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Asymmetry and empathy: Higher asymmetry is associated with lower levels of mentalizing

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ABSTRACT

People differ in their mentalizing abilities. Though past research suggests that individual differences in exposure to prenatal testosterone may be able to explain why some people excel at mentalizing, while others struggle, meta-analyses yield a null relationship between 2D:4D ratio (a proxy for prenatal testosterone) and mentalizing. Importantly, however, past research has not examined the asymmetrical differences between the digit ratios on the right and left hands. In the current work, we test whether the difference between the digit ratios of the left and right hands may function as a better predictor of mentalizing than digit ratio alone. In Study 1, we begin by validating an online, self-report measure of 2D:4D ratio, providing test-retest reliability, convergent, and concurrent validity for our measure. In Study 2, we demonstrate that a) 2D:4D is quadratically related to asymmetry, b) asymmetry is negatively associated with mentalizing, and c) the relationship between asymmetry and mentalizing cannot be explained by the relationship between asymmetry and short-term memory. Taken together, our results paint a more nuanced picture of the relationship between digit ratio and mentalizing ability.

Knowing what others are thinking and feeling is a fundamental human challenge—and one that has spawned a number of psychological strategies such as perspective-taking, empathy, and simulation. People are not, however, uniformly successful at employing these strategies from thought to thought or from person to person [39]. In the current work, we seek to identify whether and how differences in prenatal testosterone may partially explain these individual differences in mentalizing ability.

This paper aims to make three contributions. First, we show that asymmetry—a marker of developmental instability—can predict differences in mentalizing. Second, we begin to rule out possible alternative explanations of the relationship between asymmetry and mentalizing. Finally, we introduce a valid and reliable measure of the second-to-fourth digit ratio (2D:4D) that can be easily administered online at scale.

1. 2D:4D digit ratio and mentalizing

Using the 2D:4D ratio—the ratio of the length of one's second digit to the length of their fourth digit—prenatal testosterone has been extensively studied with relation to mentalizing [22,23,33,45,54,65]. The 2D:4D ratio serves as a marker for prenatal levels of testosterone, and has been validated using amniocentesis—the direct testing of the fluid from the amniotic sac that surrounds the fetus during gestation. Until quite recently, much theorizing on the relationship between testosterone and mentalizing arose from research on clinical deficits in theory-of-mind ability. For example, though most typically developing adults possess a well-developed theory-of-mind, neurodevelopmental conditions such as autism spectrum disorder can compromise these mentalizing abilities [74]. One explanation as to why those on the autism spectrum may show lower theory-of-mind abilities is the *fetal androgen theory* [2]. The theory submits that prenatal exposure to testosterone and other hormones is associated with marked reductions in social skills and theory-of-mind abilities [2,9], and with the development of autism spectrum disorders [43].

Following from the fetal androgen theory, the *empathizing-systemizing theory of sex differences* purports that deficits that are observed in autism may be explained by an extreme profile of naturally occurring sex differences [5,48]. Both of these theories have paved the way for a number of insights that have helped advance the field. However, there are a number of findings that are inconsistent with these two theories. While these theories suggest that fetal testosterone and mentalizing should be negatively related, several studies, indirectly suggest that there may be a positive relationship between testosterone and mentalizing. According to Russell and colleagues, males (who have higher prenatal androgen exposure than females) are more accurate than

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females at understanding mental states [55]. In another study, males with the *highest* levels of testosterone made fewer errors on an emotion recognition task than did males with lower levels of testosterone [18]. Two recent meta-analytic efforts have found that, across 20 studies investigating the relationship between 2D:4D and mentalizing abilities (emotion recognition), the overall effect is null [26,75].

While these meta-analyses suggest a fairly grim outlook on research examining the 2D:4D digit ratio and mentalizing, there are a number of possible reasons as to why this null relationship might not be telling the entire story. It is possible, for instance, that prenatal levels of testosterone interact with fluctuating testosterone—levels of testosterone that vary across situations—to predict mentalizing. This is consistent with the work conducted by van Honk and colleagues showing that women who were administered testosterone and who also had masculinized digit ratios performed the most poorly on an emotion recognition task [60]. Importantly, when administered testosterone, women who had non-masculinized digit ratios performed similarly to the placebo condition (if anything, women performed negligibly better when administered testosterone). In addition, more recent work shows that digit ratio interacts with fluctuating levels of testosterone to predict cooperation [61] and moral judgments [47]—two constructs that draw on one's ability to take the perspective of others.

