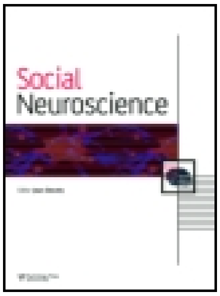

Social Neuroscience
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/psns20

Second to fourth digit ratios, sex differences, and behavior in Chinese men and women

Chi-Fu Jeffrey Yang [a], Peter B. Gray [b], Jianxin Zhang [c] & Harrison G. Pope Jr [d a]
[a] Harvard Medical School, Boston, MA, USA
[b] University of Nevada, Las Vegas, NV, USA
[c] Chinese Academy of Sciences, Beijing, China
[d] McLean Hospital, Belmont, MA, USA
Published online: 19 Dec 2008.

Psychology Press
Taylor & Francis Group

Second to fourth digit ratios, sex differences, and behavior in Chinese men and women

Chi-Fu Jeffrey Yang
Harvard Medical School, Boston, MA, USA

Peter B. Gray
University of Nevada, Las Vegas, NV, USA

Jianxin Zhang
Chinese Academy of Sciences, Beijing, China

Harrison G. Pope, Jr.
McLean Hospital, Belmont, MA, USA, and Harvard Medical School, Boston, MA, USA

The ratio of the length of the second and fourth digits (2D:4D ratio) is consistently smaller in men than in women. Additionally, within each sex, smaller digit ratios may be associated with higher testosterone levels and/or more masculine attitudes and behaviors, although these findings are less consistent. We assessed 2D:4D ratios, together with measures of masculine attitudes and behaviors, in an ethnically homogeneous population of 118 men and 103 women, aged 21–38, all heterosexual and right-handed, in Beijing, China. In men, we also measured salivary testosterone levels. As predicted, men displayed significantly smaller 2D:4D ratios than women ($p < .0001$ in both hands). Within each sex, however, 2D:4D ratios, measures of masculine characteristics, and salivary testosterone showed no significant associations with one another. These latter null findings may partially reflect cultural differences in definitions of "masculinity."

INTRODUCTION

Sex-differentiated behaviors may be associated with both activational and organizational effects of testosterone (Breedlove and Hampson, 2002; Nelson, 2005). Activational effects are the acute behavioral effects of current testosterone levels, whereas organizational effects are permanent effects on brain structures caused by prenatal or perinatal testosterone exposure.

With regard to organizational effects, evidence suggests that prenatal testosterone concentrations are associated with both structural cortical asymmetries and with cognitive abilities (see Wisniewski, 1998). For example, studies using amniocentesis have shown that prenatal testosterone concentrations are associated with both cortical lateralization (Grimshaw, Bryden, & Finegan, 1995a) and speed of mental rotation performance in female children (Grimshaw, Sitarenios, & Finegan, 1995b).

Correspondence should be addressed to: Harrison G. Pope, Jr., McLean Hospital, 115 Mill Street, Belmont, MA 02478, USA. E-mail: hpope@mclean.harvard.edu

We thank Jin Ping, Raymond Yaoshi Tian, Guobiao Tsai, Yun Tao, Songbai Xue, Fufei Yang, Haijun Qu, Tao Liu, Feng Shu and Xinyu Deng for their help with this project. For advice concerning testosterone assays, we thank Doug Granger, Susan Lipson and Peter Ellison. The Green Fund provided financial support for this project.

www.psypress.com/socialneuroscience DOI:10.1080/17470910801942876

Psychosocial and behavioral traits may also be influenced by the organizational effects of testosterone. This impression stems primarily from the findings of animal studies suggesting that prenatal testosterone exposure influences subsequent behavior (see Hines, 2006). In humans the data are more limited, but studies have demonstrated an association between prenatal testosterone concentrations and social attributes such as eye contact and vocabulary development (Baron-Cohen, Lutchmaya, & Knickmeyer, 2004), as well as empathy (Knickmeyer, Baron-Cohen, Raggatt, Taylor, & Hackett, 2006).

Due to ethical and logistical challenges, however, it remains difficult to assess directly the social and neural consequences of prenatal testosterone levels in humans. Therefore, most inferences regarding the organizational effects of testosterone on sex-differentiated human cognition and behavior rely on nonhuman primate experiments, clinical case studies (e.g., androgen insensitivity syndrome), ''accidental'' cases of human androgenic hormone exposure, and attempts to correlate amniotic or umbilical cord testosterone levels with subsequent social outcomes (see Cohen-Bendahan, van de Beek, & Berenbaum, 2005).

To further explore the organizational effects of testosterone on cognition and behavior, an alternative approach is to use the digit ratio as an indicator of intrauterine testosterone concentration. Specifically, it has been hypothesized that the organizational effects of testosterone may be reflected in adulthood by the so-called 2D:4D ratio—the length of the second digit divided by that of the fourth digit (Manning, 2002). This ratio is apparently established *in utero* and is sexually dimorphic, with men showing smaller ratios than women (Brown, Hines, Fane, & Breedlove, 2002); this difference is present in children as early as 2 years of age (Manning, Scutt, Wilson, & Lewis-Jones, 1998). The organizational effects of fetal testosterone on digit ratios in girls and boys have also recently been demonstrated by Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning (2004); these investigators assessed fetal testosterone (FT) and estrogen (FE) via amniocentesis and found an association between low 2D:4D and high levels of FT relative to FE, and high 2D:4D with low FT relative to FE. These associations were independent of sex.

