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Is digit ratio (2D:4D) related to systemizing and empathizing? Evidence from direct finger measurements reported in the BBC internet survey

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ABSTRACT

The ratio of 2nd to 4th digit length (2D:4D), the systemizing quotient (SQ) and the empathizing quotient (EQ) are putative correlates of prenatal testosterone. However, the evidence that 2D:4D is related to SQ or EQ is mixed. Voracek and Dressler (2006) used indirect finger measurements and found no significant associations with 2D:4D and SQ or EQ, whereas von Horn, Bäckman, Davidsson, and Hansen (2010) reported significant correlations between 2D:4D and a composite measure of SQ and EQ using direct finger measurements. Here we report associations of 2D:4D, SQ and EQ in participants from a large internet survey in which direct measurements of fingers were collected. We found (i) significant negative correlations of SQ with 2D:4D, this being stronger for right hand 2D:4D and independent of sex, age, height, ethnicity, sexual orientation, and education, (ii) no significant correlation of EQ and 2D:4D. We further examined mean 2D:4D's and found suggestions of a distortional effect of indirect finger measurement in the Voracek and Dressler (2006) study. Our results partly replicate those of von Horn et al. (2010) and emphasize the use of direct finger measurements when studying associations between 2D:4D and target traits with small effect size.

1. Introduction

There are morphological and behavioural traits that may serve as markers for prenatal testosterone (PT). Included in the former, is the ratio of the length of the 2nd and 4th digit (2D:4D; Manning, Scutt, Wilson, & Lewis-Jones, 1998). With regard to the latter, systemizing (systemizing quotient, SQ) and empathizing (empathy quotient, EQ) have been reported to correlate positively (SQ: Auyeung et al., 2006) and negatively (EQ: Knickmeyer, Baron-Cohen, Raggatt, Taylor, & Hackett, 2006) with PT. In order to clarify why links between PT and 2D:4D, SQ and EQ are likely we briefly consider some of the strands of this evidence.

It has been suggested that 2D:4D is negatively related to PT and that the association is particularly strong for the right hand (Manning, 2002, 2008; Manning et al., 1998). Digit ratio shows sex differences. Thus, males tend to have lower values of 2D:4D than females and this arises in utero (Galis, Ten Broek, Van Dongen, & Wijnaendts, 2010; Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, & Manning, 2004; Malas, Dogan, Hilal Evcil, & Desdicioglu, 2006). The sex difference is found in children (Manning, Stewart, Bundred, & Trivers, 2004) and its strength in infants is strongly related to the sex difference in adults (McIntyre, Ellison, Lieberman, Demerath, & Towne, 2005). Moreover, 2D:4D of children does not change substantially during development (Trivers, Manning, & Jacobson, 2006). While a direct link between 2D:4D and PT in humans is difficult to show, there is accumulating evidence for this association. Studies that provide a direct test of the link between 2D:4D and PT report that: (i) children with congenital adrenal hyperplasia (CAH), who were exposed to high levels of PT had lower 2D:4D than controls (Brown, Hines, Fane, & Breedlove, 2002; Okten, Kalyoncu, & Yaris, 2002; but see Buck, Williams, Hughes, & Acerini, 2003), and (ii) males with various levels of androgen insensitivity have high 2D:4D in comparison to controls (Berenbaum, Bryk, Nowak, Quigley, & Moffat, 2009; Manning, Bundred, Newton, & Flanagan, 2003).

With regard to SQ and EQ, systemizing is the drive to analyse and construct systems by understanding the rules that govern the system, whereas empathizing is the drive to identify the thoughts and emotions of others and respond appropriately (Baron-Cohen, 2002, 2003; Baron-Cohen, Richler, Bisarya, Gurunathan, & Wheelwright, 2003). Males on average score higher on tests of systemizing and females usually score higher on tests of empathy (Baron-Cohen, 2002, 2003). These sex differences may arise as a result of the influence of PT acting on the foetus such that it has an organising effect on the brain and thus facilitates the ability in systemizing but reduces the ability to emphasize. There is indeed evi-

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dence that PT (as measured from routine amniocentesis) is positively related to systemizing (Auyeung et al., 2006) and negatively related to empathizing (Knickmeyer et al., 2006).

