

**2D:4D digit ratio and types of adult paranormal belief: An attempted replication
and extension of Voracek (2009) with a UK sample**

Paul Rogers PhD^a, Noreen Caswell PhD^b & Gayle Brewer PhD^b

^a Anomalistic Psychology Research Unit, Department of Psychology, Goldsmith's College, University of London, New Cross, London SE14 6NW, UK

^b School of Psychology, Darwin Building, University of Central Lancashire, Preston, Lancashire PR1 2HE, UK

Highlights

1. Females reported (marginally) stronger beliefs in ESP and life after death.
2. Females also reported higher indirect rater-based 2D:4D ratios.
3. Females' direct self-rated 2D:4D correlated positively with their ESP and PK beliefs.
4. Females' direct self-rated functional asymmetry correlated with their PK beliefs.
5. No significant digit-related \times paranormal belief associations existed for males.

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Abstract

This study examines the extent to which mean digit length (MDL), second-to-fourth digit ratio (2D:4D), digit asymmetry (DA) and fluctuating asymmetry (FA) correlate with belief in three types of alleged paranormal phenomena (extrasensory perception, psychokinesis, and life after death). An opportunistic sample of 275 undergraduate students completed standard paranormal belief and demographics questionnaires with the absolute length of their 2D and 4D on both hands measured by participants themselves (direct self-based measures) as well as by two independent from hand photocopies (indirect rater-based measures). As hypothesised, females presented a lower MDL (both measurement sources) but higher indirect rater-based 2D:4D ratio than males. Additionally, females' left hand 2D:4D correlated positively with their belief in psychokinesis with their right hand 2D:4D correlating with belief in both extrasensory perception and psychokinesis. Females' direct self-based FA was also associated with stronger PK beliefs. These trends did not exist for male participants. Finally, no significant relationships were found between either MDL or DA and any belief type regardless of measurement source, hand or participant sex. Results are discussed in relation to previous work by Voracek (2009) and their support for genetic bio-markers of adult paranormality. Methodological limitations are also considered.

Keywords: Paranormal belief; 2D:4D digit ratio; Genetic; Hormones; Sex Differences

25 **1. Introduction**

26 Numerous studies suggest women are more likely to believe in paranormal concepts such
27 as extrasensory perception (ESP), psychokinesis (PK), and life after death (LAD) than are
28 men. Early writers claimed these sex differences developed as a reaction to feelings of
29 alienation experienced by those with low or marginal status in society which at the time
30 included women (e.g., Emmons & Sobal, 1981). Others have since argued women's
31 heightened paranormality reflects their preference for intuitive over rational thinking (Aarnio
32 & Lindeman, 2005) else a socially constructed gender role stereotype (Simmonds-Moore &
33 Moore, 2009). At present, empirical support for these arguments is either sparse or mixed
34 (Irwin, 2009). Another possibility is that sex differences in adult paranormal belief have a
35 genetic basis. The present study investigates this possibility by testing the degree to which
36 various digit-related measures - mean digit length, 2D:4D digit ratio, digit asymmetry and
37 fluctuating asymmetry - correlate with specific *types* of adult paranormal belief.

38 **1.1 Digit ratio**

39 As its name implies 2D:4D digit ratio reflects the relative length of a person's second digit
40 (2D) to that of their fourth digit (4D). This ratio develops in utero under the influence of
41 Homeobox genes which determine prenatal levels of male and female hormone both of which
42 exert a permanent thus organising effect on brain physiology. Because 2D:4D remains
43 relatively stable post partum, it acts as a retrospective bio-marker for prenatal exposure to
44 testosterone and oestrogen levels and is directly linked to, not only adult physique and sexual
45 development, but also to adult traits, cognitions and behaviour (Manning 2002; 2008).

46 Digit ratio is sexually dimorphic with females typically displaying higher 2D:4D than
47 males. In general, higher 2D:4D is associated with characteristics typically deemed more
48 feminine in nature with sex-differences, for the most part, robust to variations in
49 measurement protocol (Manning, 2002; 2008; Voracek, Manning, & Dressler, 2007; although

50 see Ribeiro, Neave, Morais & Manning, 2016). For example, higher (more feminized) 2D:4D
51 has been shown to correlate with a preference for intuitive over reflective decision-making
52 (Bosch-Domènech, Brañas-Garza, & Espín, 2014).