Although the 2D:4D ratio is a ''noisy'' measure of prenatal and perinatal testosterone exposure, it has attracted considerable attention recently because it can be measured with minimal invasiveness in participants of various ages (McIntyre, 2006). Numerous studies of Caucasian populations have consistently demonstrated male–female differences in 2D:4D ratios, but only a limited literature has extended this finding to other ethnic groups (e.g., Manning, Churchill, & Peters, 2007; Manning, Henzi, Venkatramana, Martin, & Singh, 2003b; Manning, Stewart, Bundred, & Trivers, 2004a; Trivers, Manning, & Jacobson, 2006). Although one study (Manning et al., 2004a) has found a sex difference among Chinese children, and another (Manning et al., 2007) has found a sex difference among Chinese adults on the basis of self-report, no study, to our knowledge, has assessed East Asian adults using measurements performed by the investigators.

Within each sex, digit ratios may provide a means of investigating the organizational effects of testosterone on behavior. Specifically, many studies have reported significant associations between digit ratios and various cognitive and behavioral measures. For example, Scarbrough and Johnston (2005) found a positive association between digit ratios and femininity in women, as measured by the Bem Sex Role Inventory (Bem, 1981); in other words, larger, more ''feminine'' digit ratios were associated with higher femininity scores. In contrast, studies have found negative associations between 2D:4D and (1) aggression in men (Bailey and Hurd, 2005); (2) sensation-seeking in women (Austin, Manning, McInroy, & Mathews, 2002); (3) lifetime number of sexual partners in heterosexual men (Hönekopp, Voracek, & Manning, 2006). However, findings involving digit ratios have not always been consistent (see Putz, Gaulin, Sporter, & McBurney, 2004; Rahman, Korhonen, & Aslam, 2005; Van Anders & Hampson, 2005). No study, to our knowledge, has examined any of these associations in Asian populations.

In this study, we measured 2D:4D ratios, together with a range of behavioral and cognitive measures, among men and women in Beijing, China. Among men, we also assessed salivary testosterone levels. Extrapolating from studies that have used Western samples, we predicted that (1) Chinese men would display significantly lower 2D:4D ratios than women; (2) within men, salivary testosterone levels would be associated with both lower (i.e., more ''masculine'') 2D:4D ratios and more masculine attitudes and behaviors; and (3) within each sex, lower 2D:4D digit ratios would also be associated with more masculine attitudes and behaviors.

METHODS

Sample

We recruited 126 men and 110 women, aged 21–38, by advertisement at a Beijing university as detailed previously (Gray, Yang, & Pope, 2006). All participants first completed a demographic questionnaire, presented in both English and Chinese, assessing occupation, educational attainment, marital status, handedness (Edinburgh Handedness Scale; Oldfield, 1971) and sexual orientation—the latter structured as a choice of ‘‘heterosexual,’’ ‘‘bisexual,’’ or ‘‘homosexual.’’ We excluded 4 participants with incomplete data, 7 left-handed participants, and 4 reporting homosexual or bisexual orientation—since handedness and sexual orientation may be associated with 2D:4D ratios (Manning et al., 2000; Rahman and Wilson, 2003)—leaving 118 men and 103 women.

Although we did not formally assess the ethnic origins of the participants, approximately 91.9% of all Chinese are of *Han* origin (United States Central Intelligence Agency, 2008) and officials at the university estimated that more than 95% of their students were *Han* (Cai, G. B., personal communication, Beijing, China, December 2005). Thus, the sample likely represented an ethnically homogeneous group.

Outcome measures

We next administered a battery of measures assessing attributes suggested to differ between the sexes in studies using Western samples (see Lippa, 2005, for review); these attributes included aggression, sexual behavior, sensation-seeking, and gambling. We reasoned that these measures, when applied *within* the subgroups of men and women, would assess ‘‘masculine’’ attitudes and behaviors. Our instruments included the Aggression Questionnaire (Buss & Perry, 1992), Bem Short Form Sex Role Inventory (BSFRI; Bem, 1981), Impulsive Sensation-Seeking Scale (ImpSS; Zuckerman, 1994), and ratings of sexual behavior from the Sociosexual Inventory (Simpson & Gangestad, 1991)—scales that have all shown good reliability and validity in Western populations. We also included the Self-Efficacy Scale (Zhang & Schwarzer, 1995)—a scale not specifically designed to assess masculine behaviors, but unique in that it had been previously validated in China. We assessed frequency of gambling with eight response options ranging from ‘‘never’’ to ‘‘daily.’’ Finally, we asked women to specify the number of days since the onset of their last menstrual period, and whether they were taking birth control pills. All questions and scales were translated and back-translated by four independent Chinese colleagues, two of whom did not know the original English text. A provisional version was piloted to 10 Chinese graduate students at an American university. The final version was fixed by consensus to ensure careful cultural adaptation.

Scales were scored according to published criteria. Gambling activity was coded as 0 (never), 1 (less than once a month) or 2 (at least once a month). We used only two questions from the Sociosexual Inventory—number of sex partners in the previous year and anticipated number of sex partners over the next five years.

Anthropometric and hormonal measurements

We measured the length of each participant's second and fourth digits on both right and left hands, from the midpoint of the proximal crease at the base of the finger to the tip of the finger, using vernier calipers, according to a published protocol of established reliability (Manning, 2002). Because of time constraints, however, we were unable to perform test–retest reliability measurements, and thus used a single set of measurements for each participant. However, previous studies have suggested that measurements using calipers have a high degree of repeatability (e.g., Manning, 2003a). We then calculated 2D:4D ratios for each hand by dividing the length of the second digit by the length of the fourth digit. In men, we also measured morning and afternoon salivary testosterone levels as detailed previously (Gray et al., 2006). We recorded the time of collection of morning and afternoon saliva samples for each participant. Since morning saliva samples were collected over a wide time range (7:45 a.m. to 12:30 p.m.), we performed all analyses involving morning testosterone levels with adjustment for time of collection (see details below).

