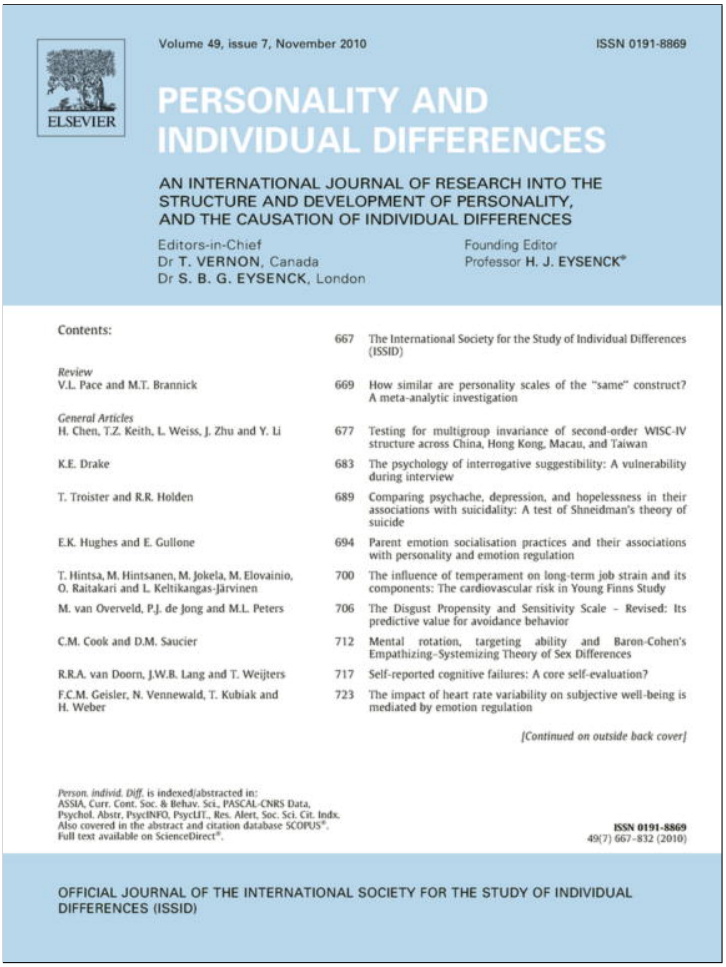

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The second to fourth digit ratio: A measure of two hormonally-based temperament dimensions

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ABSTRACT

Constellations of biobehavioral traits are associated with activity in the testosterone and estrogen systems, due to fetal priming or hormonal alterations during the life course. Using these data, we developed two 14-item measures to investigate the traits associated with these hormone systems. To reach adequate internal consistency, we used participants of an Internet dating site; the final sample was 39,913 individuals. Factorial structure and correlations with several validating criteria were consistent with the hypothesis that these scales measured these neurochemical systems (Fisher, 2009; Fisher et al., in preparation). Two of these validity measures are discussed: gender loading of each scale; and degree to which members of each scale pursued particular occupations. Then we investigated the hypothesis that individuals scoring high on either of these scales also expressed a specific second to fourth digit ratio of the right hand. Individuals who reported a longer 4th finger relative to 2nd expressed high scores on the proposed testosterone scale; individuals who reported a longer 2nd finger relative to 4th or 2nd and 4th digits of equal length expressed high scores on the proposed estrogen/oxytocin scale. These data are consistent with the hypothesis that these 2D:4D ratios are artifacts of hormonal priming in utero.

1. Introduction

Constellations of biobehavioral traits have been associated with the organizational and activational activities of the androgenic and estrogenic systems. Using these diverse data, we developed two 14-item measures to investigate the traits associated with these two hormone systems (Fisher, 2009; Fisher et al., in preparation). These two measures were part of a larger study to investigate the traits associated with each of four broad neural systems, the dopamine/norepinephrine, serotonin, testosterone and estrogen/oxytocin systems. Estrogen and oxytocin were included in the same scale because oxytocin is a peptide whose synthesis, storage and receptor expression is influenced by estrogen (Kendrick, 2000) and these neural systems produce several similar behavioral effects, suggesting they are closely related neural pathways. As there is no single testosterone–estrogen dimension, and as these two hormone systems have been correlated with different sets of behavioral traits, the testosterone and estrogen/oxytocin measures were treated as two independent scales. To reach adequate internal consistency of these four measures, we used participants of an Internet dating site; the final sample was 39,913 individuals. Factorial structure and correlations with nine validating criteria were consistent with the hypothesis that all four scales measured these four broad neurochemical systems (Fisher, 2009; Fisher et al., in preparation).