Further support for a link between PT, and 2D:4D, SQ and EQ include reports that children with autism have low 2D:4D and high SQ. Individuals with autism spectrum conditions (ASC), score higher for SQ than control males, who in turn score higher than control females (Baron-Cohen et al., 2003). In addition, children with ASC have been reported to have lower 2D:4D than controls in a number of studies (e.g., de Bruin, Verheij, Wiegman, & Ferdinand, 2006; Manning, Baron-Cohen, Wheelwright, & Sanders, 2001). There is one exception to this finding, Voracek and Dressler (2006) found no association between 2D:4D and scores for the autism-spectrum quotient.

If 2D:4D, SQ and EQ are markers of PT one may expect inter-correlations between all of them. However, Voracek and Dressler (2006) have reported no such associations, while von Horn et al. (2010) found that a composite measure of all EQ and SQ items (derived from a principal component rotated in such a way as to maximise the difference between men and women) correlated negatively with 2D:4D in males. A third report (Brosnan, Daggar, & Collomosse, 2010), considered the association between 2D:4D and systemizing (measured not as the SQ but from the intuitive physics test) but not empathizing. Here we focus on the discrepancies between studies of 2D:4D, SQ and EQ. One cause of these discrepancies may arise from measurement issues. Voracek and Dressler (2006) measured finger length indirectly from photocopies while von Horn et al. (2010) measured fingers directly from individuals. Photocopies and scans of fingers are two-dimensional facsimiles of three-dimensional objects. There is evidence from samples of UK, USA and German populations that a photocopied or scanned image of the hand distorts the relative lengths of 2D and 4D, such that in comparison to actual finger length 4D appears longer than 2D. Thus, the 2D:4Ds from indirect measurements are distorted downwards (Allaway, Bloski, Pierson, & Lujan, 2009; Burriss, Little, & Nelson, 2007; Caswell & Manning, 2009; Fink, Thanzami, Seydel, & Manning, 2006; Manning, Fink, Neave, & Caswell, 2005). Surprisingly, in Austrian samples Voracek and colleagues (Voracek & Dressler, 2006; Voracek & Offenmüller, 2007) have not replicated this distortional effect. Note that the discrepancies between mean direct and indirect 2D:4D cannot arise from differences in accuracy of measurement. Random errors in measurement of finger lengths increase dispersion of measurements around the mean, they do not result in directional distortion of means.

The aim of this study was to investigate the relationship between 2D:4D and SQ and EQ in an on-line survey of sex differences (i.e., the BBC Study). In addition, we compared our results with the reports by Voracek and Dressler (2006) and von Horn et al. (2010) to examine differences in measurement protocols of finger lengths as one possible cause of the discrepancies between reports.

2. Methods

Participants were recruited from a BBC Internet study (hereafter referred to as 'Study') (see Reimers, 2007). The Study comprised questions about demographics, personality, social attitudes and behaviour, along with cognitive tests and self-measurement of physical characteristics such as 2D:4D.

The first questions were sex (male/female) and age (0–99 years). Ethnicity also appeared on the first page in form of a dropdown menu, from which participants could choose one of seven categories (Asian/Asian British, Black/Black British, Black other, Chinese, Middle/Near Eastern, Mixed ethnic, White).

In the second part participants were requested to provide self-measured finger lengths following the methodology reported by Manning et al. (1998). After viewing a diagram of the hand, they were given instructions as to how to measure their index finger and ring finger on the palm-side of the right and left hand. The participants were asked to measure finger lengths with a ruler and to report lengths to the nearest millimetre using dropdown menus, with values between 10 and 100 mm in 1 mm increments. Participants were also asked to report their height in centimetres.

In the third part there were 10 questions selected from the full EQ and ten from the full SQ (Baron-Cohen, 2003; Table 1). The selected questions had the highest sex difference in the control data reported in Wheelwright et al. (2006). The scoring options were from left to right: definitely agree (DA), slightly agree (SA), slightly disagree (SD), and definitely disagree (DD). This was scored positively or negatively (positively: DA and SA = 0, SD = 1, DD = 2). An SQ and EQ score was calculated by summing across the 10 questions.

With regard to ethnicity, 84.1% described themselves as White, 6.3% as Asian or Asian British, 2.2% as Chinese, 1.2% as Middle or Near Eastern, 0.8% as Black or Black British, 0.8% as Black other, and the remainder (2.2%) as of mixed origin.

