D digit ratio (6). Hormonal correlations with sex are more strongly exhibited in ratios involving digit 5, demonstrating the increased insight that a 4D:5D digit ratio could provide. Furthermore, when the significance of the digit ratio correlates were compared, the 4D:5D digit ratio produced the largest effect size for sexual dimorphism, meaning that it resulted in the strongest relationship to sexual dimorphism (6). In general, a higher digit ratio is associated with femininity and a lower digit ratio is associated with masculinity, suggesting that prenatal hormones influence digit ratios (2). Specifically, a lower prenatal exposure to testosterone and a higher exposure to estrogen is correlated with increased femininity and an increased digit ratio. On the other hand, increased testosterone exposure is correlated with a decreased digit ratio, as seen in many males (8). This digit ratio can be

| | Sex | Min | Q1 | Median | Q3 | Max | Mean | SD | n |
|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 1.06 | 1.19 | 1.21 | 1.24 | 1.34 | 1.22 | .07 | 11 |
| 2 | M | 1.06 | 1.19 | 1.26 | 1.28 | 1.30 | 1.22 | .08 | 11 |

**Figure 1:** Statistical values for right 4D:5D digit ratios between males and females: Descriptive statistical values shown for the right 4D:5D digit ratios of 22 participants, both male and female. Original sample was 24 participants, but 2 were excluded from digit ratio and conscientiousness analysis due to gender not being reported. (sd= standard deviation, n= number of participants in each group).

associated with the behavioral differences that the different sexes exhibit. Sex differences are variations in the brain, leading to behavioral and psychological differences (6,9).

The Big Five personality traits are factors that can be influenced by sex differentiation and prenatal hormone exposure (10). These five traits include neuroticism, extraversion, openness, agreeableness, and conscientiousness (11). The trait of conscientiousness involves the degree to which an individual takes responsibility, demonstrates self-discipline, and strives for achievement (11). It is also a quality that reflects on the individual's organization and dependability (11). In previous studies investigating the relationships between digit ratios and the Big Five personality traits, a significant association was found for the trait of agreeableness, where females exhibited higher scores than males did (10). Neuroticism was also found to be associated with a higher digit ratio among both sexes, but only for the right-hand digit ratio in females (13). However, it is unclear whether associations exist between sex differentiation and the trait of conscientiousness. In fact, out of the big-five personality traits, conscientiousness has been understudied in regards to the trait's capacity to reflect sex differences and its relationship with digit ratio. In one previous study that looked at gender rather than sex, increased conscientiousness was weakly associated with femininity but was not significantly linked to gender differences (13). Predominantly, previous studies examining the Big-Five traits have only examined their relationships with gender, without considering the relationship to digit ratios. Thus, we conducted this study to examine the relationship between digit ratios and the expression of conscientiousness as a personality trait.

We hypothesized that females would have greater right 4D:5D digit ratios and would exhibit greater conscientiousness than males. By obtaining digit measurements from participants and obtaining their responses from a survey that assessed their masculinity and femininity, we created graphs that allowed relationships between sex, digit ratio, and conscientiousness to be visualized. Our data indicated that females have greater levels of conscientiousness, showing that there is a relationship between 4D:5D digit ratio and personality expression by different sexes.

## RESULTS

In order to investigate the relationship between 4D:5D ratios and differences in conscientiousness among the sexes, we administered a survey to quantify personality differences and concurrently calculated digit ratios of the participants. The survey was administered to 24 participants who reported their biological sex and provided measurements, in centimeters, of their second, fourth, and fifth digits of both their left and right hands. Participants were asked to take five measurements for each digit and average the measurements. The survey, which included statements with scales for participants to decide the extent to which they agreed or disagreed, allowed data to be collected and converted into a numerical score (7). Each individual's response scores were categorized into subscores for each of the Big Five personality traits.

First, we performed an analysis comparing male and female participants' digit ratios using the right hand digit ratio measurements obtained for the fourth and fifth digits. We found that the right 4D:5D digit ratios of males and females were largely similar (**Figure 1**). The mean digit ratio value in males ($M$ = 1.22, $SD$ = 0.08) was slightly greater than the mean digit ratio value in the females ($M$ = 1.22, $SD$ = 0.07). When the mean right hand 4D:5D digit ratios were compared between males and females using an independent-samples $t$-test, we found no significant difference between the means of the sexes ($t(19.819) = -0.185$, $p = 0.855$).