53 *1.2 Digit ratio, asymmetry, length and paranormal belief*

54 To date only one study has examined the relationship between digit ratio and paranormal
55 belief. Voracek (2009) took palmar-view photocopies of participants' right and left hands
56 from which three trained investigators blind to study aims used digital vernier callipers to
57 measure 2D and 4D lengths to .01 mm. Whilst women had higher 2D:4D and more
58 pronounced paranormal and superstitious beliefs than men, their ratio and paranormal belief
59 scores were uncorrelated. Significant ratio \times belief correlations did emerge for men however;
60 men with a higher (more feminized) 2D:4D ratio reported stronger paranormal and
61 superstitious beliefs than men with a lower (less feminized) 2D:4D ratio. This was true for
62 both left and right hands and persisted even after men's age, years of education, birth
63 dimensions (length and weight), and adult dimensions (height and weight at the time of
64 testing) had been partialled out. These trends existed for both positive superstitions (e.g., the
65 efficacy of lucky charms) and to a lesser extent negative superstitions (e.g. unfavourable
66 outcomes associated with the number thirteen) with one exception; men's right hand 2D:4D
67 failed to correlate with their endorsement of negative superstitions.

68 In the same study Voracek also examined the relationship paranormal and superstitious
69 beliefs had with right minus left hand 2D:4D difference (D_{R-L}) scores - also termed
70 "directional asymmetry" (DA) - and is thought to be an alternative marker of prenatal
71 testosterone and thus sex-dependent characteristics in adulthood. According to Voracek,
72 Offenmüller and Dressler (2008) DA is the likely cause of much 2D:4D variance.

73 In general, DA scores are larger and thus more "rightward biased" for women than for
74 men, implicating the existence of two entirely different sex-biased growth programmes which

75 differ in sensitivity to prenatal androgen levels (Voracek et al., 2008). Consequently, positive
76 DA scores should be associated with more pronounced adult paranormality. But, whilst
77 Voracek (2009) found women presented slightly larger (more rightward biased) DA than
78 men, DA was not related to either paranormal or superstitious beliefs for either sex.

79 Overall, women tend to have shorter 2D and 4D for both left and right hands with their
80 mean digit length (MDL) across these four digits shorter than that of men (e.g., Voracek,
81 2009). Because sex differences in 2D and 4D are negligible in pre-pubescent children but
82 large in adult populations, MDL is seen as a putative marker of androgen levels following
83 pubertal-adolescent growth spurts (Manning, 2002; 2008). As such, lower MDL should also
84 be associated with more pronounced paranormal and superstitious worldviews. In partial
85 support of this argument, Voracek (2009) found (near) significant negative associations
86 between MDL and both positive and negative superstitious - but not paranormal - beliefs for
87 women but not men. This suggests comparatively low testosterone levels during the female -
88 but not male - pubertal growth spurts heighten adult superstitiousness but not adult
89 paranormality. But in Voracek's study this relationship disappeared when the same
90 demographic and body measures outlined above were controlled for. Voracek conceded that
91 the association between women's MDL and superstitiousness may, in fact, be spurious
92 (p.108).

93 Finally, Voracek (2009) examined the extent to which "fluctuating asymmetry" (FA) is
94 associated with adult paranormal and superstitious beliefs. Bodily FA reflects the extent to
95 which bilateral body parts (such as 2D and 4D) randomly deviate from perfect symmetry and
96 is thought to reflect the cumulative effect genomic or environmental factors have on
97 development¹. Voracek reasoned that greater FA should be linked to stronger paranormal and
98 superstitious worldviews because both are also linked with various forms of adult

99 psychopathology. Contrary to this argument no sex differences in FA were found with FA
100 unrelated to both paranormal and superstitious beliefs for both sexes.

101 In sum, Voracek's (2009) findings suggest only higher (more feminized) 2D:4D is linked
102 to paranormal and superstitious thinking in adulthood, with sex differences in these beliefs
103 most likely influenced by prenatal testosterone levels rather than pubertal-adolescent
104 androgen spurts and/or developmental instability. However, there are several issues with this
105 work that render replication necessary. First, virtually all significant associations existed for
106 male participants only who, as already noted, are less inclined to uphold paranormal and
107 superstitious worldviews. In other words, Voracek's findings were in the opposite direction to
108 that hypothesised and as such, cannot explain women's preponderance for endorsing
109 paranormal and superstitious concepts (cf. Irwin, 2009). Second, observed associations were
110 generally small (all r 's $< .15$) with $< 3\%$ of belief variance explained by digit ratio
111 (Thalbourne, 2010). Finally, Voracek had 2D:4D measured indirectly from hand photocopies
112 rather than directly from participants' actual hands. Indirect 2D:4D is thought to be less
113 accurate and generally lower than corresponding direct 2D:4D, especially for males
114 (Manning, Fink, Neave & Caswell, 2005; Ribeiro et al., 2016), the implication being that
115 cross-sex correlations are unduly influenced by measurement source. These issues, coupled
116 with the widespread inconsistencies and lack of repeatability common in 2D:4D research
117 (Valla & Ceci, 2011) suggests a replication of Voracek (2009), employing both direct and
118 indirect measurement protocols, is warranted.