A total of 255,116 people completed the entire study. As in previous reports of the Study (Collaer, Reimers, & Manning, 2007; Manning & Fink, 2008; Peters, Manning, & Reimers, 2007), we restricted our analyses to participants with 2D:4D within the range of 0.80–1.20, because self-measured finger lengths can include measurement errors that result in extreme values of 2D:4D (Caswell & Manning, 2009). This adoption had the effect of removing only 1% of the participants from each tail of the distribution. Moreover, in order to remove an effect of age on 2D:4D (McIntyre et al., 2005) the analysis considered only respondents who were 18 years and older.

3. Results

3.1. Descriptive statistics

There were 201,865 participants (110,955 males) with a mean (±SD) age of 31.78 ± 11.08 years. Males were slightly older than females (males: 32.38 ± 11.30 years, females: 31.05 ± 10.75 years). There were 189,211 participants (105,900 males) who reported values for body height. As expected there was a strong sexual dimorphism with males – on average – being taller than females (males: 1.79 ± 0.08 m, females: 1.65 ± 0.08 m, $t = 2999.78$, $p = 0.0001$, $d = 1.75$). With regard to education, there were 200,364 participants (110,151 males) who reported their highest level of formal schooling. Typically higher levels of education are usually over-represented in Web studies (Reimers, 2007), and this was also the case in the Study. A total of 16.1% participants had post-graduate or professional degrees, 41.9% had attended university, 12.5% technical/vocational college, 10.6% other college, 17.7% secondary/high school, and 1.2% primary/grammar school.

The mean right hand 2D:4D was 0.988 ± 0.050, and mean left hand 2D:4D was 0.988 ± 0.049. There was a significant sex difference with males having lower values than females, this difference being stronger for the right hand (right hand; males: 0.984 ± 0.049, females: 0.994 ± 0.051, $t = 32.73$, $p = .0001$, $d = 0.20$: left hand; males: $n = 110{,}955$, 0.984 ± 0.048, females: $n = 90{,}910$, 0.992 ± 0.049, $t = 25.06$, $p = .0001$, $d = 0.17$).

The 10-item version of the SQ and EQ elicited a similar pattern to that expected from the long version. Males had significantly higher SQ scores than females (males: $n = 95{,}471$, SQ = 12.98 ± 3.54; females: $n = 74{,}693$, SQ = 8.51 ± 3.86, $t = 168.07$, $p = 0.0001$, $d = 1.21$) and lower EQ scores than females (males: $n = 95{,}447$, EQ = 7.81 ± 3.38; females: $n = 74{,}780$, EQ = 10.77 ± 3.43, $t = 123.87$, $p = 0.0001$, $d = 0.87$). SQ and EQ were negatively corre-

Table 1
The brief EQ and SQ questionnaires.

EQ

1. I really enjoy caring for other people
2. It is hard for me to see why some things upset people so much
3. I find it easy to put myself in somebody else's shoes
4. If anyone asked me if I liked their haircut, I would reply truthfully, even if I did not like it
5. Other people tell me I am good at understanding how they are feeling and what they are thinking
6. I am able to make decisions without being influenced by people's feelings
7. People sometimes tell me that I have gone too far with teasing.
8. I usually stay emotionally detached when watching a film
9. I can tell if someone is masking their true emotion
10. I tend to get emotionally involved with a friend's problems

SQ

1. I find it difficult to read and understand maps
2. I find it difficult to learn how to programme video recorders
3. I find it easy to grasp exactly how odds work in betting
4. I do not enjoy games that involve a high degree of strategy (e.g. chess, Risk, Games Workshop)
5. I can remember large amounts of information about a topic that interests me e.g. flags of the world, airline logos
6. I am fascinated by how machines work
7. I know very little about the different stages of the legislation process in my country
8. I can easily visualise how the motorways in my region link up
9. I do not enjoy in-depth political discussions
10. If I were buying a stereo, I would want to know about its precise technical features

Scoring options were from left to right: definitely agree (DA), slightly agree (SA), slightly disagree (SD), definitely disagree (DD). This was scored positively or negatively (positively: DA, SA = 0, SD = 1, DD = 2). An SQ and EQ was calculated by summing across the 10 questions.

Table 2
Correlations between SQ and right and left 2D:4D in 95,471 males and 74,693 females, and EQ and right and left 2D:4D in 95,447 males and 74,780 females.

	n	*r*	*p*
SQ males			
Right 2D:4D	95,471	−0.013	0.0001[a]
Left 2D:4D	95,471	−0.010	0.002[a]
SQ females			
Right 2D:4D	74,693	−0.019	0.001[a]
Left 2D:4D	74,693	−0.007	0.06
EQ males			
Right 2D:4D	95,447	0.005	0.15
Left 2D:4D	95,447	0.006	0.07
EQ females			
Right 2D:4D	74,780	0.004	0.24
Left 2D:4D	74,780	0.003	0.49

[a] Significant after Bonferroni correction.