Statistical analyses

Demographic measures

The distribution of ages and 2D:4D ratios in the men and women differed significantly from a normal distribution ($p < .05$ by Shapiro-Wilk test for normal data); therefore differences between the sexes on these variables were assessed using the Wilcoxon and rank sum test, two-tailed. Differences between sexes on demographic categorical variables were assessed using Fisher's exact test.

Behavioral and cognitive measures

An initial inspection of our outcome measures suggested that they did not seriously deviate from a normal distribution, with the exception of salivary testosterone levels among the men. Since the testosterone levels showed a distribution skewed to the right, we log-transformed them to more closely approach a normal distribution. We compared the sexes on behavioral and cognitive outcome measures using linear regression with adjustment for age, modeled as tertiles. We then repeated these comparisons while restricting to unmarried participants, given the possibility that marital status might represent a confound. Within each sex, we used linear regression to assess the association of right- and left-hand 2D:4D ratios with each outcome measure, again adjusting for age. Among the women, we performed additional exploratory analyses adjusting for menstrual phase and current use of birth control pills. Among the men, we also performed univariate analyses assessing the association of log-transformed morning and afternoon salivary testosterone levels with 2D:4D ratios and with the behavioral outcome measures. We then used linear regression to perform multivariate analyses examining the combined effects of salivary testosterone and 2D:4D ratios on the outcome measures, adjusting for age. We repeated these analyses with additional adjustment for the measure D r-l (2D:4D right hand – 2D:4D left hand)—a measure of "directional asymmetry"—because D r-l may be correlated with high sensitivity to T (Manning et al., 2004b; Benderlioglu & Nelson, 2004) and with behavioral measures of aggression (Benderlioglu & Nelson, 2004). We also performed a series of regression analyses using D r-l as a predictor variable in its own right. Given that morning saliva samples were collected over a wide time span, from 7:45 a.m. to 12:30 p.m. (Gray et al., 2006), we adjusted for time of collection in all analyses involving morning testosterone. As an alternative method, we also repeated all of these analyses without adjustment for time of collection, but instead restricting the sample to men tested between 8:00 and 10:00 a.m. ($N = 58$ men), to minimize possible effects due to diurnal changes in testosterone levels. We repeated all of the foregoing within-sex analyses with restriction to unmarried participants.

Because many of the measures in our various analyses were correlated, it was difficult to calculate a precise statistical correction for the effect of multiple comparisons. Therefore, we set alpha at .01, two-tailed, to partially correct for multiple comparisons—but given the large number of comparisons (more than 300 overall), it should be recognized that some comparisons might still surpass this threshold by chance alone.

RESULTS

Sex differences

Demographic measures

Table 1 gives descriptive demographic data according to sex. All participants were between 21 and 38 years of age; the men were slightly (albeit significantly) older than women, and showed significantly lower digit ratios than did women ($p < .0001$ for both hands; see Figure 1). Interestingly, the ratios that we observed in each of the two sexes in our Chinese adults closely resembled the mean ratios previously obtained by Manning et al. (2004a) in Chinese children (males, 0.940; females, 0.961).

Behavioral and cognitive measures

As predicted, men differed significantly from women on physical aggression, gambling frequency, and number of sex partners (Table 2)—but contrary to expectations, we found no significant differences between the sexes on other subscales of the Aggression Questionnaire, nor on the masculine or feminine domains of the BSFRI, nor on the ImpSS. These findings were little changed when we restricted the analysis to the 64 men and 81 women who were unmarried (Table 3).

TABLE 1
Demographic features of participants

	Men (N = 118)	*Women (N = 103)*	p^a
Age, years, median (IQR[b])	26 (25, 30)	25 (25, 28)	.003
Right 2D:4D, median (IQR)	0.951 (0.914, 0.985)	0.972 (0.967, 1.00)	<.0001
Left 2D:4D, median (IQR)	0.955 (0.931, 0.973)	0.972 (0.968, 1.00)	<.0001
Married, N (%)	54 (46%)	22 (21%)	.002

Notes: [a] Significance of differences between sexes by Wilcoxon rank sum test, two-tailed, for continuous variables and by Fisher's exact test, two-tailed, for proportions. [b] Interquartile range.

TABLE 2
Differences between men and women on behavioral and psychological measures: all men ($N = 118$) vs. all women ($N = 103$)

Outcome variable[a]	*Men, mean (SD)*	*Women, mean (SD)*	*Coefficient[b]*	*Standard error*	*p*
Aggression Questionnaire, total score	93.9 (18.8)	87.6 (15.8)	–6.90	2.40	.004
Aggression Questionnaire, anger	21.2 (6.3)	21.7 (6.6)	0.51	0.91	.58
Aggression Questionnaire, hostility	25.6 (6.6)	24.8 (6.1)	–0.86	0.88	.33
Aggression Questionnaire, verbal aggression	18.4 (4.5)	18.7 (3.5)	0.11	0.56	.85
Aggression Questionnaire, Physical Aggression	28.6 (6.9)	22.4 (5.9)	–6.50	0.88	<.0001
Bem Inventory, masculinity scale	47.6 (7.3)	46.7 (7.9)	–0.94	1.04	.37
Bem Inventory, femininity scale	55.2 (7.5)	56.7 (6.2)	1.74	0.96	.07
Impulsive Sensation Seeking Scale, total score	6.4 (3.5)	6.3 (4.2)	–0.23	0.52	.66
Gambling frequency	0.3 (0.9)	0.0 (0.2)	–0.23	0.11	.03
Self-Efficacy Scale, total score	18.1 (4.6)	18.2 (4.2)	0.12	0.61	.84
Number of sex partners last year	1.2 (1.7)	0.5 (0.8)	–0.62	0.18	.001
Number of sex partners anticipated next five years	1.7 (1.4)	1.2 (0.5)	–0.51	0.15	.001

Notes: [a]See text for details of measures used. [b]Estimated increase (SE) in outcome variable for females as compared to males, by linear regression, adjusted for age.

