RELATIVE DIGIT LENGTHS PREDICT MEN'S BEHAVIOR AND ATTRACTIVENESS DURING SOCIAL INTERACTIONS WITH WOMEN

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Recent evidence suggests that the ratio of the lengths of the second and fourth fingers (2D:4D) may reflect degree of prenatal androgen exposure in humans. In the present study, we tested the hypotheses that 2D:4D would be associated with ratings of men's attractiveness and with levels of behavioral displays during social interactions with potential mates. Our results confirm that male 2D:4D was significantly negatively correlated with women's ratings of men's physical attractiveness and levels of courtship-like behavior during a brief conversation. These findings provide novel evidence for the organizational effects of hormones on human male attractiveness and social behavior.

KEY WORDS: **2D:4D; Attractiveness; Courtship; Testosterones**

Prenatal exposure to androgens is responsible for the development of many male-typical physical and behavioral traits (for reviews, see Becker et al. 1992) and, as such, variation in prenatal androgen exposure among males may be associated with variation in mate quality and perceived attractiveness. This hypothesis can be investigated in humans via the use of somatic markers of prenatal androgen exposure, such as the ratio of the lengths of the second to fourth digits of the hand (2D:4D; Manning 2002). A number of findings support the use of 2D:4D as such a marker: it is sexually dimorphic in adults (McFadden and Shubel 2002), adult phalangeal ratios are achieved prenatally (Garn et al. 1975) and appear to be

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stable from early childhood through adulthood (Manning et al. 1998), and it is significantly lower in individuals exposed to abnormally elevated prenatal androgen levels as a consequence of congenital adrenal hyperplasia (Brown et al. 2002). Lower 2D:4D has also been associated with higher circulating testosterone levels (Manning et al. 1998; cf. Neave et al. 2003), greater sensitivity to testosterone (Manning, Bundred et al. 2003), and higher rates of putatively androgen-related outcomes such as left-handedness (Manning, Trivers et al. 2000) and autism (Manning et al. 2001).

Other research suggests that variation in 2D:4D may in part explain individual differences in aspects of mate quality in men. Lower 2D:4D has been associated with greater sperm numbers (Manning et al. 1998; Wood et al. 2003), later age at first myocardial infarction (Manning 2002), superior athletic ability (Manning and Taylor 2001), and greater number of children fathered (Manning, Barley et al. 2000; Manning, Henzi et al. 2003). In addition, elite male musicians exhibit lower 2D:4D than control men (Sluming and Manning 2000), and evidence suggests that musical talent may be a courtship-related fitness indicator (Miller 2000). These findings suggest that greater prenatal androgen exposure may organize the development of a suite of traits that make men more sexually attractive because they indicate greater fertility and better physical condition. The possession of such traits would in turn be conducive to behavioral strategies that involve high levels of mating effort (e.g., Gangestad and Simpson 2000). Two hypotheses follow. First, lower 2D:4D should predict higher ratings of men's physical attractiveness. Second, lower 2D:4D should predict greater display of courtship behaviors when in the presence of potential mates.

Only one previous study has examined the relationship between 2D:4D and ratings of male attractiveness. Neave et al. (2003) reported a marginally significant negative relationship between men's left hand 2D:4D and women's assessments of their facial attractiveness as rated from photographs. In addition, ratings of dominance and masculinity exhibited significant negative correlations with 2D:4D in both hands, though levels of testosterone as measured from saliva correlated with neither digit ratios nor ratings of male faces. Recent evidence that low 2D:4D is associated with higher facial asymmetry in men (Fink et al. 2004) may help account for the relatively weak relationship between men's digit ratios and ratings of their facial attractiveness.