Another possibility is that the relationship between 2D:4D and mentalizing may not be a strictly linear one. Instead, it is possible that the relationship is quadratic, such that digit ratios indicating both higher *and* lower levels of testosterone are associated with lower levels of mentalizing. Several streams of research support why we might expect a quadratic relationship between prenatal testosterone and mentalizing. First, there is a line of work that demonstrates a quadratic relationship between 2D:4D and asymmetry [44]—a marker of developmental instability—suggesting that individuals with both higher and lower digit ratios are exposed to a greater number of stressors. Second, the 2D:4D ratio has been associated with the ratio between testosterone and estradiol [41] making either extreme of the digit ratio distribution represents an imbalance of these two hormones. Finally, in both human and animal models, higher levels of fluctuating testosterone and estradiol have each been linked to stress, suggesting that either extreme of the distribution could be associated with a greater exposure to stressors ([24,52,57]; see [38] for work linking digit ratio and salivary measures).

Why should higher levels of stress or developmental instability lead to reductions in mentalizing? In other words, what is the mechanism that drives the relationship between asymmetry and mentalizing? Developmental instability has been associated with reductions in a variety of memory tasks, such as verbal recall and recognition [51], working memory ability in children [73], and verbal memory skill after caffeine ingestion [32]. Short-term memory capacity [58], working memory performance [40], and digit span performance [68] have all been shown to co-occur or co-vary with measures of mentalizing and perspective-taking. As such, it could be that developmental instability leads to reductions in mentalizing through short-term memory, or through a more domain-general reduction in a higher factor of intelligence that includes both short-term memory, as well as emotional/social intelligence. In the current work, we test the hypothesis that 2D:4D is quadratically related to asymmetry (Pathway 1). Then, we test the relationship between asymmetry and mentalizing (Pathway 2), between asymmetry and short-term memory (Pathway 3), between short-term memory and mentalizing (Pathway 4), and between asymmetry and mentalizing through short-term memory (mediation; see Fig. 1 for predictions).

2. Measuring testosterone and estradiol: the 2D:4D ratio

The second to fourth digit ratio (2D:4D) has become a well-used estimate of prenatal testosterone [29]. Early work using amniocentesis provided support for the use of the 2D:4D ratio as a proxy for levels of prenatal testosterone relative to levels of estradiol [41,64]. This work tends to show an *inverse* relationship between the ratio between the second and fourth digit, and the expected ratio of testosterone relative to estradiol. That is, as one's second digit increases in length relative to one's fourth, the expected ratio of testosterone to estradiol decreases. The 2D:4D ratio has been measured and studied in a variety of ways. One method that has been employed in previous research involves the experimenter measuring the length of the fingers directly, using calipers or rulers [11]. Another method measures the fingers indirectly, using a combination of photocopies or scans of participants' hands and a ruler or computer software [34].

One challenge with 2D:4D research, and endocrinological research more generally, is that—unlike with surveys of self-report measures—participants are almost always required to come to the lab in person to have endocrine levels measured. While there are seemingly no simple solutions to collecting saliva or blood samples over the internet, 2D:4D ratio may be a feasible candidate for the advantages of online data collection [50]. In the current work, we test one plausible solution to the challenges of collecting information about the 2D:4D ratio online. Specifically, we compare a self-reported direct measurement using online survey software to an experimenter-measured 2D:4D ratio for the same participants.

To our knowledge, there are two existing but limited sets of findings that can speak to the validity and reliability of self- and online-measurement of 2D:4D ratio. The first set of findings suggests that self-measuring 2D:4D ratio using an online ruler provides results with a similar distribution to results using a physical ruler [63]. This study found notable results; however, the collection of only a single submission of each respondent's digit measurement prevents estimations of measure reliability. Participants submitted a single measure of one hand, preventing comparisons of stability over repeated measurements, convergent validity between hands and concurrent validity between self-measured 2D:4D ratios and experimenter-measured 2D:4D ratios. Moreover, collection of only a single hand's data prevented comparisons of symmetry between hands. In the second relevant set of findings, 2D:4D ratio was both self-measured and experimenter-measured for each participant [8]. Participants came into the lab and were asked to measure their own digits using a ruler, and scan their hands. This method was able to provide support for the relationship between self-measured and experimenter-measured 2D:4D ratios (removing outliers in the self-measured ratios also increased the size of this correlation). One key difference between Caswell and Manning [8] and the current study is that the current participants measured their hands in an online setting remote from any experimenter supervision. Comparing this remote online measurement to lab measures provides a more stringent test of the effectiveness of large scale online digit ratio collection.

3. Study 1: validating an online measure of 2D:4D ratio

To refine the field's efforts to create scalable online digit ratio measurement, we developed and validated a new measure of self-reported online 2D:4D ratio. We use self-reported direct measurement using multiple-click heat-maps on Qualtrics' online survey software, along with experimenter-measured 2D:4D ratio using scans of participants' hands and computer software to derive the ratio. We assess and provide support for a measure that exhibits test-retest reliability, convergent validity, and concurrent validity. In Study 2, we use this method to speak to the debate about the relationship between prenatal testosterone and mentalizing, finding that quadratic 2D:4D is related to asymmetry, and asymmetry is related to a number of subjective and objective measures of theory-of-mind and emotion recognition.

3.1. Method

This study was approved by the Institutional Review Board at the University of Oregon.