Finger digit ratios, behavior and testosterone

Within each sex, we found virtually no significant associations between the behavioral and cognitive measures and left-hand or right-hand digit ratios, regardless of whether the analysis included all men and women or was restricted to single men and women (see Tables 4 and 5). The only exception was a positive association between right 2D:4D ratios and verbal aggression among single women, which generated a p of .008. However, this finding (1) was in the opposite direction to what would be expected (i.e., higher, more feminine digit ratios would be expected to be associated with *less* aggression); (2) did not reach significance in the overall group of women ($p = .09$; see Table 5); and (3) barely exceeded our chosen alpha of .01 in any case. Collectively, these

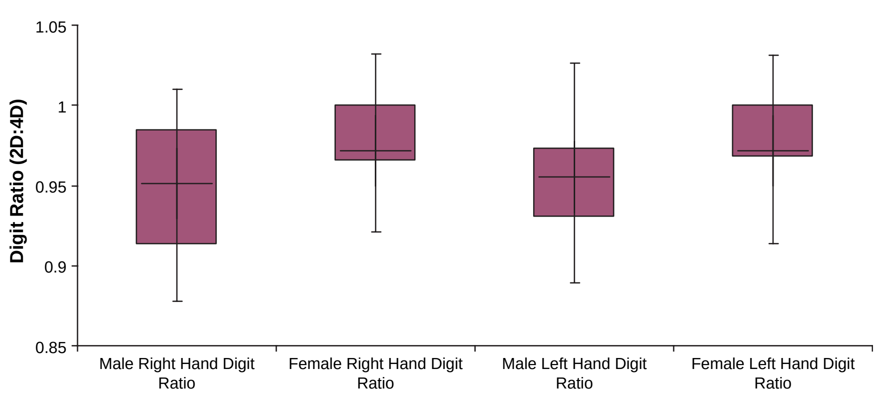

Figure 1. Right and left hand 2D:4D of Chinese men ($N = 118$) and Chinese women ($N = 103$). The middle line represents the median; the limits of the colored box represent the 25th and 75th percentiles, and the limits of the error bars represent the 5th and 95th percentiles.

TABLE 3
Differences between men and women on behavioral and psychological measures: single men ($N = 64$) vs. single women ($N = 81$)

Outcome Variable[a]	*Men, mean (SD)*	*Women, mean (SD)*	*Coefficient*[b]	*Standard error*	*p*
Aggression Questionnaire, total score	93.1 (17.3)	87.5 (15.6)	−6.35	2.77	.02
Aggression Questionnaire, anger	20.3 (6.0)	21.8 (6.8)	1.35	1.1	.23
Aggression Questionnaire, hostility	25.5 (5.8)	24.6 (6.3)	−1.08	1.04	.30
Aggression Questionnaire, verbal aggression	18.2 (4.6)	18.6 (3.3)	0.34	0.66	.61
Aggression Questionnaire, physical aggression	29.0 (6.9)	22.7 (6.3)	−6.71	1.1	<.0001
Bem Inventory, masculinity scale	46.4 (7.1)	47.0 (8.0)	0.64	1.3	.62
Bem Inventory, femininity scale	54.2 (7.5)	56.3 (6.5)	2.27	1.19	.06
Impulsive Sensation Seeking Scale, total score	6.3 (3.3)	6.3 (4.2)	−0.03	0.65	.97
Gambling frequency	0.3 (0.9)	0.0 (0.2)	−0.12	0.13	.36
Self-Efficacy Scale, total score	18.0 (4.3)	18.5 (4.0)	0.56	0.71	.44
Number of sex partners last year	1.0 (2.1)	0.4 (0.8)	−0.56	0.27	.04
Number of sex partners anticipated next year	1.6 (1.5)	1.1 (0.5)	−0.39	0.18	.03

Notes: [a]See text for details of measures used. [b]Estimated increase (SE) in outcome variable for females as compared to males, by linear regression, adjusted for age.

observations suggest that the finding represented a chance observation (see further discussion below).

We also performed numerous additional analyses, as detailed in the Methods section above, but found no significant associations; as a result, these numerical data are not shown. Specifically, we found no significant associations between D r-l and any of the behavioral or cognitive measures in either sex, regardless of whether we assessed all participants or only unmarried participants. Among the women, adjustment for menstrual phase and use of birth control pills had little effect on any of the findings. Among men, salivary testosterone levels showed no significant associations with 2D:4D ratios (see Table 4 and Figures 2 and 3). Salivary testosterone levels showed no significant association with D r-l, or with any of the cognitive or behavioral outcome measures. We also found no significant associations of either salivary testosterone or 2D:4D ratios with outcome measures in any of the numerous subsequent multivariate analyses.

DISCUSSION

In a study of Chinese university students, likely representing an ethnically homogeneous population,

TABLE 4
Associations between digit ratios and outcome measures for all men ($N = 118$) and for single men ($N = 64$)