We then compared the relationship between digit ratios and numerical conscientiousness scores in both males and females. Conscientiousness scores positively correlated with the right 4D:5D digit ratio in females (**Figure 2**). Spearman rank-order correlations were calculated and resulted in a strong trend, although it did not meet statistical significance, for female participants' conscientiousness scores and their right 4D:5D ratios ($\rho(9) = 0.638$, $p = 0.064$). Male participants, however, did not exhibit either a positive or significant relationship between conscientiousness scores and right 4D:5D digit ratio ($\rho(9) = -0.156$, $p = 0.713$).

On average, levels of conscientiousness were found to be higher in female participants than in male participants (**Figures 3 and 4**). The average conscientiousness score for

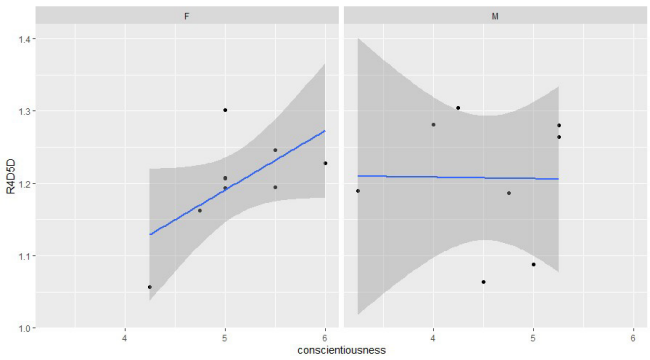


**Figure 2:** Relationships between conscientiousness, right 4D:5D ratio, and sex: Correlation plots showing the relationship between conscientiousness and right 4D:5D digit ratios for females and males. The female plot shows a strong positive correlation, as indicated by the blue line. The deviation of the female digit ratios is indicated by the gray area. The male plot demonstrates the lack of correlation, as indicated by the horizontal blue line. The deviation of the male digit ratios is indicated by the gray area. In both plots, points located outside of the gray area indicate outliers.

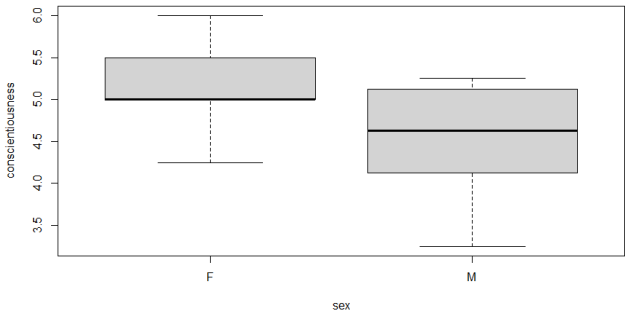


**Figure 3:** The effect of sex on the personality trait of conscientiousness: Box-and-whisker plots showing the relationship between sex and conscientiousness for females and males (a total of 22 participants). The female plot indicates a higher median and lower range for conscientiousness scores. The male plot indicates a lower median and higher range for conscientiousness scores.

females was 5.111 (*SD* = 0.502) while the average for males was 4.531 (*SD* = 0.687). However, these differences were not significant at the $p < .05$ significance level ($t(12.71) = 1.966$, $p = .072$). Our results suggest that, overall, conscientiousness is more strongly expressed in females than in males, which supports our hypothesis.

4D:5D digit ratio was initially chosen for our study because it has been investigated as a more accurate measure of digit ratio differences. However, we also tested if the more established measure, the right 2D:4D ratio, would result in different findings upon running the same statistical tests. The mean right 2D:4D ratio for males (*M* = 1.01, *SD* = 0.05) was significantly higher than for females (*M* = 0.967, *SD* = 0.027) at the $p < .01$ significance level ($t(16.279) = -2.828$, $p = .01$) (**Figure 5**). Interestingly, Spearman rank-order correlations showed that female participants' mean right 2D:4D ratio was significantly positively correlated with their conscientiousness scores at the $p < .05$ level ($\rho(7) = -0.680$, $p = 0.044$). Conversely, the male participants' digit ratios were not significantly correlated with their conscientiousness scores ($\rho(9) = -0.116$, $p = 0.784$). Although the females did not have greater right 4D:5D ratios or right 2D:4D ratios than the males, they did have significant correlations with conscientiousness scores for 2D:4D measure of digit ratio in contrast to the males.

## DISCUSSION

To test the hypothesis that females would have greater 4D:5D digit ratio and greater conscientiousness scores, we collected digit ratio measurements and survey responses. We then used statistical tests and graphs to determine the relationship between sex and right 4D:5D digit ratio as well as the relationship between sex and conscientiousness.