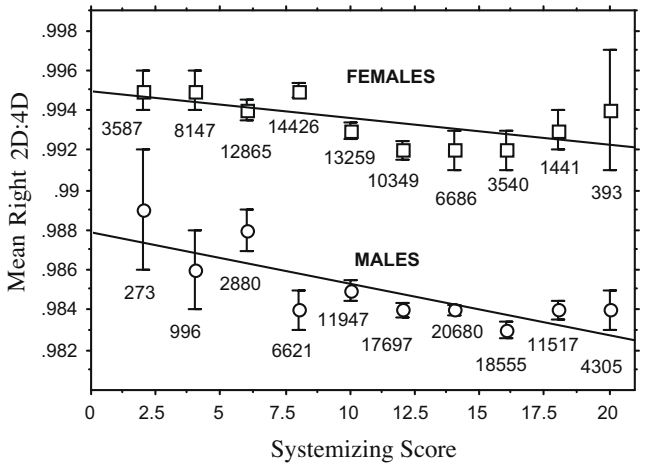

Fig. 1. The relationship between mean right 2D:4D and mean SQ in 95,471 males and 74,693 females. SE bars and numbers of participants are plotted against each mean 2D:4D. The systemizing score is given for intervals 0–2, 3–4, 5–6, . . .,17–18, 19–20.

lated (n = 167,241, r = −0.28, p = 0.0001). The correlation between responses for the control version (Wheelwright et al., 2006) and the 10-item version was r = 0.75 for the SQ and r = 0.86 for the EQ.

3.2. Relationships between SQ, EQ and 2D:4D

Correlations between SQ, EQ and 2D:4D are shown in Table 2. SQ scores were significantly and negatively correlated with right and left 2D:4D (Fig. 1), although the correlations with left hand 2D:4D were significant only for males. EQ scores were positively but non-significantly correlated with 2D:4D.

3.3. Possible confounding variables

Relationships between 2D:4D and SQ, EQ may be obscured by confounding factors. SQ and EQ are negatively related, and right and left 2D:4D are positively correlated. Also there are ethnicity and sexual orientation effects on 2D:4D in the Study (Manning, Churchill, & Peters, 2007). In addition height, as a possible marker of adult sex steroids, life experience (age), and education may correlate with SQ and EQ. Thus, in a sample of heterosexual White participants we removed the effects of sex (dummy variable; males = 0, females = 1), age, height and education and considered the relationship between (i) SQ (independent of EQ; i.e. the residuals from SQ on EQ) and right 2D:4D (independent of left 2D:4D; i.e. the residuals from right 2D:4D on left 2D:4D), and (ii) EQ (independent of SQ; i.e. the residuals from EQ on EQ) and right 2D:4D (independent of left 2D:4D; i.e. the residuals from right 2D:4D on left 2D:4D). With regard to SQ, we found significant negative relationships with right 2D:4D and sex, and significant positive relationships with age, height and education. Considering EQ, there were no significant associations with right 2D:4D, and height, but significant positive associations with sex and education (Table 3).

3.4. Indirect vs. direct measurements

Means for 2D:4D by country, sex, type of measurement (direct vs. indirect), and group (Voracek & Dressler, 2006: n = 423, 206 males; von Horn et al., 2010: n = 92, 46 males; the Study: Austria

Table 3
The results of two multiple regression tests with SQ (independent of EQ) and EQ (independent of SQ) scores the dependent variables and independent variables 2D:4D (right independent of left 2D:4D), sex, age, height, and education.

	Beta	*t*	*p*
SQ (independent of EQ)			
Right 2D:4D(independent of left 2D:4D)	−0.008	3.33	0.0009
Sex	−0.40	112.63	0.0001
Age	0.009	3.68	0.0001
Height	0.06	17.05	0.0001
Education	0.14	53.80	0.0001
EQ (independent of SQ)			
Right 2D:4D (independent of left 2D:4D)	0.001	0.19	0.85
Sex	0.29	75.44	0.0001
Age	0.003	1.11	0.27
Height	0.005	1.27	0.20
Education	0.06	22.17	0.0001

$n = 308$, 169 males, Sweden $n = 961$, 670 males) are given in Table 4.