	All men (N = 118)			*Single men (N = 64)*		
Outcome variable[a]	*Coefficient*[b]	*Standard error*	*p*	*Coefficient*[b]	*Standard error*	*p*
Morning testosterone, pmol/l	3.01	1.88	0.11	4.50	2.89	.13
Morning testosterone, log transformed	0.03	0.01	0.05	0.05	0.02	.03
Evening testosterone, pmol/l	0.07	1.68	0.96	–3.93	2.73	.16
Evening testosterone, log transformed	0.0007	0.01	0.96	–0.02	0.02	.30
Aggression Questionnaire, total score	0.36	0.42	0.40	–0.11	0.52	.83
Aggression Questionnaire, anger	0.12	0.14	0.38	0.04	0.18	.83
Aggression Questionnaire, hostility	0.05	0.15	0.72	–0.14	0.17	.43
Aggression Questionnaire, verbal aggression	0.02	0.10	0.81	–0.08	0.13	.56
Aggression Questionnaire, physical aggression	0.12	0.15	0.42	0.03	0.20	.87
Bem Inventory, Masculinity Scale	–0.11	0.16	0.48	–0.12	0.21	.57
Bem Inventory, Femininity Scale	–0.18	0.17	0.26	0.006	0.22	.98
Impulsive Sensation Seeking Scale, total score	–0.04	0.08	0.64	–0.03	0.10	.75
Gambling frequency	0.008	0.02	0.69	–0.02	0.02	.50
Self-Efficacy Scale, total score	0.02	0.10	0.81	0.12	0.13	.35
Number of sex partners last year	0.04	0.04	0.29	0.07	0.06	.28
Number of Sex Partners Anticipated Next Five Years	0.008	0.03	0.80	−0.03	0.04	.49

Notes: [a]See text for details of measures used. [b]Estimated increase (SE) in outcome variable per increase of 0.01 in right digit ratio.

TABLE 5
Associations between digit ratios and outcome measures for all women ($N = 103$) and single women ($N = 81$)

	All women (N = 103)			*Single women (N = 81)*		
Outcome variable[a]	*Coefficient*[b]	*Standard error*	*p*	*Coefficient*[b]	*Standard error*	*p*
Aggression Questionnaire, total score	–0.12	0.43	0.77	0.07	0.51	.89
Aggression Questionnaire, anger	–0.09	0.18	0.63	–0.07	0.22	.76
Aggression Questionnaire, hostility	–0.08	0.17	0.62	–0.05	0.21	.80
Aggression Questionnaire, verbal aggression	0.15	0.09	0.09	0.28	0.10	.008
Aggression Questionnaire, physical aggression	–0.09	0.16	0.55	–0.06	0.20	.77
Bem Inventory, Masculinity Scale	0.008	0.20	0.97	0.13	0.26	.61
Bem Inventory, Femininity Scale	–0.007	0.17	0.97	0.03	0.21	.88
Impulsive Sensation Seeking Scale, Total Score	–0.02	0.11	0.83	–0.02	0.13	.89
Gambling frequency	0.02	0.02	0.29	0.02	0.02	.44
Self-Efficacy Scale, Total Score	0.10	0.11	0.34	0.14	0.13	.28
Number of sex partners last year	–0.003	0.02	0.89	0.02	0.03	.38
Number of sex partners anticipated next five years	–0.01	0.01	0.43	–0.004	0.02	.80

Notes: [a]See text for details of measures used. [b]Estimated increase (SE) in outcome variable per increase of 0.01 in right digit ratio.

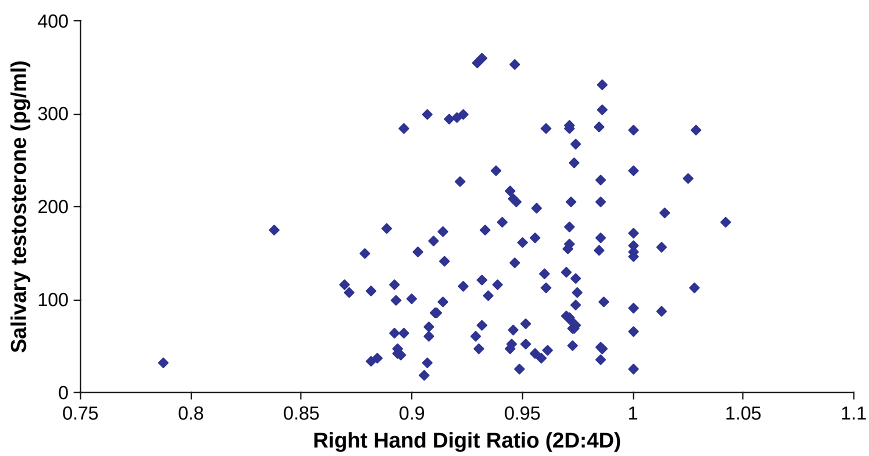

Figure 2. The relationship between morning salivary testosterone levels (pg/ml) and right hand 2D:4D in Chinese men ($N = 118$). This association did not achieve significance ($p = .11$ by linear regression adjusted for age and time of saliva collection; see Table 4).

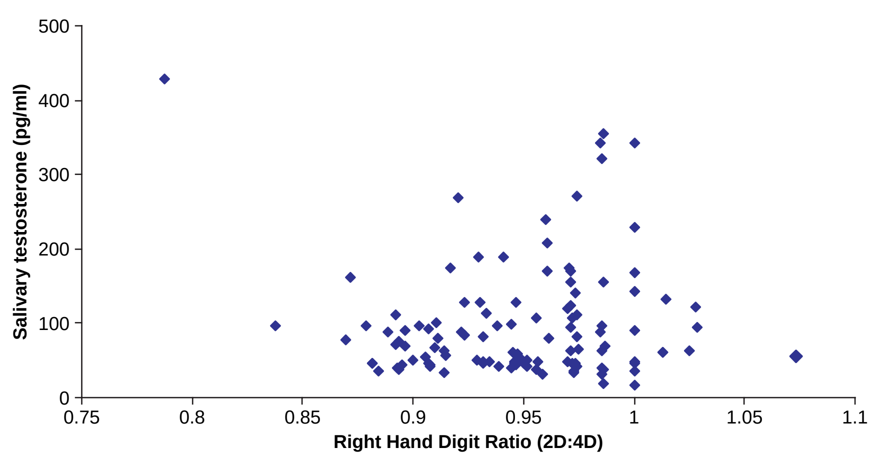

Figure 3. The relationship between afternoon salivary testosterone (pg/ml) and right hand 2D:4D in Chinese men ($N = 118$). This association did not achieve significance ($p = 0.96$ by linear regression adjusted for age; see Table 5).

we found that men displayed significantly lower 2D:4D ratios than women, consistent with findings in Western populations. This finding represents, to our knowledge, the first demonstration of this difference in an adult East Asian population; it is consistent with a previous study of Chinese children (the only other such study of East Asians, to our knowledge), and it adds to the growing evidence that male–female differences in 2D:4D ratios hold across a wide range of ethnic groups.