Our analyses of survey scores demonstrated that there is a relationship between sex and conscientiousness. Females received greater scores in the section of the survey that assessed conscientious traits whereas males received lower scores (**Figures 3 and 4**). These results highlight a relationship between sex and the degree of expression of the personality trait conscientiousness, although the driving factor behind the correlation may not be prenatal hormonal exposure. Since personality could be impacted by biological factors, such as prenatal hormone exposure, and environmental factors, the lack of a correlation seen between higher 4D:5D digit ratio and increased conscientiousness suggests that there may be environmental factors that cause females to have greater conscientiousness.

Our experiment demonstrated the connection between sex and personality, specifically regarding the trait of conscientiousness, where females received higher conscientiousness scores than males on our survey. However, a relationship between a higher 4D:5D digit ratio and increased conscientiousness across both sexes was not indicated since both the male and female participants had similar 4D:5D digit ratios. The lack of a relationship between higher digit ratio and conscientiousness was further supported in our examination of 2D:4D ratios, where males had higher right 2D:4D digit ratios but did not have higher conscientiousness scores. While females did not have a greater digit ratio than the males, as predicted by our hypothesis, the aspect hypothesizing that females exhibit increased levels of conscientiousness was supported. Therefore, it can be inferred that rather than prenatal hormone exposure serving as the driving factor behind the increased trait of conscientiousness in females, there may be different factors causing the relationship. Such factors include "nurture" factors, which refer to the social and environmental influences that shape individuals' personality traits. Specifically, the family environment and

| | Sex | Min | Q1 | Median | Q3 | Max | Mean | SD | n | missing |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | F | 4.3 | 5.0 | 5.0 | 5.5 | 6.0 | 5.1 | 0.5 | 9 | 2 |
| 2 | M | 3.3 | 4.2 | 4.6 | 5.1 | 5.3 | 4.5 | 0.9 | 8 | 3 |

**Figure 4:** Statistical scores for conscientiousness in males and females: Descriptive statistical values shown for conscientiousness scores of 17 participants total, 8 males and 9 females. Out of 22 participants, 2 females' scores were missing, and 3 males' scores were missing. (sd= standard deviation, n= number of participants in each group).

| | Sex | Min | Q1 | Median | Q3 | Max | Mean | SD | n |
|---|---|---|---|---|---|---|---|---|---|
| 1 | F | .935 | .944 | .965 | .984 | 1.021 | 0.967 | 0.027 | 11 |
| 2 | M | .93 | .99 | 1.02 | 1.04 | 1.08 | 1.01 | 0.05 | 11 |

**Figure 5:** Statistical values for right 2D:4D digit ratios between males and females: Descriptive statistical values shown for the right 2D:4D digit ratios of 22 participants, both male and female. Original sample was 24 participants, but 2 were excluded from ratio and conscientiousness analysis due to gender not being reported. (sd= standard deviation, n= number of participants in each group).

social relationships can influence how a male or female views themselves, causing an increased expression of certain personality traits. Social pressures, for instance, can cause females to become increasingly conscientious (2). Interestingly, the spread of conscientiousness scores as measured by standard deviation was smaller for the females than the males, showing that the female scores did not vary as greatly as the male scores. This lesser variance in female conscientiousness scores could imply that females, in general, possess a level of conscientiousness that is higher than males.

One limitation of this experiment was the small sample size. The trends exhibited in this experiment may be strengthened if there are more participants. Another limitation was that there was not a complete data set for some participants as certain sections of their information were not entered. Having a full data set may also help strengthen the results. Additionally, sampling bias may have influenced our findings as the participants were not randomly selected. Many of the participants belonged to the Bethel College Summer Science Institute group of high school-aged participants, while others were family members of these students. With a randomized sample including participates with locational, ethnic, and age diversity, the trends found between sex and conscientiousness could be further established and generalized.

Furthermore, the digit ratio itself is a measure that has been surrounded with debate regarding its accuracy in indicating prenatal hormone exposure. While many studies have supported that digit ratio is an accurate measure (3,4,5,6,7), others express limitations (15,16,17). Studies supporting the validity of the digit ratio have found a variety of behaviors and abilities that are connected to prenatal androgens, and the scientists support the idea that digit ratios reflect prenatal hormone exposure (15). However, the scientists that express limitations do so because the results of some studies have not been reproducible when they were conducted multiple times (15). Some scientists have also expressed skepticism because of the primary assumption behind the digit ratio, which is that the lengths of digits correlate with hormone level differences in the fetal stage (15). The results from one study in pregnant mice supports this assumption but another animal study that aimed to replicate the findings found contradictory results (16). Such conflicting natures of results have led to some scientists expressing reservations about the digit ratio.