Although the Neave et al. study found only equivocal evidence for a relationship between 2D:4D and male attractiveness, it measured attractiveness only from static photos of faces. An arguably more ecologically valid assessment of overall attractiveness could come from ratings made

after actual social interactions with the individuals being rated. This is not only because 2D:4D might be associated with behavioral or non-facial physical components of attractiveness, but also because various traits in combination might affect attractiveness differently from the effects of the traits considered in isolation. For example, the finding that women do not rate male faces with markers of high testosterone as the most attractive (e.g., Penton-Voak et al. 1999; Rhodes et al. 2003; Swaddle and Reierson 2002) may be due to the attribution of antisocial traits to such faces when they are rated in the absence of additional information (Perrett et al. 1998). Men with more masculine and dominant faces might in fact be rated the most attractive when their social behavior is nonthreatening. Ratings of attractiveness from actual social encounters can capture such interactions between traits and thus provide a more general test of the possible relationship between 2D:4D and male attractiveness.

The present study was part of a larger project on male courtship, which demonstrated behavioral and hormonal reactions of men to brief encounters with women (Roney et al. 2003). Young men engaged in a brief conversation with either a male or female confederate. Saliva samples were collected before and after the conversation for testosterone assay. The confederates subsequently rated the men's behavior during the interaction, also rating them for physical attractiveness, desirability as a romantic partner, and the presence of various personality characteristics, including dominance. Subjects' digit ratios were measured from photocopies of their right hands. Data analyses were designed to test the hypotheses that lower 2D:4D will predict higher ratings of attractiveness and dominance as well as greater levels of courtship-like behaviors directed toward the female conversation partners. The availability of saliva samples also allowed for an additional test of the possible relationship between 2D:4D and circulating testosterone.

METHODS

Forty-one male students were recruited from an electronic mail list and paid $10 for their participation. Data from two participants who reported a gay sexual orientation were excluded. Ages of the remaining 39 participants ranged from 18 to 36 (mean = 21.36, s.d. = 3.56). In addition, two men (ages 23 and 32) and five women (ages 19–23) served as the conversation partners with whom the participants interacted.

Participants were randomly assigned to engage in a conversation with a male (n = 18) or female (n = 21) stimulus person. A male experimenter greeted each participant in the lobby of the testing building and then led

him to an isolated testing room. Participants were told that a research assistant was late but would probably show up soon and take over data collection. The confederates in fact were seated in an office next to the testing room and noted the time when the experimenter and participant passed them en route to the test location. Upon arrival in the testing room, participants first completed the informed consent process during which they read the cover story that described the study as an investigation of possible relationships between hormone levels and psychological variables such as mood and personality traits. Participants next provided a saliva sample for testosterone assay. Approximately five minutes after having seen the participant walk by, the confederate came into the testing room and apologized for being late. At that point, the experimenter made a show of orienting the confederate to where the participant was in the process, but also announced that he had the wrong version of the next questionnaire and would have to go print out the correct version. This ruse left the participant and confederate alone with nothing to do and so served as the pretense for their conversation. Stimulus persons were instructed to engage in a friendly but natural conversation with the participant. These conversations were timed to last five minutes, after which the experimenter returned with the next surveys.

Participants then privately completed a number of psychological measures. During this time, the stimulus persons completed surveys that assessed their perception of the participant and his behavior during the preceding conversation (see below). Photocopies of the ventral surface of participants' right hands were taken. A second saliva sample was collected 20 minutes after the onset of the stimulus conversation and preceded debriefing.

Confederates' ratings of participants' physical attractiveness were assessed via three items measured on a 7-point scale: physically attractive, sexy, and cute (Cronbach's $\alpha = .89$). Attractiveness as a romantic partner was assessed via items that asked the confederates to rate on a 7-point scale the likelihood that the participant would be desirable to others as a romantic or date partner, be a desirable marriage partner, and be desirable to others as a casual date (Cronbach's $\alpha = .78$). A single-item measure of dominance (1 = not all, 7 = very) was chosen for analysis out of a larger group of traits because of an earlier reported relationship between 2D:4D and dominance as rated from faces (Neave et al. 2003). Finally, confederates rated the degree to which the participants engaged in various behaviors (1 = not at all, 7 = very much) during their conversation. These ratings were factor analyzed as part of the larger study (see Roney et al. 2003) and the resulting factors are presented in Table 1. The "display"