119 ***1.3 Study overview and hypotheses***

120 The current study investigates the extent to which MDL, 2D:4D digit ratio, DA, and FA
121 scores correlate with *specific* beliefs in three "core" paranormal concepts namely
122 extrasensory perception (ESP), psychokinesis (PK) and life after death (LAD). Participants'
123 self-reported ("direct self-based") digit lengths plus digit lengths derived from hand

124 photocopies and assessed by two independent and trained judges (“indirect rater-based”) are
125 included. In general digit-related measures indicative of greater femininity - hence less
126 prenatal testosterone - should correlate positively with all types of paranormal belief. As
127 such, the following hypotheses are proposed.

128 First, females will report stronger beliefs in ESP, PK, and LAD than males (H01). Second,
129 females will present shorter MDL, larger (more feminized) 2D:4D digit ratios, larger (more
130 rightward biased) DA and more FA than males (H02 to H05 respectively). Third, females
131 with shorter MDL, larger 2D:4D, larger DA, and larger FA scores will have stronger beliefs
132 in ESP, PK, and LAD (H06 to H09 respectively) with fourth, parallel associations less
133 pronounced for male participants (H10 to H13 respectively). Fifth, the above differences and
134 trends should be equally strong for ESP, PK, and LAD beliefs (H14). Finally, larger/stronger
135 relationships will be found for direct self-based over indirect rater-based measures (H15).

136 **2 Method**

137 **2.1 Participants**

138 Undergraduate students ($N = 344$) were recruited from a large university in North-West
139 England. Of these, 275 returned usable data, a response rate of 79.9%. Most participants were
140 female (77.1%) and of Caucasian ethnicity (94.9%), with age ranging from 18 to 44 years (M
141 $= 19.74$ years; $SD = 3.65$ years). No other demographic details were collected.

142 **2.2 Materials**

143 *2.1.1 Paranormal Belief:* This was assessed via the *Australian Sheep-Goat Scale* (ASGS:
144 Thalbourne & Delin, 1993) a psychometrically sound measure of belief in ESP, PK, and
145 LAD across three subscales (Thalbourne, 2010). Participants rate 18 statements on a 7-point
146 Likert scale from 1 ‘strongly disagree’ to 7 ‘strongly agree’ with items (re)coded such that
147 higher scores reflected stronger belief in each paranormal concept.

148 *2.1.2 Demographics:* A standard demographics questionnaire assessing participant's age,
149 sex, and ethnicity (16 categories) was also included.

150 *2.1.3 Digit-Related Measures:* Both direct self and indirect rater-based digit lengths were
151 measured. For the former, participants were given a photocopy of the ventral surface of a
152 hand on which the base (i.e. the crease where the finger joins the palm) and tip of both 2D
153 and 4D were marked. This served as an instructive sheet. They were then asked to hold out
154 their left hand, establish the 2D base and, using a ruler provided ensuring this ran up the
155 middle of each digit, measure the distance in millimetres from the mid-point of this crease to
156 the tip of that finger (excluding fingernails). This procedure was repeated for right hand 4D,
157 left hand 2D and left hand 4D.

158 For indirect rater-based measures, the ventral surface of participants' left and right hands
159 were photocopied onto sheets of A4 paper. Participants were asked to press their hands gently
160 on the copier's glass plate ensuring all fingers were straight and laying flat². Landmark
161 locations at the tip and base of each digit were highlighted on the copy, with the distance
162 between these points measured in millimetres by two trained raters blind to each other's
163 calculations. This method of establishing finger length - and thus 2D:4D ratio - is both
164 common and highly reliable (Caswell & Manning, 2009).

165 **2.3 Procedure**

166 Demographic, paranormal belief and digit length data were collected from an
167 opportunistic sample of undergraduate students. The order of photocopying and questionnaire
168 completion was counterbalanced with all digit-related measures computed according to
169 standard protocols (e.g., Voracek et al., 2007). No incentives were provided with adhering to
170 British Psychological Society (BPS) ethical guidelines.