Two of these validity measures are relevant to this paper: gender loading of each scale; and the degree to which members of each scale pursued particular occupations. We predicted that more males would score high on the proposed testosterone scale than females. Conversely, females would score higher on the proposed estrogen/oxytocin scale than males. This was supported. Further, we predicted that those who scored high on the proposed testosterone scale would be more likely to pursue a career in engineering that required proficiency in mathematics and linear and logic-based problem-solving, as these proclivities are associated with testosterone activity (e.g., Grimshaw, 1995; Janowsky, Oviatt, & Orwoll, 1994; Nyborg, 1994). We also predicted that those who scored high on the proposed estrogen/oxytocin scale would be more likely to pursue a career in teaching, as educational vocations require linguistic skills, people skills and nurturance associated with estrogen activity (e.g., Nyborg, 1994) and oxytocin activity

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(Feldman, Weller, Zagoory-Sharon, & Levine, 2007; Kendrick, 2000; Pedersen, Caldwell, Jirikowsk, & Insel, 1992). These predictions were also supported.

Then, using the above data and pictorial illustrations of four variations in digit ratio of the right hand, we used the final sample of 39,913 individuals to investigate the hypothesis that individuals scoring high on either the proposed testosterone or estrogen/oxytocin scale also expressed a particular digit ratio of the right hand. Specifically, those who scored high on the proposed testosterone scale would have a longer fourth finger relative to their second finger; while those who scored high on the proposed estrogen/oxytocin scale would exhibit a longer second finger relative to their fourth or these digits would be of equal length (Manning, 2002). We anticipated that any correlations found would be modest for several reasons: our data were collected using self-report data on the Internet; we used only four images of hands; and a myriad of biological, cultural and epigenetic factors are likely to affect digit ratio (Manning & Fink, 2008; see also Hönekopp & Watson, in press, who suggested that correlations between self-reported 2D:4D and target variables should be increased threefold to take account of inaccuracy of self-report). Regardless of these limitations, the relevance of the association between the 2D:4D ratios and neurochemical predictors of temperament is both timely and meaningful given the broad literature on both independent topics.

2. Traits associated with the testosterone and estrogen/oxytocin systems in humans

In a meta-analysis of 150,000 Americans aged 13–22, those whose scores fell in the top 5–10% in math, geometry, mechanical reasoning and engineering were overwhelmingly male (e.g., Hyde, Fennema, & Lamon, 1990). Questionnaire studies in several other countries yielded similar results (e.g., Mann, Sasanuma, Sakuma, & Masaki, 1990). Most young adult men express approximately eight to ten times more testosterone than most women; and it is widely hypothesized that this sex difference in hormone expression contributes to the above sex differences in cognition.

Although adult sex differences in cognitive tasks are not sufficient evidence for hormonal effects, biological data support this hypothesized correlation. The brain architecture associated with these spatial/mathematical skills has been associated with fetal testosterone (e.g., Geschwind & Galaburda, 1985; Grimshaw, 1995); and bodily levels of testosterone also contribute to spatial/mathematical dexterity across the life span (Janowsky et al., 1994). Further, it has been proposed that greater understanding of spatial, mechanical, mathematical, engineering and other rule-based systems is the result of more short-range and less long-distance neural connectivity, due to the exposure to prenatal androgens (e.g., Manning, 2002).

Other traits that may be linked with prenatal testosterone expression are heightened attention to detail, intensified focus, and restricted (narrow) interests (e.g., Baron-Cohen, Knickmeyer, & Belmonte, 2005; Knickmeyer, Baron-Cohen, Raggatt, & Taylor, 2005); and elevated adult levels of testosterone have also been associated with these traits (Dabbs & Dabbs, 2000). It has been suggested that prenatal testosterone expression is also linked with less emotion recognition, eye contact and social sensitivity (e.g., Baron-Cohen et al., 2005), a poorer ability to judge what others are thinking or feeling (Baron-Cohen, 1995); and lack of empathy (Baron-Cohen et al., 2005). Adult expression of testosterone has been correlated with being less polite, respectful, considerate or friendly (Dabbs, 1997; Harris, Rushton, Hampson, & Jackson, 1996); and being more confident, forthright and bold (Nyborg, 1994). Adult levels of testosterone have also been positively correlated with sensitivity to social dominance, drive for rank, the tendency to create dominance hierarchies (e.g., Mazur, Susman, & Edelbrock, 1997), and aggressiveness (e.g., Dabbs, 1990; Mazur et al., 1997). Poor verbal fluency and other language deficiencies have been associated with testosterone priming in the womb (e.g., Baron-Cohen et al., 2005; Knickmeyer, Baron-Cohen, Raggatt, Taylor, & Hackett, 2006; Knickmeyer et al., 2005; Geschwind & Galaburda, 1985; Manning, 2002). Last, a lower (masculinized) second to fourth digit ratio has been associated with high prenatal testosterone (Manning, 2002).