Table 1. Factor Scales for Ratings of Participants' Behavior during the Conversation

Factor: Polite Interest (28%)	
Listened carefully	0.91
Interested in hearing about you	0.88
Asked questions about you	0.87
Made eye contact	0.68
Was bored	-0.53
Was talkative	0.52
Was quiet	-0.50
Factor: Display (21%)	
Tried to impress you	0.93
Showed off to you	0.87
Eager to talk about himself	0.66
Revealed details about himself	0.65
Was talkative	0.43
Factor: Arousal (20%)	
Was speaking fast	0.88
Was excited	0.76
Was bored	-0.61
Was quiet	-0.61
Was talkative	0.54
Eager to talk about himself	0.46

factor was interpreted as an index of courtship-like behavior given the nature of its highest loading items.

Lengths of the 2nd and 4th digits were measured from the photocopies of participants' hands using digital calipers that measure to the nearest .01 mm. Measurements were made from the basal crease to the tip of the digit. All measurements were made twice in order to assess measurement repeatability.

Saliva samples were sent to the Northwestern University Medical School. Testosterone was measured by radioimmunoassay with an intra-assay coefficient of variation of 13.29% (for additional assay details, see Chatterton et al. 1997; Roney et al. 2003).

Pearson correlation coefficients with two-tailed significance levels were employed as initial tests of our hypotheses; structural equation models were subsequently used in order to describe relationships between the various dependent measures.

RESULTS

The first and second measures of 2D:4D had a reasonably high intraclass correlation coefficient (r_1 = .93). Following Manning (2002), a repeated measures ANOVA was performed to demonstrate that the error mean squares (i.e., the error associated with repeated measures) were low relative to the groups mean squares (i.e., the differences between individuals), $F_{1,38}$ = 27.65, $p < .001$. It therefore appears that real individual differences in 2D:4D were captured via the measurements. The analyses presented below use the mean of the two measurements as the estimate of 2D:4D.

Tests of the main hypotheses are presented in Table 2. It can be seen that there was a large effect of 2D:4D on female confederates' ratings of male subjects' physical attractiveness such that lower 2D:4D was associated with higher attractiveness. This relationship was much weaker and not significant for male ratings of male subjects. Similarly, the degree to which the female raters perceived the male subjects as attractive romantic partners exhibited a nearly significant (p = .057) negative relationship with subjects' 2D:4D. Dominance ratings were not significantly correlated with 2D:4D in either condition, though ratings in the male condition exhibited an effect size comparable to that reported by Neave et al. (2003). Finally, female confederates perceived men with lower 2D:4D as having exhibited more courtship-like "display" behaviors during their conversation together. This effect may be specific to courtship behaviors, as the correlations between 2D:4D and scores on the other two behavioral scales were not significant in either condition.

Not surprisingly, many of the ratings presented in Table 2 were correlated with one another. Focusing only on the female condition (since significant associations with 2D:4D were restricted to female raters), ratings of subjects' desirability as a romantic partner correlated highly with both ratings of their physical attractiveness (r = .76, df = 18, $p < .0001$) and ratings of their display behaviors (r = .62, df = 18, p = .003). Physical

Table 2. Pearson Product-Moment Correlations between Subjects' 2D:4D and Ratings of their Traits and Behavior from a Brief Social Interaction.