171 **3 Results**

172 **3.1 Paranormal belief**

173 Specific beliefs in ESP, PK, and LAD were all internally reliable (see Table 1). That said,
 174 removal of one item (“non-hallucinatory visions”) improved the internal reliability of the
 175 LAD subscale considerably (from $\alpha = .64$ to $\alpha = .73$) with this revised measure subsequently
 176 computed. Only ESP beliefs were normally distributed with PK beliefs presenting noticeable
 177 positive skew and LAD beliefs slight negative skew. No outliers were found in any belief
 178 measure.

179 *** Table 1 here ***

180 Mann-Whitney tests revealed (near) significant participant sex differences in two of the
 181 three belief subscales with females having (marginally) stronger beliefs in both ESP, $U =$
 182 5679.5 ; $Z = -1.80$; $p = .072$, and LAD, $U = 5447.0$; $Z = -2.23$; $p = .026$, than males. No sex
 183 differences were found in PK beliefs. Thus, H01 is partially supported.

184 Belief in ESP alone correlated with participant age, $\tau = .12$; $p = .009$; two-tailed; $n =$
 185 274 , with no significant associations found between any paranormal belief type and
 186 participants’ (Caucasian vs. non-Caucasian) ethnicity.

187 **3.2 Digit-related measures: Preliminary analyses**

188 **3.2.1 Inter rater Reliability:** Highly significant positive intra-class correlations emerged
 189 between raters’ independent measurements for 2D and 4D on both hands, all r_I ’s = 1.00; all
 190 p ’s <.001; two-tailed; $n = 273$ to 275 , with perfect inter- rater reliability found in all cases.
 191 Mean digit lengths across the two raters were subsequently computed to generate indirect
 192 rater-based measurements (cf. Caswell & Manning, 2009).

193 **3.2.2 Descriptive Data:** Normality, skew and means data for direct self and indirect rater-
 194 based digit-related measures across relevant digit (2D vs. 4D) \times hand (left vs. right)
 195 combinations were examined, with variance explained (η^2) figures calculated following
 196 guidelines in Fritz, Morris, and Richler (2012). Of the eighteen digit-related measures
 197 thirteen were non-normal as follows: direct self-based 2D and 4D lengths for both left and

198 right hands, all Z_{K-S} from .12 to .14; $p < .001$; indirect rater-based 2D and 4D for the right hand,
 199 $Z_{K-S} = .07$; $p = .006$ and $Z_{K-S} = .06$; $p = .012$ respectively; direct self-based MDL, $Z_{K-S} = .12$;
 200 $p < .001$; direct self-based 2D:4D ratios for both left and right hands, $Z_{K-S} = .36$; $p < .001$ and
 201 $Z_{K-S} = .39$; $p < .001$ respectively; indirect rater-based 2D:4D ratio for the right hand, $Z_{K-S} = .06$;
 202 $p = .027$; direct self-based DA, $Z_{K-S} = .37$; $p < .001$; and finally, both direct self-based and
 203 indirect rater-based FA, $Z_{K-S} = .16$; $p < .001$ and $Z_{K-S} = .07$; $p = .007$ respectively.

204 With the Kolmogorov-Smirnov ($K-S$) test sensitive to sample size (Field, 2013), index of
 205 skew (IS) figures were also examined. Direct self-based MDL was negatively skewed ($IS = -$
 206 3.16) whereas indirect rater-based MDL ($IS = .25$) was not. Direct self-based 2D:4D ratios
 207 for both left and right hands were also negatively skewed ($IS = -.18$ and -1.30 respectively)
 208 unlike indirect rater-based ratios ($IS = .17$ and $.18$ respectively). Similarly, direct self-based
 209 but not indirect rater-based, DA presented slight negative skew (IS of $-.80$ and $-.25$
 210 respectively). In contrast, direct self and indirect rater-based FA presented positive skew; the
 211 former noticeably large ($IS = 2.77$ and $.70$ respectively). No outliers were removed with all
 212 data retained. Subsequent analyses employed non-parametric two-tailed tests.