Personality development is influenced by biological factors as well as environmental factors. Analysis of digit ratios provides insight into the biological aspects that impact personality development, but individuals' traits, such as conscientiousness, are further shaped by environmental influences during development. From the biological standpoint, females generally have higher digit ratios and males have lower digit ratios (2). Digit ratio is one of the biological factors that we chose to focus on in this study.

Since the 2D:4D and 4D:5D digit ratios were not higher in females as expected, the described limitations indicate there may be similar "nurture" factors or shared experiences that have impacted personality development in the females in this specific sample. This field would benefit from studies with larger sample sizes. If there are strong results regarding the association between sex and increased conscientiousness, psychologists could work to identify a biological basis for personality traits of males and females. Additionally, it is important to validate the right hand 4D:5D digit ratio as a reliable measure for the study of certain personality traits since we did not find a significant difference in right 4D:5D digit ratios between males and females, although expected. The right hand 2D:4D digit ratio for this sample demonstrated a significant difference between the sexes, as expected, which indicates that the right 4D:5D digit ratio needs to be studied further to understand patterns of significance. Lastly, studying the age as a factor in the relationship between sex and conscientiousness is important because sex hormones can change across stages of development, especially puberty, which could possibly impact the development of certain personality traits (2). This study could open up new pathways of research in nature and nurture factors as they relate to personality traits and development, which can be important in further understanding human behavior and factors in sex differentiation. In addition, the insights can open up new questions in digit ratio research.

## MATERIALS AND METHODS

We asked 24 people, with an ultimate sample comprised of 11 males and 11 females (see missing data reasoning below), to provide their digit measurements and take a survey where they indicated the extent to which they agreed or disagreed to specific statements. The broad range of participants included high school students participating in the Bethel College Summer Science Institute and their family members. Each participant took pictures of their right and left hands using their phones and then uploaded the images to the FIJI software program to measure the length of their pinky finger, ring finger, and pointer finger for each hand in pixels (14). Each participant also measured the length of a credit card to provide a standard of conversion from pixels to centimeters for data organization purposes. The participants entered their biological sex and digit measurements into an Excel spreadsheet. In order for measurements to be recorded more accurately, each participant used FIJI to measure each digit five times and took the average of these measurements, which is the number they entered into the spreadsheet. In addition to providing digit measurements, participants took a 70-question online survey administered to them through Google Forms. This survey included standardized questions from the Open Sex-Role Inventory (6,12) and the open-source SAPA Personality Project (10) that were intended to assess levels of the Big Five personality traits that they displayed, as part of a larger set of questions about different categories of risk-taking behaviors, and level of masculinity and femininity. The categories of risk-taking behaviors included financial risks, social risks, ethical risks, recreational risks, and health risks (the risk-taking variables and their results are beyond the scope of the currently reported personality results). The five personality traits that were assessed included neuroticism, agreeableness, conscientiousness, openness, and extraversion. Overall femininity and masculinity were also assessed. Once we obtained the survey scores for each participant, we averaged and entered them into the spreadsheet. For the final step of the experiment, we analyzed the data using the language R in the program RStudio version 3.6.1. Through RStudio, right 4D:5D and 2D:4D digit ratios were calculated, independent-sample T-tests were performed, Spearman rank-order calculations were determined, correlation graphs were created, a box-

and-whisker plot was created, and tables with descriptive and statistical values were created. We excluded two participants, who had not indicated their sex, from the statistical analysis since the study primarily focused on sexual dimorphisms. Not all of the statistical tests and graphs involved the same number of females and males due to missing data from some participants in certain categories, such as conscientiousness (see caption(s) of those plots). Furthermore, while there were 11 females and 11 males included in the analyses for both the right 2D:4D digit ratios and the right 4D:5D digit ratios, 9 females and 8 males were used in the conscientiousness analyses. Specifically, the t-tests for determining differences in right 4D:5D and 2D:4D digit ratios between males and females were compared at the $p < 0.01$ level. The *t*-test for determining differences in conscientiousness between the sexes was compared at the $p < 0.05$ level. For the Spearman rank-order calculations, the strength of the correlation was decided based upon the value's proximity to 1.0 or -1.0, and it was specifically categorized as moderately strong if the value was above 0.5 or below -0.5. To perform these tests in RStudio, the Mosaic package and its relevant codes were used, allowing calculations to be performed automatically.

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