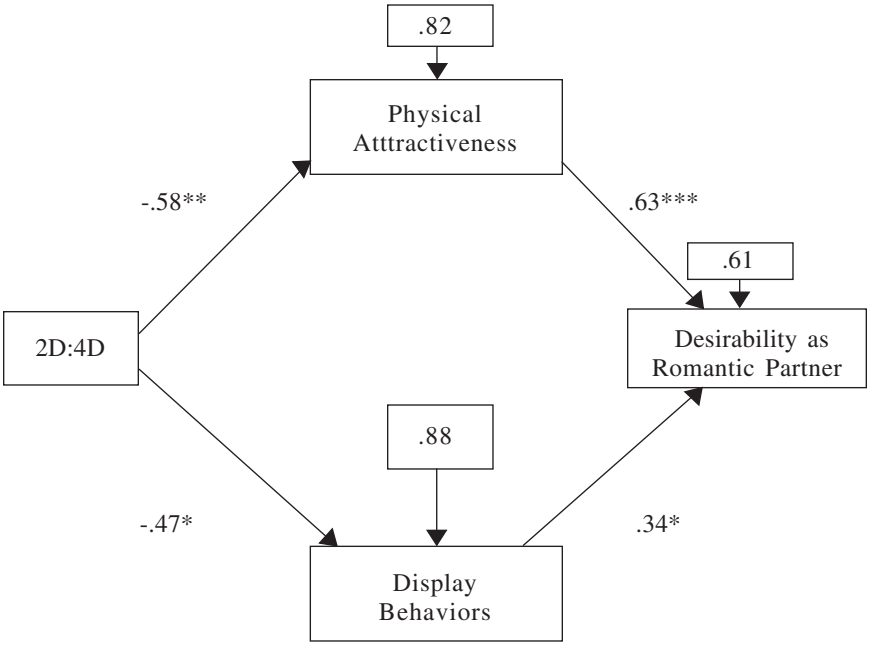
Rating of Subject	*Female Raters* (N = 21)	*Male Raters* (N = 18)	*All Raters* (N = 39)
Physical Attractiveness	-.58**	-.18	-.37*
Attractiveness as Romantic Partner	-.43†	-.14	-.23
Dominance	.07	-.37	-.12
Display Behaviors	-.44*	.32	-.03

† $p < .06$; * $p < .05$; ** $p < .01$

attractiveness and display behaviors exhibited a marginally significant relationship (r = .40, df = 19, p = .071), though 2D:4D continued to predict attractiveness ratings even when display behaviors were held constant (partial r = -.49, df = 18, p = .028). Dominance ratings were not significantly correlated with any of the other rating measures.

In order to elucidate the nature of these interrelationships between measures in the female condition, structural equation modeling was employed to test the hypothesized path model presented in Figure 1. In this model, desirability as a romantic partner is the final endpoint since it is the variable that is logically most directly related to mating success. Physical attractiveness and courtship-like behaviors, in turn, were hypothesized to independently predict desirability as a romantic partner. Finally, 2D:4D is presented as an entirely exogenous variable since its early developmental determination ensures that it could not be caused by the other variables. Since the confederates did not report noticing subjects' hands, furthermore, any relationship between 2D:4D and desirability as a romantic partner should be fully mediated by judgments of subjects' behavior and physical attractiveness.

Figure 1. Path analysis of the effects of men's 2D:4D on women's ratings of their physical attractiveness, display behaviors, and desirability as a romantic partner. * $p < .05$, ** $p < .01$, *** $p < .001$.



Path analyses were performed using the EQS program (Bentler 1993) with parameter estimates based on maximum likelihood estimation. The hypothesized model fit the data quite well ($\chi^2_2 = 2.31$, $p = .315$; CFI = 0.99). Standardized beta coefficients are indicated next to each path in Figure 1. It can be seen that 2D:4D is a significant negative predictor of both physical attractiveness and display ratings, and that physical attractiveness and display each account for significant variance in ratings of desirability as a romantic partner when the influence of the other variable is held constant. Furthermore, the direct path between 2D:4D and desirability as a romantic partner was not significant when added to the model in Figure 1 ($\beta = .11$, $p = .564$), and the Wald test indicated that removal of this direct path did not harm the fit of the model ($\chi^2_1 = .35$, $p = .554$). As such, it appears that any influence of 2D:4D on attractiveness as a romantic partner was fully mediated by the effects of digit ratio on physical attractiveness and display behaviors.