213 *3.2.3 Measurement Source:* Wilcoxon signed-ranks tests revealed direct self-based 2D to
 214 be higher than indirect rater-based 2D for both left and right hands, $T = -8.92$; $p < .001$ and $T =$
 215 -3.81 ; $p < .001$ respectively. The same was also true of indirect rater-based 4D for the left, $T =$
 216 -2.51 ; $p = .011$, but not right hand. Subsequent analyses confirmed significant cross-source
 217 differences in MDL, $T = -5.22$; $p < .001$; in both left and right hand 2D:4D, $T = -5.66$; $p < .001$
 218 and $T = -2.73$; $p = .006$ respectively; in DA, $T = -3.64$; $p = .006$ and finally in FA scores, $T =$
 219 -3.64 ; $p < .001$. With one exception, direct self-based scores were higher/larger than their
 220 indirect rater-based equivalents; only DA was smaller for self than for indirect rater-based
 221 measures.

222 *3.3 Sex differences*

223 Table 2 presents means data for digit-related measures across male versus female
224 participants.

225 *** Table 2 here ***

226 Unsurprisingly, females presented shorter MDLs than males. This was true of both direct
227 self-based and indirect rater-based measures, $U = 2825.0$; $Z = -6.95$; $p < .001$ and $U =$
228 2993.5 ; $Z = -7.01$; $p < .01$ respectively, with H02 thus fully supported. Whilst direct self-
229 based 2D:4D did not differ across participant sex for either hand, indirect rater-based ratios
230 for both left and right hands did, $U = 5479.5$; $Z = -2.11$; $p = .034$ and $U = 5358.5$; $Z = -2.38$;
231 $p = .017$ respectively, with these significantly higher (more feminized) for females over
232 males. As such, H03 is partially supported. In all cases 2D:4D ratios fell just below unity. In
233 contrast, neither direct self nor indirect rater-based ratio difference scores varied significantly
234 across participant sex, with males and females both displaying near zero DA. H04 is not
235 supported. Finally, neither direct self nor indirect rater-based FA differed across males versus
236 females with, in all cases, FA representing $< 3.0\%$ of trait size (cf. Voracek, 2009). H05 is
237 not supported either.

238 ***3.4 Associations with participant age and ethnicity***

239 All digit-related measures were unrelated to participants' age and (Caucasian vs. non-
240 Caucasian) ethnicity. These two demographics are no longer considered.

241 ***3.5 Associations with paranormal belief: Trends for males vs. females***

242 Correlations between all digit-related measures and the three paranormal belief types are
243 presented separately for male and female participants in Table 3. Corresponding variance
244 explained (η^2) figures - calculated from guidelines in Walker (2003) – are given in the
245 supplementary Appendix.

246 *** Table 3 here ***

247 As Table 3 shows, only four (near) significant correlations were found, First, females'
248 belief in ESP correlated positively with their self-rated right hand 2D:4D. Second, females'
249 belief in PK did likewise with self-rated 2D:4D for both hands, with the right hand
250 correlation marginally significant ($p = .058$). Finally, females' belief in PK also correlated
251 positively with their self-rated FA. No more than 4% of belief variance was explained by
252 these relationships (see Appendix) which were not replicated for male participants. In sum,
253 there was limited support for H07 and H09 with all other hypotheses unsupported.

254 ***3.7 Trends for different paranormal belief types***

255 Of these above (near) significant belief \times digit associations, one involved ESP with three
256 involving PK beliefs, with all four of comparable magnitude (τ - b from .10 to .12). Some
257 support for H14 was therefore found.

258 ***3.8 Direct Self vs. Indirect Rater-Based Digit Measurements***

259 Noticeably, these four the (near) significant correlations existed only for females' direct
260 self-based measures. Some support for H15 was also found.

261 **4. Discussion**

262 For the most part, digit-related scores derived from participants' self-judged digit lengths
263 were higher/larger than those measured by two independent and trained raters. Only DA
264 showed the opposite trend. These findings are consistent with previous claims that indirect
265 2D:4D is generally lower (and less accurate) than direct 2D:4D (Manning et al., 2005;
266 Ribeiro et al., 2016). All subsequent discussion will take this bias into account.

267 ***4.1 Sex differences***

268 As expected, females presented (marginally) stronger ESP and LAD beliefs supporting
269 previous claims of robust sex differences in these paranormal belief types (Irwin, 2009). The
270 lack of parallel sex differences for PK beliefs was surprising. It is worth noting that belief in
271 PK is generally less prevalent than belief in either ESP or LAD, in part because PK is

272 arguably more controversial and easier to dismiss as a misinterpretation of some natural event
273 (Irwin & Watt, 2007). In this sense, PK belief may be considered a more “extreme”
274 paranormal endorsement with the current lack of sex differences perhaps reflecting this
275 apparent extremity.