Women excel at several linguistic skills in US populations (e.g., Halpern, 1992; McGuinness & Pribram, 1979) and other countries (Mann et al., 1990). Cross-culturally, women also excel at recognizing emotions in faces (e.g., Hall, 1984; McClure, 2000), reading a person's emotions from voice, gestures and other non-verbal cues (e.g., Hall, 1984; McGuinness & Pribram, 1979) and interpreting a range of mental states (Baron-Cohen, Jolliffe, Mortimore, & Robertson, 1997). Although these sex differences are not sufficient evidence for hormonal effects, studies suggest that nurturance and other prosocial skills are associated with adolescent and adult estrogen activities in human females (Nyborg, 1994) and females of many other mammalian species (Carlson, 2001). Adult estrogen facilitates memory for emotional experiences (Canli, Desmond, Zhoa, & Gabrieli, 2002). Estrogen replacement therapy increases verbal memory (Hogervorst, Williams, Budge, Riedel, & Jolles, 2000). In addition, estrogen receptor modulators can elevate adult working and episodic memory, executive function and verbal skills (Goekoop et al., 2005).

Data suggest that fetal steroids affect several adult behaviors (Manning et al., 2000; Nyborg, 1994). Data also suggest that a higher (feminized) digit ratio is positively correlated with fetal estrogen (Manning, 2002). At present, however, there is insufficient evidence that fetal testosterone enhances the growth of the 4th digit or that fetal estrogen facilitates the growth of the 2nd digit.

3. Method

3.1. Participants

A United States sample of 39,913 anonymous men and women were used to measure the reliability and validity of the above-mentioned four scales (Fisher-Rich-Island neurochemical questionnaire, FRI-NQ). They ranged in age from 18 to 88 years ($M = 37.0$; SD = 12.6); 56.4% were female ($N = 22{,}521$); 89.6% ($N = 35{,}759$) were individuals seeking a partner of the opposite sex; 45.2% ($N = 18{,}035$) had children.

3.2. Measure

FRI-NQ, a self-report measure, was developed for online and paper–pencil administration. The 56-item measure contains four 14-item scales to investigate the traits associated with testosterone, estrogen/oxytocin, and the dopamine/norepinephrine and serotonin systems (Fisher, 2009; Fisher et al., in preparation). A Likert-like 4-point scale was used, providing participants with the options: 0: strongly disagree, 1: disagree, 2: agree, 3: strongly agree. Raw scores on each scale ranged from 0 to 42.

3.3. Procedure

Data were collected on the FRI-NQ regularly between 2005 and 2006 on the Internet dating site, Chemistry.com. Participants completed demographic information, the FRI-NQ measure, and separate validity questions to find a romantic partner. Approximately 30,000–40,000 individuals took this test every 3–4 weeks; this sample was then examined using factor analysis. This iterative

process occurred monthly between 2005 and 2006 with items retained, modified or replaced to increase correlations within their own scale and minimize correlations with other scales until adequate internal consistency was obtained in all four scales in a final US sample of 39,913 anonymous men and women. Using factor analysis on the final sample we found that a four-factor solution provided the cleanest and most interpretable factor structure. The extraction method was principal axis factoring. The rotation method was direct oblimin (see Tables 1a–1d for factor loadings by scale; Table 2 for factor correlations). The final FRI-NQ measure was then placed on an international dating site (Match.com®) in 39 countries and data to measure reliability were collected on 15,000 individuals in each of five translations: German, French, Spanish, English (Australian), and Swedish.

Last, the final US sample of 39,913 individuals was used to examine the validity of the FRI-NQ measure. Data were collected from nine queries not integrated in the FRI-NQ measure; the results constituted nine validity measures.