Voracek and Dressler (2006) reported means for heterosexuals, so we report heterosexual Study means (the exclusion of homosexuals from the Swedish sample made little difference). For Austria, the indirect means of 2D:4D measurements of Voracek and Dressler (2006) did not overlap with the direct means of 2D:4D Study means (Voracek and Dressler: 0.952–0.973, the Study: 0.979–0.991). A paired *t*-test (four pairs: indirect right male mean with Study right male mean; ...) showed that the average difference between indirect and direct mean 2D:4D was significant ($x - y = -0.025$, $t = 7.44$, $p = 0.005$). That is, the means reported by Voracek and Dressler (2006) were significantly smaller than those from the Study. For Sweden, the means for direct measurements of 2D:4D in von Horn et al.'s (2010) study and the Study overlapped (von Horn et al.: 0.97–0.99, the Study: 0.982–0.995). A paired *t*-test showed no significant difference between the von Horn et al. (2010) and Study direct means ($x - y = -0.008$, $t = 2.87$, $p = 0.07$).

4. Discussion

We have found that (i) the means for 2D:4D, SQ, EQ and height showed sex differences such that males had lower 2D:4D, higher SQ, lower EQ and were taller than females, (ii) the correlations between 2D:4D, SQ and EQ showed a weak but highly significant negative association between 2D:4D (particularly right hand 2D:4D) and systemizing, but no significant relationships between 2D:4D and EQ, (iii) considering heterosexual White participants only the right hand 2D:4D (independent of left 2D:4D) remained significantly related to SQ (independent of EQ) after the removal of the influence sex, age, height and education, and (iv) mean 2D:4D's obtained from direct finger measurements (from the Study) were significantly higher than those obtained from indirect finger measurements reported by Voracek and Dressler (2006). However, mean 2D:4D's of the direct measurements of Swedish participants from the Study did not significantly differ from those reported from direct finger measurements by von Horn et al. (2010).

Our data support a negative correlation between 2D:4D and SQ in men and women. The relationship is very weak, but with self-measurement of fingers random error is high (Caswell & Manning, 2009), and this will reduce effect sizes. Therefore, we stress that we do not know what the correct effect size is for the relationship but we anticipate it will be higher for experimenter-measured direct 2D:4D. However, we have a pattern of results that is concordant with theory, with negative relationships between 2D:4D and SQ (that were stronger for right 2D:4D than left) and positive relationships between 2D:4D and EQ. If our very large sample was simply causing everything to be significantly related to everything else we would not expect this pattern, nor would we expect strikingly different *p* values for the links between 2D:4D and SQ (highly significant) and EQ (non-significant). In contrast, the Voracek and Dressler (2006) study reported higher effect sizes but with a pattern of relationships that were theory-discordant across the whole of their study including negative associations between 2D:4D and both SQ and EQ.

With regard to the EQ, the finding of no significant association does not necessarily mean that EQ is unrelated to PT. There is evidence that the sex difference in 2D:4D is established at the end of the first trimester (Manning, 2002). The sex difference in EQ may arise as a result of PT levels outside this developmental window.

The Austrian means in the Study were higher than those reported from indirect measurements by Voracek and Dressler (2006). This is surprising as it has also been reported that direct and indirect 2D:4D is not significantly different in Austrian samples (Voracek & Dressler, 2006; Voracek & Offenmüller, 2007). Studies reporting samples from the USA, UK and Germany have shown that in comparison to 2D:4D from direct measurements the 2D:4D from indirect measurements were distorted downwards (Allaway et al., 2009; Burriss et al., 2007; Caswell & Manning, 2009; Fink et al., 2006; Manning et al., 2005). We are unable to explain these discrepancies between studies, although they are unlikely to arise as the result of different measurement methodologies (Voracek, Manning, & Dressler, 2007).

The contrasting effects of direct and indirect finger measurement may explain why a relationship between 2D:4D and SQ/EQ was found by von Horn et al. (2010) and in the Study, whereas no association was reported by Voracek and Dressler (2006). It is unlikely that the distortion of 2D:4D by indirect finger measurement is a simple reduction in mean 2D:4D. Manning et al. (2005) found that the distortional effect differs between males and females, right and left hands, and male heterosexuals and homosexuals. Such complex discrepancies may arise from group and individual differences in degrees of pressure applied when the hands are placed on the photocopier or scanner. Thus a simple arithmetical adjustment in mean 2D:4D is unlikely to correct for the discrepancies between directly and indirectly-measured 2D:4D. In this regard Burriss et al. (2007) compared correlations between facial-metric traits and 2D:4D's obtained from indirect

Table 4
Mean 2D:4D reported for (i) Austria for indirect measurements of the fingers from photocopies and direct measurements of the fingers (C the Study) and (ii) Sweden for direct measurements and direct measurements.