276 As hypothesised, females’ 2D and 4D lengths for both hands across both measurement
277 sources - and hence their direct self and indirect rater-based MDLs - were shorter than those
278 of their male counterparts. Contrary to hypotheses, MDLs failed to correlate with any
279 paranormal belief type regardless of measurement source or participant sex. These findings
280 are consistent with those reported by Voracek (2009).

281 Females also presented larger (more feminized) 2D:4D than males. This was true of both
282 hands further highlighting the sexually dimorphic nature of digit ratios (Manning, 2002,
283 2008) although here, only for those generated from indirect rater-based assessments. As such,
284 they may be less accurate (cf. Manning et al., 2005; Ribeiro et al., 2016)

285 Surprisingly females’ DA scores did not vary significantly from those of males, with both
286 sexes displaying comparatively little directional asymmetry in digit ratios. Whilst contrary to
287 general trends (Manning, 2002; 2008; Voracek et al., 2007) this finding *is* consistent with
288 Voracek (2009), the implication being that males and females experience prenatal growth
289 programmes that are equally sensitive to in utero androgen levels (cf. Voracek et al., 2008).

290 Finally, the two sexes were equally prone to FA implying females’ biopsychological
291 development is just as sensitive to the cumulative effects of genomic and environmental
292 factors as is that of males. This is consistent with Voracek (2009).

293 ***4.2 Associations with paranormal belief: Trends for males vs. females***

294 Females with higher (more feminized) self-rated 2D:4D maintained stronger beliefs in
295 both ESP (both hands) and PK (left hand only) - but not LAD - than those with lower (more
296 masculine) ratios. With self-rated ratios less prone to measurement bias (Manning et al.,

297 2005; Ribeiro et al., 2016), this suggests that at least some of the variance in female's
298 heightened paranormality may be explained by genetic factors, namely sex differences in
299 prenatal exposure to testosterone and/or oestrogen (Voracek, 2009). But, as with Voracek's
300 work, current associations were weak explaining no more than 4% of belief variance, further
301 highlighting the complex nature of adult paranormality (Irwin, 2009). Furthermore, parallel
302 trends did not exist among male participants. As such, current findings are in direct contrast
303 to those of Voracek (2009) who found more feminized 2D:4D was only associated with
304 heightened (global) paranormal and superstitious beliefs among men. Thus, whilst both
305 studies support the idea that prenatal hormone exposure may influence sex differences in
306 adult paranormality, there is considerable disagreement as to whether this is true for just men,
307 just women, or both.

308 Current findings seem to add to the various inconsistencies characteristic of 2D:4D
309 research (Valla & Ceci, 2011) and further studies are required to clarify this position. That
310 said, the magnitude of correlation coefficients and thus the percentage of belief variance
311 explained by 2D:4D ratios are comparably small in both studies, with current findings
312 suggesting they exist only with direct self-based measurements.

313 Contrary to hypotheses, directional asymmetry in 2D:4D ratios (as measured by D_{R-L}
314 scores) were unrelated to specific beliefs in ESP, PK, and LAD. With DA being an alternative
315 bio-marker of prenatal testosterone (Voracek et al., 2008), the suggestion is that this
316 particular male hormone has little influence in shaping adult paranormality. This too is
317 consistent with Voracek (2009).

318 Likewise, MDL averaged across the four digit \times hand combinations failed to correlate
319 with any paranormal belief type regardless of measurement source and/or participant sex.
320 These non-significant findings support those of Voracek (2009) who found MDL was
321 unrelated to *global* paranormal beliefs. And whilst Voracek found women with a longer MDL

322 had more pronounced superstitious beliefs - the implication being that pubertal-adolescent
323 levels of androgen exposure shape adult superstitiousness but not adult paranormality - he
324 subsequently acknowledged this relationship was most likely spurious (p. 108). Current
325 findings should be interpreted the same way.

326 Finally, FA scores were, for the most part, also unrelated to ESP, PK, and LAD beliefs
327 again regardless of both measurement source and participants' biological sex. These data are
328 largely consistent with those reported by Voracek (2009). The single exception was that in
329 the present study females with higher self-rated FA were more predisposed to PK beliefs than
330 those with lower self-rated FA. The implication here is that genome and environmental
331 factors in human development somehow shape adult acceptance that physical objects can be
332 moved through "mind control" alone. However, the relatively small *tau-b* and associated *eta*²
333 figures, coupled with concerns over measurement biases (cf. Caswell & Manning, 2009) and
334 inflated alpha rates from multiple testing, means a more parsimonious interpretation is that
335 this too is a statistical artefact.