3.4. Reliability and validity of the Fisher-Rich-Island neurochemical questionnaire (FRI-NQ)

The Cronbach's alpha internal consistency coefficient in the final US sample of 39,913 was .80 for the proposed testosterone scale and .78 for the proposed estrogen/oxytocin scale. The Cronbach's alpha coefficients for the other countries were also adequate. Australia: testosterone scale $\alpha = 0.82$; estrogen $\alpha = 0.80$; France: testosterone scale $\alpha = 0.76$; estrogen/oxytocin scale $\alpha = 0.73$; Germany: testosterone scale $\alpha = 0.76$; estrogen/oxytocin scale $\alpha = 0.79$; Spain: testosterone $\alpha = 0.80$; estrogen/oxytocin scale $\alpha = 0.78$; Sweden: testosterone scale $\alpha = 0.79$; estrogen/oxytocin scale $\alpha = 0.76$. All individuals expressed all four-temperament dimensions, yet varied in the degree to which they expressed each.

Further, all nine validity measures suggested that these four scales reflect specific biological underpinnings (Fisher, 2009; Fisher et al., in preparation). Two are relevant to this paper.

3.4.1. Gender composition

In a sample of 1.24 million US members of Chemistry.com®, those scoring highest on the proposed testosterone scale were 17.4% of the population: 9.9% of all females; 25.4% of all males. Those scoring highest on the proposed estrogen/oxytocin scale were 28.5% of the population: 36.6% of all females; 19.9% of all males (see Table 3). The same correlations between gender and the testosterone and estrogen/oxytocin scales were also found in the five other countries studied.

3.4.2. Occupation

We predicted that those who scored highest on the proposed testosterone scale would be the most likely to pursue a career in engineering or an analogous math-based occupation. We had also predicted that those who scored highest on the proposed estrogen/oxytocin scale would be the most likely to pursue a career in teaching, social work, or profession focused on social advocacy. Self-report information regarding occupation was provided in a free text field, and a participant was designated as a "teacher" if the text field included the string "educat" or "teach." A participant was designated as an "engineer" if the text field included the string "engineer." In the sample of 39,913 participants, 16,382 completed the "occupation" field. Of these, 3.1% were teachers and 2.1% were engineers by our criteria. The "teachers" obtained a mean score of 27.5 on the proposed estrogen/oxytocin scale vs. a score of 24.8 obtained by engineers, $t = 7.68$, $df = 852$, $p < .001$, eta = .25. Teachers obtained a relative mean score of 23.1 on the proposed testosterone scale vs. a score of 28.1 obtained by engineers, $t = 14.44$, $df = 852$, $p < .001$, eta = .44.

As predicted, teachers scored higher than engineers on the proposed estrogen/oxytocin scale and engineers scored higher than teachers on the proposed testosterone scale. This effect was partly due to gender. In this sample, 81.1% of the engineers were men and 79.0% of the teachers were women. However, the effect was still seen when men and women were examined separately. Among males, mean scores were 28.6 on the proposed testosterone scale for engineers vs. 25.5 for teachers, $t = 5.80$, $df = 384$, $p < .001$, eta = .28. Female engineers scored 25.7 on the proposed testosterone scale vs. 22.4 for female teachers, $t = 4.96$, $df = 466$, $p < .001$, eta = .22. On the proposed estrogen/oxytocin scale, female teachers scored 27.5 vs. 25.5 for female engineers, $t = 3.15$, $df = 466$, $p < .01$, eta = .14; male teachers scored 27.1 vs. 24.7 for male engineers, $t = 4.35$, $df = 384$, $p < .001$, eta = .22.

4. Results

4.1. Second to fourth digit ratio

Using the above data, we examined the possibility that individuals who scored highest on the proposed testosterone scale would have a longer fourth finger relative to their second finger; while those who scored highest on the estrogen/oxytocin scale would exhibit a longer second digit relative to their fourth or these digits would be of equal length. Illustrations were presented to improve the accuracy of self-report. Finger length was coded as follows: 1 = 4th finger shorter than 2nd; 2 = 2nd and 4th fingers equal; 3 = 4th finger longer than 2nd; 4 = 4th much longer than 2nd. Participants in the final sample of 39,913 individuals on Chemistry.com®

Table 1a
Factor loadings for the dopamine scale of the FRI-NQ items: four-factor solution.