	Austria				Sweden			
	Male		Female		Male		Female	
Indirect[a]	.952(.028)	.955(.028)	.969(.030)	.973(.032)				
Direct[b]					.97(.03)	.98(.03)	.98(.03)	.99(.03)
Direct[c]	.979(.041)	.988(.041)	.990(.042)	.991(.039)	.982(.050)	.983(.046)	.995(.051)	.994(.048)

[a] Voracek and Dressler (2006).
[b] Experimenter-measured; von Horn et al. (2010).
[c] Self-reported; the Study.

and direct (self- and experimenter-measured) measurements. Indirectly-measured 2D:4D had lower mean 2D:4D and lower *r* values with target traits than did directly-measured 2D:4D, and among the latter the experimenter – measured 2D:4D had stronger relationships with target traits than self-measured 2D:4D. Therefore, we suggest using experimenter-measured direct finger measurement where 2D:4D is likely to be weakly related to target traits.

In conclusion, we have found that right hand 2D:4D was negatively correlated with SQ in males and females. The relationship was robust to the effects of sex, age, height and education. This suggests that 2D:4D and SQ are influenced by PT at similar developmental times. There was no association between 2D:4D and EQ. We used direct finger measurements in our calculation of 2D:4D. Such measurements give 2D:4D ratios that are not prone to distortions associated with indirect finger measurements. It is suggested that replications of 2D:4D associations with weak effect size should use direct rather than indirect measurements of fingers.

References

Allaway, H. C., Bloski, T. G., Pierson, R. A., & Lujan, M. E. (2009). Digit ratios determined by computer-assisted analysis are more reliable than those using physical measurements, photocopies, and printed scans. *American Journal of Human Biology, 21*(3), 365–370.

Auyeung, B., Baron-Cohen, S., Chapman, E., Knickmeyer, R., Taylor, K., & Hackett, G. (2006). Foetal testosterone and the child systemizing quotient (SQ-C). *European Journal of Endocrinology, 155*, 123–130.

Baron-Cohen, S. (2002). The extreme male brain theory of autism. *Trends in Cognitive Sciences, 6*, 248–254.

Baron-Cohen, S. (2003). *The essential difference: men, women and the extreme male brain*. London: Allen Lane.

Baron-Cohen, S., Richler, J., Bisarya, D., Gurunathan, N., & Wheelwright, S. (2003). The systemising quotient (SQ): An investigation of adults with asperger syndrome or high functioning autism and normal sex differences. *Philosophical Transactions of the Royal Society, Series B, 358*, 361–374.

Berenbaum, S. A., Bryk, K. K., Nowak, N., Quigley, C. A., & Moffat, S. (2009). Fingers as a marker of prenatal androgen exposure. *Endocrinology, 150*(11), 4819–4822.

Brosnan, M., Daggar, R., & Collomosse, J. (2010). The relationship between systemising and mental rotation and the implications for the extreme male brain theory of autism. *Journal of Autism and Developmental Disorders, 40*(1), 1–7.

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 & Behavior, 42*(4), 380–386.

Buck, J. J., Williams, R. M., Hughes, I. A., & Acerini, C. L. (2003). In-utero androgen exposure and 2nd to 4th digit length ratio-comparisons between healthy controls and females with classical congenital adrenal hyperplasia. *Human Reproduction, 18*(5), 976–979.

Burriss, R. P., Little, A. C., & Nelson, E. C. (2007). 2D:4D and sexually dimorphic facial characteristics. *Archives of Sexual Behavior, 36*(3), 377–384.

Caswell, N., & Manning, J. T. (2009). A comparison of finger 2D:4D by self-report direct measurement and experimenter measurement from photocopy: methodological issues. *Archives of Sexual Behavior, 38*(1), 143–148.

