Personality and Individual Differences 108 (2017) 86–90

Contents lists available at ScienceDirect

Personality and Individual Differences

journal homepage: www.elsevier.com/locate/paid

# Male sex hormones and criminal behavior: The predictive power of a two-factor model of organizational androgen exposure

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ARTICLE INFO

*Article history:*
Received 24 December 2015
Received in revised form 27 October 2016
Accepted 14 November 2016
Available online 8 December 2016

*Keywords:*
Testosterone
Androgens
2D:4D digit ratio
Crime
Violence

ABSTRACT

Research on the relationship between prenatal testosterone and criminal behavior has produced mixed results. The 2D:4D digit ratio is typically employed as the measure of prenatal testosterone, but its proxy nature might play a role in the inconsistent findings. This study examines the usefulness of a multi-item approach to the measurement of organizational androgens. Principal components factor analysis of data from a convenient sample of adults reveals that two factors emerge from five androgen-promoted trait items. These two factors, however, do not predict self-reported criminal behavior better than the single right-hand 2D:4D digit ratio item. It is concluded that a multi-item measurement strategy is unlikely to be a more predictive measure of organizational androgens than digit ratio.



## 1. Introduction

The greater involvement by males in criminal activity is well-established (Moffitt, Caspi, Rutter, & Silva, 2001). The gender gap is universal and large, especially for violent crime (Felson, 2002). A finding so central to the study of crime has inspired a number of theories, most of which are focused on differences in gender socialization and social roles (Steffensmeier & Allan, 1996). Biologically-oriented scholars have looked to male sex hormones and their connection to risk-taking and empathy in order to explain the gender imbalance in criminality (Dabbs & Dabbs, 2000; Hoskin & Ellis, 2015). While most of the relevant research has focused on the link between current circulating levels of testosterone and criminal offending (Dabbs & Dabbs, 2000), recent theoretical and empirical developments have turned attention to androgen exposure in utero (Hoskin & Ellis, 2015).

Empirical research on the link between prenatal testosterone and criminal behavior has produced mixed results. Ellis and Hoskin have recently published two papers which reported significant associations between the 2D:4D digit ratio–a putative biomarker of fetal sex hormone exposure—and involvement in crime (Ellis & Hoskin, 2015; Hoskin & Ellis, 2015). According to a study of German men, those with lower finger ratios (i.e., those with more "masculine" ratios) had more traffic violations (Schwerdtfeger & Heer, 2010). A UK study of men found that those with at least one criminal conviction had a lower mean 2D:4D ratio than those with no conviction (Hanoch, Gummerum, & Rolison, 2012). On the other hand, the same study failed to find an association between finger ratio and the number of times adjudicated guilty among the convicted group.

Other studies have reported findings that do not support the fetal testosterone-crime hypothesis. In a British study of offenders and non-offenders, the former group had a lower mean 2D:4D, but the difference failed to reach statistical significance (Anderson, 2012). Digit ratio was found to be *positively* related to a self-report measure of psychopathy among a sample of British females (Blanchard & Lyons, 2010). In other words, participants with female-typical ratios had higher psychopathy scores. In a population-based Swedish study, neither males or females with congenital adrenal hyperplasia—a disorder which causes the excessive production of prenatal androgens—had higher rates of criminal offending than unaffected controls (Ohlsson-Gotby et al., 2015).

### 1.1. Digit ratio and the organizational effects of sex hormones

Much of the research on prenatal sex hormones has relied on the use of 2D:4D digit ratio as an indirect measure, but is it a reliable and valid biomarker, and what does it measure exactly? Research supports 2D:4D as a valid, if approximate, measure of the relative concentrations of prenatal testosterone and estrogen. Examining the testosterone to estrogen ratios obtained from pregnant mothers' amniotic fluid, Lutchmaya, Baron-Cohen, Raggatt, Knickmeyer, and Manning (2004) found a strong association with the newborn's 2D:4D finger ratio. Testosterone appears to lengthen the fourth digit while estrogen shortens it (Manning, 2008). Experimental studies of rats (Auger et al., 2013; Talarovičová, Kršková, & Blažeková, 2009) and mice (Zheng and Cohn, 2011) are consistent with this model. Studies of congenital conditions that affect fetal testosterone levels also provide evidence that the 2D:4D ratio is controlled by sex hormones as predicted (Berenbaum,

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http://dx.doi.org/10.1016/j.paid.2016.11.034
0191-8869/

Bryk, Nowak, Quigley, & Moffat, 2009; Hönekopp & Watson, 2011; Manning, Kilduff, & Trivers, 2013).

New research is revealing a more complex relationship between organizational and activational testosterone, other hormones, and behavior. Male-typical digit ratios have been linked with the tendency to produce surges in testosterone as an adult (Crewther, Cook, Kilduff, & Manning, 2015). Digit ratio appears to be a biomarker of sensitivity to surges of testosterone, and to the ratio of testosterone to cortisol (Crewther et al., 2015).

How do high concentrations of prenatal testosterone promote adolescent and adult criminality? A lack of cognitive empathy has been found to be an important predictor of criminality (Jolliffe & Farrington, 2004) and exogenous testosterone has been shown to reduce cognitive empathy, especially if the subject has low 2D:4D (Carré et al., 2015; van Honk et al., 2011). Furthermore, the interaction of testosterone and cortisol evidently raise the risk of antisocial behavior. Glenn, Raine, Schug, Gao, and Granger (2012) found that as testosterone increased over levels of cortisol in response to a stressor, psychopathy scores increased. In a sample of young adolescents, Portnoy et al. (2015) reported that low cortisol reactivity was associated with more aggression and rule-breaking, but only among males with low digit ratios.