336 ***4.3 Methodological limitations and future research***

337 The current study utilised both direct self and indirect rater based digit related measures
338 and thus offers a direct comparison of differing measurement techniques/sources. With the
339 former likely to be more accurate (Manning et al., 2005; Ribeiro et al., 2016) future studies
340 should employ direct-from-hand rather than indirect-from-photocopy protocols. Several other
341 methodological issues are worthy of mention.

342 First, one anonymous reviewer suggested the current sample size ($N = 275$) was rather
343 small compared to other digit ratio studies³. Subsequently the current study's statistical
344 "sensitivity" was tested via a retrospective power analysis. With $N = 275$, alpha set at .05, r
345 ranging from .10 to .12 for two-tailed tests and effect sizes (*eta*²) of .03 and .04 entered into
346 *G*Power* (Faul, 2008), analysis revealed power ($1-\beta$) figures ranging from .9327 to .9988

347 indicating a very high - over 93% - chance of detecting genuine effects. In short, Type II
348 errors were unlikely (Field, 2013).

349 Second, current findings are based on an undergraduate rather than general public sample
350 so are less generalizable than those of Voracek (2009) whose (Austrian) participants came
351 from a wide range of domestic, educational and occupational backgrounds. Present data are
352 also restricted to predominately Caucasian participants with a Westernized socio-cultural
353 background who may hold different paranormal beliefs than those from other ethno-cultural
354 groups (see Irwin, 2009).

355 Third, current trends are limited to just three (core) parapsychological concepts, namely
356 ESP, PK, and LAD. With women more likely to endorse witchcraft and astrology, and less
357 likely to accept extraterrestrial visitation and extraordinary life forms (Irwin, 2009), it seems
358 pertinent to explore the relationship all digit-related measures have with these beliefs.

359 Fourth, the present study did not include body dimensions such as participants' weight and
360 length at birth or weight and height at the time of testing. This aspect of Voracek's (2009)
361 work requires independent verification.

362 Finally, direct comparison between biological verses socio-cultural and/or cognitive
363 factors underlying females' heightened paranormality seems warranted. For example, the
364 extent to which 2D:4D and a preference for intuitive thinking independently predict
365 heightened adult paranormality is worth investigating (cf. Aarnio & Lindeman, 2005; Bosch-
366 Domènech et al., 2014). Other factors such as (scientific) education might also be explored as
367 potential moderators of these relationships (see Irwin, 2009).

368 **4.4 Conclusion**

369 At first glance, current findings appear to suggest belief in certain types of paranormal
370 phenomena, notably psychokinesis and to some extent extrasensory perception, may be
371 shaped by higher exposure to testosterone and oestrogen *in utero* and thus, that genetic

372 factors play some role in determining adult paranormality. But current belief \times digit
373 associations are relatively weak, emerge only for direct self-based measures and are in the
374 opposite direction to those reported by Voracek (2009). Further work incorporating direct-
375 from-hand measures of finger length is needed to fully understand the veracity and true
376 magnitude of these effects. It is hoped the present study will stimulate such research.

377 **Footnotes**

378 1. FA is calculated as $\{Rd |Rd - Ld| / [(Rd + Ld)/2]\}/2$ where $d = 2D$ and $4D$, and is
379 expressed as a percentage of trait size (Voracek, 2009; p.107).

380 2. Second copies were taken if the base and/or tip of any finger was not clearly defined.

381 3. Voracek (2009) for instance, sampled 1118 individuals comprising 491 men plus 627
382 women.

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Table 1: Internal reliability, skew, normality and descriptive data for paranormal belief types across participant sex

| Belief | Reliability ^a α | Skew | | Normality ^b | | Males | | Females | | Sig. Effect s | η^2 |
|--------|--------------------------------------|----------|---------------|------------------------|----------|----------|---------------|----------|---------------|------------------|----------|
| | | <i>M</i> | (<i>SD</i>) | <i>Z_{K-S}</i> | <i>p</i> | <i>M</i> | (<i>SD</i>) | <i>M</i> | (<i>SD</i>) | | |
| ESP | .89 | .04 | (.15) | .05 | .06 | 3.1 | (1.1) | 3.4 | (1.1) | S | .01 |
| PK | .85 | .62 | (.15) | .17 | <.01 | 2.1 | (1.1) | 2.3 | (1.1) | S | .01 |
| LAD | .73 | -.27 | (.15) | .11 | <.01 | 3.9 | (1.6) | 4.4 | (1.6) | S | .02 |

Key: *Extrasensory Perception* (ESP); *Psychokinesis* (PK) and *Life After Death* (LAD) beliefs. ^aFinal Cronbach's alpha (α) coefficients.