Collaer, M. L., Reimers, S., & Manning, J. T. (2007). Visuospatial performance on an internet line judgment task and potential hormonal markers: sex, sexual orientation, and 2D:4D. *Archives of Sexual Behavior, 36*(2), 177–192.

de Bruin, E. I., Verheij, F., Wiegman, T., & Ferdinand, R. F. (2006). Differences in finger length ratio between males with autism, pervasive developmental disorder-not otherwise specified, ADHD, and anxiety disorders. *Developmental Medicine & Child Neurology, 48*(12), 962–965.

Fink, B., Thanzami, V., Seydel, H., & Manning, J. T. (2006). Digit ratio (2D:4D) and hand grip strength in German and Mizos men: Cross-cultural evidence for an organising effect of parental testosterone on strength. *American Journal of Human Biology, 18*(6), 776–782.

Galis, F., Ten Broek, C. M., Van Dongen, S., & Wijnaendts, L. C. (2010). Sexual dimorphism in the prenatal digit ratio (2D:4D). *Archives of Sexual Behavior, 39*(1), 57–62.

Knickmeyer, R., Baron-Cohen, S., Raggatt, P., Taylor, K., & Hackett, G. (2006). Foetal testosterone and empathy. *Hormones & Behavior, 49*(3), 282–292.

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.

Malas, M. A., Dogan, S., Hilal Evcil, E., & Desdicioglu, K. (2006). Fetal development of the hand, digits and digit ratio (2D:4D). *Early Human Development, 82*(7), 469–475.

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

Manning, J. T. (2008). *The finger book: Sex, behavior and disease revealed in the fingers*. London: Faber and Faber.

Manning, J. T., Baron-Cohen, S., Wheelwright, S., & Sanders, G. (2001). The 2nd to 4th digit ratio and autism. *Developmental Medicine & Child Neurology, 43*(3), 160–164.

Manning, J. T., Bundred, P. E., Newton, D. J., & Flanagan, B. F. (2003). The second to fourth digit ratio and variation in the androgen receptor gene. *Evolution and Human Behavior, 24*(6), 399–405.

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

Manning, J. T., & Fink, B. (2008). Digit ratio (2D:4D), dominance, reproductive success, asymmetry, and sociosexuality in the BBC Internet Study. *American Journal of Human Biology, 20*(4), 451–461.

Manning, J. T., Fink, B., Neave, N., & Caswell, N. (2005). Photocopies Yield Lower Digit Ratios (2D:4D) Than Direct Finger Measurements. *Archives of Sexual Behavior, 34*(3), 329–333.

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*(11), 3000–3004.

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

McIntyre, M. H., Ellison, P. T., Lieberman, D. E., Demerath, E., & Towne, B. (2005). The development of sex differences in digital formula from infancy in the Fels Longitudinal Study. *Proceedings of the Royal Society B: Biological Sciences, 272*(1571), 1473–1479.

Okten, A., Kalyoncu, M., & Yaris, N. (2002). The ratio of second- and fourth-digit lengths and congenital adrenal hyperplasia due to 21-hydroxylase deficiency. *Early Human Development, 70*(1), 47–54.

Peters, M., Manning, J. T., & Reimers, S. (2007). The effects of sex, sexual orientation, and digit ratio (2D:4D) on mental rotation performance. *Archives of Sexual Behavior, 36*(2), 251–260.

Reimers, S. (2007). The BBC internet study: general methodology. *Archives of Sexual Behavior, 36*(2), 147–161.

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

von Horn, A., Bäckman, L., Davidsson, T., & Hansen, S. (2010). Empathizing, systemizing and finger length ratio in a Swedish sample. *Scandinavian Journal of Psychology, 51*(1), 31–37.

Voracek, M., & Dressler, S. G. (2006). High (feminised) digit ratio (2D:4D) in Danish men: a question of measurement method? *Human Reproduction, 21*(5), 1329–1331.

Voracek, M., Manning, J. T., & Dressler, S. G. (2007). Repeatability and interobserver error of digit ratio (2D:4D) measurements made by experts. *American Journal of Human Biology, 19*(1), 142–146.

Voracek, M., & Offenmüller, D. (2007). Digit ratios (2D:4D and others) and relative thumb length: a test of developmental stability. *Perceptual and Motor Skills, 105*(1), 143–152.

Wheelwright, S., Baron-Cohen, S., Goldenfeld, N., Delaney, J., Fine, D., Smith, R., et al. (2006). Predicting autism spectrum quotient (AQ) from the systemizing quotient-revised (SQ-R) and empathy quotient (EQ). *Brain Research, 1079*, 47–56.