Items	Testosterone	Serotonin	Estrogen	Dopamine
I find unpredictable situations exhilarating	0.10	−0.20	0.02	−0.39
I do things on the spur of the moment	−0.03	−0.17	0.01	−0.48
I get bored when I have to do the same familiar things	0.06	−0.16	0.09	−0.23
I have a wide range of interests	0.15	−0.03	0.09	−0.44
I am more optimistic than most people	−0.06	0.13	−0.08	−0.48
I am more creative than most people	0.18	−0.03	0.16	−0.31
I am always looking for new experiences	0.11	−0.04	0.05	−0.57
I am always doing new things	0.08	−0.01	−0.03	−0.61
I am more enthusiastic than most people	−0.05	0.12	−0.02	−0.59
I am willing to take risks to do what I want to do	0.18	−0.10	0.05	−0.44
I get restless if I have to stay home for any length of time	0.00	−0.06	0.06	−0.26
My friends would say I am very curious	0.20	−0.09	0.21	−0.30
I have more energy than most people	0.06	0.09	−0.10	−0.52
On my time off, I like to be free to do whatever looks fun	0.09	0.00	0.11	−0.33

Table 1b
Factor loadings for the serotonin scale of the FRI-NQ items: four-factor solution.

Items	Testosterone	Serotonin	Estrogen	Dopamine
I think consistent routines keep life orderly and relaxing	0.08	0.37	0.06	0.20
I consider (and reconsider) every option thoroughly before making a plan	0.26	0.31	0.14	0.18
People should behave according to established standards of proper conduct	0.02	0.54	−0.03	0.10
I enjoy planning way ahead	0.14	0.37	0.08	0.14
In general, I think it is important to follow the rules	−0.04	0.57	−0.02	0.09
Taking care of my possessions is a high priority for me	0.08	0.39	−0.01	−0.05
My family and friends would say I have traditional values	−0.08	0.55	−0.08	−0.01
I tend to be meticulous in my duties	0.20	0.36	0.02	−0.03
I tend to be cautious, but not fearful	0.11	0.35	0.04	0.05
People should behave in ways that are morally correct	−0.02	0.49	0.04	−0.03
It is important to respect authority	−0.13	0.61	−0.07	−0.07
I would rather have loyal friends than interesting friends	0.00	0.38	0.04	−0.05
Long established customs need to be respected and preserved	−0.07	0.49	−0.05	−0.08
I like to work in a straightforward path toward completing the task	0.12	0.47	−0.07	0.04

Table 1c
Factor loadings for the testosterone scale of the FRI-NQ items: four-factor solution.

Items	Testosterone	Serotonin	Estrogen	Dopamine
I understand complex machines easily	0.52	−0.04	−0.09	−0.04
I pursue intellectual topics thoroughly and regularly	0.55	−0.06	0.18	−0.05
Debating is a good way to match my wits with others	0.47	−0.06	0.09	−0.04
I enjoy competitive conversations	0.47	−0.06	0.02	−0.12
I am intrigued by rules and patterns that govern systems	0.55	0.02	0.08	0.06
I am more analytical and logical than most people	0.59	0.04	0.05	0.06
I am able to solve problems without letting emotion get in the way	0.45	0.02	−0.29	−0.12
I like to figure out how things work	0.55	0.02	0.01	−0.08
I am tough-minded	0.41	0.04	−0.06	−0.11
I have no trouble making a choice, even when several alternatives seem equally good at first	0.26	0.10	−0.26	−0.21
When I buy a new machine (like a camera, computer or car), I want to know all of its technical features	0.42	0.10	0.01	0.01
I like to avoid the nuances and say exactly what I mean	0.27	0.12	−0.08	−0.16
I think it is important to be direct	0.29	0.14	0.02	−0.17
When making a decision, I like to stick to the facts rather than be swayed by people's feelings	0.39	0.18	−0.18	−0.03

Table 1d
Factor loadings for the estrogen/oxytocin scale of the FRI-NQ items: four-factor solution.