^bKolmogorov-Smirnov (K-S) test where $df = 273$. Sig. non-normality and Respondent Sex effects (S) at the $*p < .05$ level; *a* = approaches significance (two-tailed; $n_{\text{males}} = 62$ to 63 ; $n_{\text{females}} = 210$ to 212 ; $n_{\text{all}} = 273$ to 275)

Table 2: Descriptives and effects for digit-related measures across participant sex

| Measure | Source | Hand | Digit(s) | Males | | Females | | Sig. Effects | <i>Eta</i> ² |
|---------|----------------|-------|--|----------|---------------|----------|---------------|--------------|-------------------------|
| | | | | <i>M</i> | (<i>SD</i>) | <i>M</i> | (<i>SD</i>) | | |
| MDL | Direct self | Both | all | 74.85 | (7.84) | 69.92 | (6.80) | S *** | .18 |
| | Indirect rater | Both | all | 74.66 | (4.54) | 69.62 | (4.24) | S *** | .18 |
| 2D:4D | Direct self | Left | 2D:4D | .98 | (.07) | .98 | (.07) | | .00 |
| | | Right | 2D:4D | .98 | (.07) | .99 | (.06) | | .00 |
| | Indirect rater | Left | 2D:4D | .95 | (.03) | .96 | (.04) | S * | .02 |
| | | Right | 2D:4D | .97 | (.03) | .98 | (.03) | S * | .02 |
| DA | Direct self | Both | D _{R-L} | .00 | (.05) | .01 | (.06) | | .00 |
| | Indirect rater | Both | D _{R-L} | .02 | (.03) | .02 | (.03) | | .00 |
| FA | Direct self | Both | <i>f</i> (D _R ,D _L) | 2.32 | (2.25) | 2.22 | (1.97) | | .00 |
| | Indirect rater | Both | <i>f</i> (D _R ,D _L) | 1.95 | (1.13) | 2.02 | (1.15) | | .00 |

Key: Mean Digit Length (MDL); Second-to-Fourth Digit Ratio (2D:4D); Differential Asymmetry (DA); Functional Asymmetry (FA). Respondent Sex effects (S) at the * $p < .05$, ** $p < .01$ and *** $p < .001$ levels (two-tailed; $n_{\text{males}} = 62$ to 63 ; $n_{\text{females}} = 210$ to 212 ; $n_{\text{all}} = 273$ to 275).

1 **Table 3: Correlations (*tau-b*) between digit-related measures and paranormal belief**
 2 **types by measurement source, hand, digit type & participant sex**

| Measure | Source | Hand | Digit(s) | Males | | | Females | | | |
|---------|----------------|-------|--|-------|-----|-----|---------|-----|-------|--------------|
| | | | | ESP | PK | LAD | ESP | PK | LAD | |
| MDL | Direct self | Both | all | - | - | - | .01 | - | .02 | |
| | Indirect rater | Both | all | .04 | .08 | .01 | .01 | .01 | .06 | |
| 2D:4D | Direct self | Left | 2D:4D | .01 | .03 | .01 | .02 | .06 | .06 | |
| | | Right | 2D:4D | .11 | .02 | .05 | .07 | .12 | * .03 | |
| | Indirect rater | Left | 2D:4D | .10 | .10 | .11 | .11 | * | .11 | <i>a</i> .05 |
| | | Right | 2D:4D | .12 | .16 | .13 | - | .04 | .00 | |
| DA | Direct self | Both | D _{R-L} | .02 | .01 | .03 | .02 | .01 | - | |
| | Indirect rater | Both | D _{R-L} | .02 | .01 | .03 | .02 | .01 | .07 | |
| FA | Direct self | Both | <i>f</i> (D _R ,D _L) | - | - | - | .03 | .10 | * - | |
| | Indirect rater | Both | <i>f</i> (D _R ,D _L) | .11 | .08 | .15 | .03 | .10 | * .02 | |
| | | | | .03 | .00 | .03 | .02 | .01 | .02 | |

Key: Mean Digit Length (MDL); Second-to-Fourth Digit Ratio (2D:4D); Differential Asymmetry (DA); Functional Asymmetry (FA).
 Sig. at the **p* < .05 level; *a* = approaches significance (two-tailed; *n*_{males} = 62 to 63; *n*_{females} = 210 to 212).

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