Among the men, salivary testosterone levels showed no significant association with digit ratios. Although one Western study has shown an association between these measures (Manning et al., 1998), at least three studies have not (Neave, Laing, Fink, & Manning, 2003; Manning et al., 2004b; Hönekopp et al., 2006). Therefore, our null finding on this measure in an Asian population adds further weight to the hypothesis that 2D:4D ratios are not generally associated with circulating testosterone levels in men. Indeed, our findings in this regard are consistent with those of a recent study and meta-analytic review suggesting that adult testosterone levels are not associated with digit ratios in men (Hönekopp, Bartholdt, Beier, & Liebert, 2007).

Turning to behavioral and cognitive measures, the Chinese men and women differed significantly on a few measures of ''masculine'' attributes, but they failed to show expected differences on measures of masculinity, femininity, or sensation-seeking. Furthermore, looking within each sex, we found no association between these measures and salivary testosterone levels among the men, nor any significant associations between these measures and digit ratios among either men or women, save for a modest association of digit ratio with verbal aggression among single women. However, this association was in the opposite direction to what might be expected (i.e., smaller, more ''masculine'' ratios were associated with *less* verbal aggression) and also opposite to the observations of Benderlioglu and Nelson (2004), who found that a measure of verbal aggression was significantly *higher* among women with smaller ratios. Thus, it seems likely that this isolated significant association in our study represents a chance finding.

What accounts for these latter null findings? Our observations suggest that many of our standard Western-based measures of ''masculinity'' are unsuited for China. Chinese ideals of masculinity (and by extension, femininity) are very different from Western ideals, as we have discussed previously (Yang, Gray, & Pope, 2005). For example, in the Confucian Chinese tradition, masculinity comprises both *wen* 文 (translated as ''mental'' or ''civil,'' with core meanings centering around literary and cultural attainment) and *wu* 武 (''physical'' or ''martial,'' with core meanings of force and power) (Louie, 2002; Yang et al., 2005). Several items on the BSFRI, such as understanding, warmth, and reliability, are classified as feminine or neutral traits—but in Chinese culture would be considered part of *wen* masculinity. Indeed, Asian cultures in general may define masculinity differently from Western cultures (Hofstede, 1998; Leung & Moore, 2003). Therefore, our findings suggest the need to develop more culture-specific measures of masculinity for Asian populations.

The ImpSS appeared similarly unsuited to assess masculinity in China. For example, items such as ''I like doing things just for the thrill of it,'' and ''I often do things on impulse,'' would likely be seen in Confucian tradition as simply irresponsible, rather than masculine. In the aggression questionnaire, also, certain questions may be poorly suited for Chinese culture. For example, the item ''I am suspicious of overly friendly strangers'' is used as an index of hostility—yet in our anecdotal experience this would be normal behavior in a large Chinese city, where there is general distrust of strangers. Finally, the Self-Efficacy Scale, although previously validated in China, is not explicitly a measure of masculine or feminine attitudes and behaviors, and thus would not be expected to show differences between the sexes.

These cultural differences in questionnaire measures appear to be increasingly corroborated by new social neuroscience findings. For example, Zhu et al. (2007), using functional magnetic resonance imaging (fMRI), found that Chinese individuals exhibited increased medial prefrontal cortex (MPFC) activation when judging personal trait adjectives related to themselves or to their mothers. In contrast, Western individuals exhibited increased MPFC activation only when associating adjectives with themselves, and not their mothers. In another recent study, Tang et al. (2006) used fMRI to demonstrate functional distinctions between Chinese and English individuals in the brain networks used to represent Arabic numbers and to perform calculations. Given these differences between East and West in the cognitive processing of stimuli such as trait adjectives or Arabic numbers, it seems likely that there might be even greater differences between cultures in the cortical representation of a complex construct such as "masculinity." Therefore, even though the organizational effects of testosterone may produce similar structural differences between the sexes across cultures—as suggested by our findings on digit ratio—one must not assume that these organizational effects translate into similar cognitive or behavioral outcomes across cultures.

Several other limitations of the study should be considered. First, it was not practical in our setting to assess the test–retest reliability of finger measurements; however, as noted above, we followed a previously published protocol that has consistently shown a high degree of repeatability (Manning, 2002; Manning et al., 2003b). Also, it should be noted that, despite the absence of retesting, our methods were able to demonstrate a marked and significant difference between men and women in the digit ratios for both hands, consistent with predictions. This observation suggests that our methodology was sufficiently reliable that serious type II errors would be unlikely.

Second, Chinese individuals may tend to give more socially desirable responses than Western individuals (Liu, Jian, & Yang, 2003)—thus potentially diluting the findings. A recent North American study controlled for this phenomenon by excluding individuals who scored high on a scale of self-deception and impression management (Bailey and Hurd, 2005), but we could not perform such exclusions. Third, it is possible that, despite our efforts, the meaning of some questions may have been distorted in translation.

Fourth, sexual orientation was assessed by a simple three-choice question, and some individuals with purely or partly homosexual orientation might have misrepresented themselves as heterosexual. It is possible that a scale with a wider range of choices, such as the Kinsey scale, might have been more effective in identifying such individuals. However, given that the questionnaire was entirely anonymous, there would likely be at most only a few such individuals, and thus their inclusion would seem unlikely to have affected our findings.