Items	Testosterone	Serotonin	Estrogen	Dopamine
I like to get to know my friends' deepest needs and feelings	−0.02	0.19	0.36	−0.16
I highly value deep emotional intimacy in my relationships	−0.02	0.24	0.35	−0.17
Regardless of what is logical, I generally listen to my heart when making important decisions	−0.18	0.11	0.28	−0.20
I frequently catch myself daydreaming	0.07	−0.14	0.57	0.06
I change my mind easily	−0.12	−0.13	0.31	0.02
After watching an emotional film, I often still feel moved by it several hours later	−0.07	0.09	0.48	−0.02
I vividly imagine both wonderful and horrible things happening to me	0.15	−0.09	0.52	0.13
I am very sensitive to people's feelings and needs	−0.17	0.28	0.38	−0.18
I often find myself getting lost in my thoughts during the day	0.12	−0.15	0.60	0.12
I feel emotions more deeply than most people	−0.06	0.16	0.58	−0.05
I have a vivid imagination	0.22	−0.10	0.46	−0.14
When I wake up from a vivid dream, it takes me a few seconds to return to reality	0.07	−0.10	0.47	0.02
When reading, I enjoy it when the writer takes a sidetrack to say something beautiful or meaningful	0.01	0.09	0.35	−0.11
I am very empathetic	−0.10	0.15	0.39	−0.15

Table 2
Factor correlation matrix.

	Testosterone	Serotonin	Estrogen	Dopamine
Testosterone	1.0			
Serotonin	0.13	1.00		
Estrogen	0.02	0.00	1.00	
Dopamine	−0.25	−0.01	−0.19	1.00

reported their relative finger lengths. The proposed testosterone scale was significantly correlated in the positive direction with respect to the length of the fourth digit (Spearman's rho = .098, $p < .001$); and the proposed estrogen/oxytocin scale was significantly negatively correlated relative to fourth digit length (Spearman's rho = −.081, $p < .001$) (see Table 4). These predicted digit ratios occurred in all populations of the five other countries examined and is consistent with the research hypotheses.

5. Discussion

The focus of this paper was to assess the relationship between the testosterone and estrogen/oxytocin systems and the second to fourth digit ratios, a correlation that within the literature is relatively inconsistent (e.g., Berenbaum, Bryk, Nowak, Quigley, & Moffat, 2009; Kratochvil & Flegr, 2009; Manning, Baron-Cohen, Wheelwright, & Fink, 2010; Voracek & Loibl, 2009; Wallen, 2009). Our approach was a bottom-up method, taking our primary data on the traits associated with testosterone and estrogen di-

Table 3
Descriptive information by gender for the validity study sample.

	Dopamine/norepinephrine		Serotonin		Testosterone		Estrogen/oxytocin	
	N (%)	*M* (SD)	*N* (%)	*M* (SD)	*N* (%)	*M* (SD)	*N* (%)	*M* (SD)
Males	17,392 (27.1)	26.35 (4.87)	17,392 (27.6)	26.01 (4.71)	17,391 (24.8)	26.83 (5.02)	17,391 (20.4)	25.62 (4.99)
Females	22,521 (25.1)	25.70 (4.82)	22,521 (29.4)	26.00 (4.54)	22,521 (9.7)	23.60 (4.99)	22,521 (35.8)	26.94 (5.00)
Total	39,913 (26.0)	25.98 (4.85)	39,913 (28.6)	26.00 (4.61)	39,912 (16.3)	25.00 (5.25)	33,912 (29.1)	26.36 (5.04)

Percentages indicate prevalence, the proportion of participants scoring higher on the given scale than on the other three scales.

Table 4
Spearman rho correlations with longer 2nd vs. 4th finger length ratios.

Scale	Males and females (n = 39,909)	Males (n = 17,390)	Females (n = 22,519)
Dopamine	−0.005	0.006	−0.015*
Serotonin	−0.007	0.010	0.006
Testosterone	0.098**	0.016*	0.049**
Estrogen/oxytocin	−0.081**	−0.029**	−0.040**

* $p < .05$.
** $p < .001$.

rectly from the biological, psychological and cross-cultural literature then constructing our scales based on these data. These scales were validated using two independent measures. Then they were used to investigate the hypothesis that individuals scoring high on either of these scales also expressed a specific second to fourth digit ratio of the right hand.

Consistent with the findings of Manning, Churchill, and Peters (2007) and Manning and Fink (2008), that also examined large Internet samples of individuals who self-measured finger length, the results yielded significant, positive correlations between 2D:4D and sexually dimorphic traits. High scorers on the behavioral measure associated with testosterone had longer fourth to second digits, while those who scored high on the estrogen/oxytocin measure had shorter fourth digits relative to the second.

Although, this study does not confirm an association between the 2D:4D and specific behavioral and dispositional traits associated with endocrine function, it does suggest that there is a positive correlation between the FRI-NQ temperament subscales of testosterone and estrogen/oxytocin and specific digit ratios.

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