While various types of evidence point to the utility of 2D:4D as maker of prenatal testosterone and estrogen, some researchers consider the digit ratio to be a "noisy" marker of fetal sex hormones (Putz, Gaulin, Sporter, & McBurney, 2004). The magnitude of the association between the testosterone/estrogen ratio measured from amniotic fluid and a newborn's 2D:4D digit ratio was found to be moderately strong (Lutchmaya et al., 2004) but not as strong as that recommended for a proxy measure (Gujarati, 2004).

Recent research has attempted to improve on 2D:4D by measuring multiple physical traits that are known to be influenced by androgens. Traits include height, muscularity, physical strength, and athletic ability (Ellis, Lykins, Hoskin, & Ratnasingam, 2015), biomarkers which are highly sexually dimorphic and have been shown to be moderately related to various measures of testosterone (Cashdan, 1995; Folland, Mc Cauley, Phypers, Hanson, & Mastana, 2012; Hönekopp & Schuster, 2010; Lukas, Campbell, & Ellison, 2004). Measures have been factor analyzed in order to create multi-item scales. Such an approach has been employed, for example, to examine the effect of organizational testosterone on mate preferences (Ellis & Ratnasingam, 2015) and sexual orientation (Ellis et al., 2015). The present study follows this methodological strategy to model the relationship between multi-item measures of prenatal testosterone and criminal behavior.

## 2. Methods

### 2.1. Participants

Respondents consisted of 190 (43%) males and 255 (57%) females. Undergraduate college students in criminology classes at a public university in Texas were invited to complete a questionnaire and to recruit volunteers who were at least 18 years of age to participate as well. Mean age for the sample was 31.6 (sd = 12.7), and the racial and ethnic composition was 53% Hispanic, 40% non-Hispanic White, and 7% African American. Participants were assured that the original data collected would be: 1) kept in a secure place, 2) identified by number and not by respondent name, 3) examined by research personnel only, and 4) destroyed as soon as the information was coded and entered into an electronic file.

### 2.2. Materials

A four-page questionnaire was constructed which covered a wide variety of topics, only a few of which are analyzed here. Respondents were asked to report how many times (if any) they had committed each of 14 different offenses. Four questions concerned violence, five dealt with property theft or damage, two asked about reckless driving, and the remaining questions were about consensual but illegal behaviors.

### 2.3. Procedure

The number of times respondents stated they had committed each offense was recorded unless it exceeded 10, in which case 10 was recorded. Two crime scales were also constructed from the individual items. The first was the total number of crimes committed of any type (Cronbach's alpha = 0.72) and the second was the total number of crime categories committed, a measure referred to as "criminal versatility" (Piquero, Farrington, & Blumstein, 2007). This was computed by assigning each case a score of 1 for each category of crime with at least one reported offense (and assigning a 0 for no offenses), and then summing across the fourteen crime categories.

To measure each respondent's 2D:4D ratio, we used a desktop printer/scanner with a 600 × 600 dpi scanner resolution. The right hand was chosen for measurement because a meta-analysis showed it to be a better indicator of prenatal androgenization (Hönekopp & Watson, 2010). (Digit ratio will subsequently be referred to as r2D:4D to denote the right hand.) The respondent's hand was placed palm down on the glass and was held flat to make certain that fingers were equally extended and to ensure that the scanner captured a clear picture of the entire right hand. GNU Image Manipulation Program (GIMP 2.8) software was used to measure digitally the length of the fingers. For both the second and the fourth digits, mouse-controlled calipers were placed on the basal crease of the finger and extended to the tip of the finger so that the lengths were measured in number of pixels rounded to one decimal place. The length of the 2nd digit divided by the length of the 4th digit was recorded as the r2D:4D ratio.

If the two fingers are approximately equal length (r2D:4D ≈ 1) or if the index finger is longer (r2D:4D > 1), this indicates low fetal testosterone (and high fetal estrogen). If the ring finger is noticeably longer than the index finger (r2D:4D < 1), testosterone levels were high (and estrogen levels were low) prenatally. For reliability purposes, the r2D:4D ratio was measured on two different occasions, three months apart by a person who was unaware of which scan belonged to which questionnaire. Intra-observer reliability was 0.89, a coefficient comparable to other studies and indicative of strong reliability (Allaway, Bloski, Pierson, & Lujan, 2009).

In order to investigate the claim that additional indicators of organizational testosterone improve the predictive power of digit ratio, respondents were asked to estimate four physical characteristics about themselves that are dependent on organizational androgens: height and muscularity (Wells, 2007), physical strength (Fink, Thanzami, Seydel, & Manning, 2006), and athletic ability (Hönekopp & Schuster, 2010). Specifically, participants were asked to give their height (which was converted to centimeters for the American sample) and to rate themselves on the other three traits using a scale between 1 and 10.

The associations between r2D:4D and single-item and multiple-item measures of criminal offending were estimated by calculating the Spearman rank order correlation. This statistic was chosen because the crime measures are skewed, and, unlike Pearson correlation coefficients, Spearman does not assume the normal distribution of variables (Hotelling & Pabst, 1936).

## 3. Results

Table 1 displays descriptive statistics, *t*-tests for sex differences, and Cohen's d, a measure of the magnitude of mean group differences. As expected, the mean r2D:4D for males is significantly lower than the female mean. The size of the difference is moderate (d = 0.49), a finding that is consistent with most research. The sex difference is also significant for the other four biomarkers – the gender gap is of moderate