In summary, both the positive and the null findings of this study are instructive. Our principal positive finding—the significant difference in digit ratios between Chinese men and women—adds further support to the validity of this measure across ethnic groups. Our null findings regarding the association of salivary testosterone with digit ratios add weight to the evidence that these measures are probably not related, regardless of the ethnicity of the population studied. Finally, our largely null findings with cognitive and behavioral measures demonstrate the importance of cultural differences in definitions of "masculinity," and emphasize the need to develop more culture-specific measures of this concept. Indeed, these latter findings invite further exploration of the differing cultural concepts of "masculinity," perhaps with the aid of functional brain imaging, as illustrated by other recent cross-cultural studies (Tang et al., 2006; Zhu et al., 2007).

Manuscript received 24 January 2007
Manuscript accepted 24 January 2008
First published online 18 March 2008

REFERENCES

Austin, E. J., Manning, J. T., McInroy, K., & Mathews, E. (2002). A preliminary investigation of the associations between personality, cognitive ability and digit ratio. *Personality and Individual Differences*, *33*, 1115–1124.

Bailey, A. A., & Hurd, P. L. (2005). Finger length ratio (2D:4D) correlates with physical aggression in men but not in women. *Biological Psychology*, *68*, 215–222.

Baron-Cohen, S., Lutchmaya, S., & Knickmeyer, R. (2004). *Prenatal testosterone in mind: Amniotic fluid studies*. Cambridge, MA: MIT Press.

Bem, S. (1981). Theory and measurement of androgyny—reply. *Journal of Personality and Social Psychology*, *37*, 1047–1054.

Benderlioglu, Z., & Nelson, J. (2004). Digit length ratios predict reactive aggression in women, but not in men. *Hormones and Behavior*, *46*, 558–564.

Breedlove, S. M., & Hampson, E. (2002). Sexual differentiation of the brain and behavior. In J. B. Becker, S. M. Breedlove, D. Crews, & M. M. McCarthy (Eds.), *Behavioral Endocrinology* (pp. 75–151). Cambridge, MA: MIT Press.

Brown, W. M., Hines, M., Fane, B. A., & Breedlove, S. M. (2002). Masculinized finger length patterns in human males and females with congenital adrenal hyperplasia. *Hormones and Behavior*, *42*, 123–127.

Buss, A. H., & Perry, M. (1992). The aggression questionnaire. *Journal of Personality and Social Psychology*, *63*, 452–459.

Cohen-Bendahan, C. C. C., van de Beek, C., & Berenbaum, S. A. (2005). Prenatal sex hormone effects on child and adult sex-typed behavior: Methods and findings. *Neuroscience and Biobehavioral Reviews*, *29*, 353–384.

Gray, P. B., Yang, C. J., & Pope, H. G., Jr. (2006). Fathers have lower salivary testosterone levels than unmarried men and married non-fathers in Beijing, China. *Proceedings of the Royal Society of London, Series B*, *273*, 333–339.

Grimshaw, G. M., Bryden, M. P., & Finegan, J. K. (1995a). Relations between prenatal testosterone and cerebral lateralization in children. *Neuropsychology*, *9*(1), 68–79.

Grimshaw, G. M., Sitarenios, G., & Finegan, J. A. (1995b). Mental rotation at 7 years: Relations with prenatal testosterone levels and spatial play experiences. *Brain and Cognition*, *29*(1), 85–100.

Hines, M. (2006) Prenatal testosterone and gender-related behaviour. *European Journal of Endocrinology*, *155*, S115–S121.

Hofstede, G. (1998). *Masculinity and femininity: The taboo dimension of national cultures.* Thousand Oaks, CA: Sage.

Hönekopp, J., Voracek, M., & Manning, J. T. (2006). 2nd to 4th digit ratio (2D:4D) and number of sex partners: Evidence for effects of prenatal testosterone in men. *Psychoneuroendocrinology*, *31*, 30–37.

Hönekopp, J., Bartholdt, L., Beier, L., & Liebert, A. (2007). Second to fourth digit length ratio (2D:4D) and adult sex hormone levels: new data and a meta-analytic review. *Psychoneuroendocrinology*, *32*(4), 313–321.

Knickmeyer, R., Baron-Cohen, S., Raggatt, P., Taylor, K., & Hackett, C. (2006). Fetal testosterone and empathy. *Hormones and Behavior*, *49*, 282–292.

Leung, C., & Moore, S. (2003). Individual and cultural gender roles: A comparison of Anglo-Australians and Chinese in Australia. *Current Research in Social Psychology*, *8*, 302–316.

Lippa, R. A. (2003). Are 2D:4D finger-length ratios related to sexual orientation? Yes for men, no for women. *Journal of Personality and Social Psychology*, 85, 179–188.

Lippa, R. A. (2005). *Gender, nature and nurture* (2nd ed.). Mahwah, NJ: Lawrence Erlbaum.

Liu, C., Jian, X., & Yang, Z. (2003). A compromise between self-enhancement and honesty: Chinese self-evaluations on social desirability scales. *Psychological Reports*, *92*, 291–298.

Louie, K. (2002). *Theorising Chinese masculinity: Society and gender in China*. Cambridge, UK: Cambridge University Press.

Lutchmaya, S., Baron-Cohen S., Raggatt, P., Knickmeyer R., & Manning, J. T. (2004). 2nd to 4th digit ratios, fetal testosterone and estradiol. *Early Human Development*, *77*(1–2), 23–28.

Manning, J. T. (2002). *Digit ratio: A pointer to fertility, behaviour, and health*. New Brunswick, NJ: Rutgers University Press.