Finally, digit ratios were tested for possible associations with salivary testosterone levels. Testosterone levels were log transformed to eliminate skew in the data. Data analyses presented elsewhere revealed a significant increase in testosterone following the interaction with female confederates (Roney et al. 2003). 2D:4D, however, was not significantly correlated with first sample, second sample, or testosterone change scores either in the full sample or when the male and female conditions were considered separately (all p values > .20).

DISCUSSION

This study provides evidence for an association between prenatal androgen exposure and men's attractiveness and courtship behavior. Digit ratios that were likely determined in utero correlated highly with women's ratings of men's attractiveness and behavioral displays during a brief social interaction. Ratings of display behaviors and physical attractiveness, in turn, jointly accounted for 62% of the variance in female confederates' ratings of male subjects' desirability as a romantic partner. These results suggest that variance in prenatal hormones as indexed by 2D:4D may affect men's developmental trajectories in ways that produce systematic differences in adult social behavior and perceived attractiveness.

Lower 2D:4D could be associated with many possible determinants of male physical attractiveness. Evidence indicates that lower 2D:4D may be associated with more masculine facial features (Neave et al. 2003) and such features may in turn increase male attractiveness (e.g., Johnston et al. 2001), at least under conditions in which the man's social behavior is

nonthreatening (see introductory section). Evidence that lower 2D:4D is associated with lower facial symmetry (Fink et al. 2004), however, suggests that androgen exposure may positively influence facial attractiveness via its effects on masculinity but negatively impact attractiveness via its effects on symmetry (see Penton-Voak et al. 2001 for evidence that masculinity and symmetry may be somewhat independent characteristics of male faces). Higher prenatal androgens might also increase the probability of developing a more muscular physique, and recent research has demonstrated female preferences for mesomorphic body types (e.g., Dixson et al. 2003; Maisey et al. 1999). Given the nature of the social interaction in the present study, furthermore, attractiveness ratings could have been influenced by characteristics of men's voices (Collins 2000) or even their scent (e.g., Rikowski and Grammer 1999). Finally, although the influence of 2D:4D on ratings of physical attractiveness was independent of women's ratings of men's display behaviors, it is possible that dimensions of subjects' behavior not captured by the behavioral questionnaire also influenced judgments of physical attractiveness.

The association between 2D:4D and behavioral displays is particularly intriguing. If, as previous studies have suggested, low 2D:4D is associated with aspects of male fitness such as good health (Manning 2002), high sperm numbers (Manning et al. 1998), and high number of offspring (Manning, Barley et al. 2000), then such behavioral displays may be honest indicators of fitness. The fact that such displays influenced women's ratings of men's attractiveness as romantic partners further implies that women can make accurate judgments about aspects of men's fitness after only a brief social interaction. Future research will be necessary, however, to determine the mechanisms whereby prenatal androgen exposure may be translated into higher levels of courtship behavior.

The present results provide no evidence that the relationship between 2D:4D and male attractiveness may be mediated by circulating testosterone levels. Although the men in this study experienced an increase in salivary testosterone following the interaction with women (Roney et al. 2003), there was no significant association between 2D:4D and either basal testosterone levels or testosterone change scores. Nor did our results confirm the finding of Neave et al. (2003) that lower 2D:4D was associated with higher dominance, though differences in method might account for this discrepancy.

From a methodological standpoint, the use of ratings from actual social interactions had both advantages and drawbacks. On the plus side, this method allowed an assessment of whether 2D:4D might be related to overall attractiveness even if it might not predict the attractiveness of

certain individual traits considered in isolation. In addition, this method has an ecological validity that many other trait rating methods do not have since people usually evaluate potential mates as whole persons within face-to-face social interactions. On the negative side, the method used here does not allow precise determination of which specific components of male attractiveness were associated with 2D:4D. The strong correlations between 2D:4D and ratings of attractiveness invite future research designed to decompose the specific determinants of attractiveness associated with digit ratios. Future research should also further address the relationship between 2D:4D and male fitness, as well as the mechanisms by which variation in prenatal androgen exposure affects physical and behavioral traits that play important roles in courtship and mate attraction.

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