Manning, J. T., Barley, L., Walton, J., Lewis-Jones, D. I., Trivers, R. L., Singh, D., Thornhill, R., Rohde, P., Bereczkei, T., Henzi, P., Soler, M., & Szwed, A. (2000). The 2nd:4th digit ratio, sexual dimorphism, population differences, and reproductive success: Evidence for sexually antagonistic genes? *Evolution and Human Behavior*, *21*, 163–183.

Manning, J. T., Bundred, P. E., Newton, D. J., & Flanagan, B. F. (2003a). The second to fourth digit ratio and variation in the androgen receptor gene. *Evolution and Human Behavior*, *24*, 399–405.

Manning, J. T., Churchill, A., & Peters, M. (2007). The effects of sex, ethnicity, and sexual orientation on self-measured digit ratio (2D:4D). *Archives of Sexual Behavior*, *36*, 223–233.

Manning, J. T., Henzi, P., Venkatramana, P., Martin, S., & Singh, D. (2003b). Second to fourth digit ratio: Ethnic differences and family size in English, Indian and South African populations. *Annals of Human Biology*, *30*, 579–588.

Manning, J. T., Scutt, D., Wilson, J., & Lewis-Jones, D. I., 1998. The ratio of 2nd to 4th digit length: A predictor of sperm numbers and concentrations of testosterone, luteinizing hormone and oestrogen. *Human Reproduction*, *13*, 3000–3004.

Manning, J. T., Stewart, A., Bundred, P. E., & Trivers, R. L. (2004a). Sex and ethnic differences in 2nd to 4th digit ratio of children. *Early Human Development*, *80*, 161– 168.

Manning, J. T., Wood, S., Vang, E., Walton, J., Bundred, P. E., van Heyningen C., & Lewis-Jones, D. I. (2004b). Second to fourth digit ratio (2D:4D) and testosterone in men. *Asian Journal of Andrology*, *6*, 211–216.

McIntyre, M. H. (2006). The use of digit ratios as markers for perinatal androgen action. *Reproductive Biology and Endocrinology*, *4*, 10.

Neave, N., Laing, S., Fink, B., & Manning, J. T. (2003). Second to fourth digit ratio, testosterone and perceived male dominance. *Proceedings of the Royal Society of London, Series B*, *270*, 2167–2172.

Nelson, R. J. (2005). *An introduction to behavioral endocrinology* (3rd ed.). Sunderland, MA: Sinauer.

Oldfield, R. C. (1971). The assessment and analysis of handedness: The Edinburgh Inventory. *Neuropsychologia*, *9*, 97–113.

Putz, D. A., Gaulin, S. J. C., Sporter, R. J., & McBurney, D. H. (2004). Sex hormones and finger length: What does 2D:4D indicate? *Evolution and Human Behavior*, *25*, 182–199.

Rahman, Q., Korhonen, M., & Aslam, A. (2005). Sexually dimorphic 2D:4D ratio, height, weight, and their relation to number of sexual partners. *Personality and Individual Differences*, *39*, 83–92.

Rahman, Q., & Wilson, G. D. (2003). Sexual orientation and the 2nd to 4th finger length ratio: Evidence for organizing effects of sex hormones or developmental instability? *Psychoneuroendocrinology*, *28*, 288–303.

Scarbrough, P. S., & Johnston, V. S. (2005). Individual differences in women's facial preferences as a function of digit ratio and mental rotation ability. *Evolution and Human Behavior*, *26*, 509–526.

Simpson, J. A., & Gangestad, S. W. (1991). Individual differences in sociosexuality: Evidence for convergent and discriminant validity. *Journal of Personality and Social Psychology*, *60*, 870–883.

Tang, Y., Zhang, W., Chen, K., Feng, S., Ji, Y., Shen, J., et al. (2006). Arithmetic processing in the brain shaped by cultures. *Proceedings of the National Academy of Sciences of the United States of America*, *103*, 10775–10780.

Trivers, R., Manning, J., & Jacobson, A. (2006). A longitudinal study of digit ratio (2D:4D) and other finger ratios in Jamaican children. *Hormones and Behavior*, *49*(2),150–156.

United States Central Intelligence Agency. (2008). China. In *The World Factbook*. Washington, DC: CIA. Retrieved February 20, 2006, from https://www.cia.gov/library/publications/the-world-factbook/geos/ch.html.

Van Anders, S. M., & Hampson, E. (2005). Testing the prenatal androgen hypothesis: Measuring digit ratios, sexual orientation, and spatial abilities in adults. *Hormones and Behavior*, *47*, 92–98.

Ward, C., & Sethi, R. (1986). Cross-cultural validation of the Bem Sex-Role Inventory: Malaysian and South Indian research. *Journal of Cross Cultural Psychology*, *17*, 300–314.

Wisniewski, A. B. (1998). Sexually-dimorphic patterns of cortical asymmetry, and the role for sex steroid hormones in determining cortical patterns of lateralization. *Psychoneuroendocrinology*, *23*, 519–547.

Yang, C. F., Gray, P., & Pope, H. G., Jr. (2005). Male body image in Taiwan vs. the West: Yanggang Zhiqi meets the Adonis complex. *American Journal of Psychiatry*, *162*, 263–269.

Zhang, J. X., & Schwarzer, R. (1995). Measuring optimistic self-beliefs: A Chinese adaptation of the General Self-Efficacy Scale. *Psychologia*, *38*, 174–181.

Zhu, Y., Zhang, L., Fan, J., & Han, S. (2007). Neural basis of cultural influence on self-representation. *NeuroImage*, *34*, 1310–1316.

Zuckerman, M. (1994). *Behavioral expressions and biosocial bases of sensation seeking*. Cambridge: Cambridge University Press.