Arch Sex Behav (2014) 43:299–310
DOI 10.1007/s10508-013-0175-0

ORIGINAL PAPER

Biological Markers of Asexuality: Handedness, Birth Order, and Finger Length Ratios in Self-identified Asexual Men and Women

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Received: 13 July 2011 / Revised: 3 April 2013 / Accepted: 16 June 2013 / Published online: 18 September 2013

Abstract Human asexuality is defined as a lack of sexual attraction to anyone or anything and it has been suggested that it may be best conceptualized as a sexual orientation. Non-right-handedness, fraternal birth order, and finger length ratio (2D:4D) are early neurodevelopmental markers associated with sexual orientation. We conducted an Internet study investigating the relationship between self-identification as asexual, handedness, number of older siblings, and self-measured finger-lengths in comparison to individuals of other sexual orientation groups. A total of 325 asexuals (60 men and 265 women; *M* age, 24.8 years), 690 heterosexuals (190 men and 500 women; *M* age, 23.5 years), and 268 non-heterosexuals (homosexual and bisexual; 64 men and 204 women; *M* age, 29.0 years) completed online questionnaires. Asexual men and women were 2.4 and 2.5 times, respectively, more likely to be non-right-handed than their heterosexual counterparts and there were significant differences between sexual orientation groups in number of older brothers and older sisters, and this depended on handedness. Asexual and non-heterosexual men were more likely to be later-born than heterosexual men, and asexual women were more likely to be earlier-born than non-heterosexual women. We found no significant differences between sexual orientation groups on measurements of 2D:4D ratio. This is one of the first studies to test and provide preliminary empirical support for an underlying neurodevelopmental basis to account for the lack of sexual attraction characteristic of asexuality.

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Keywords Asexuality · Sexual orientation · Finger length ratios · 2D:4D · Handedness · Birth order

Introduction

Human asexuality is loosely defined as an absence of sexual attraction to anyone or anything, and it is estimated that at least 1 % of the population fit this definition (Bogaert, 2004; Poston & Baumle, 2010). Other definitions of asexuality include: a lack of sexual behavior (Rothblum & Brehony, 1993), a lack of sexual orientation (Storms, 1980), and a lack of sexual desire or excitement (Prause & Graham, 2007). Media attention focused on asexuality (e.g., 20/20, 2006; CNN Showbiz Tonight, 2006; Fox News Dayside, 2006; Montel Williams show, 2007; The View, 2006; Tucker Carlson, 2006) has suggested that asexual individuals may have hypoactive sexual desire disorder (HSDD) (American Psychiatric Association, 2000), a type of sexual dysfunction characterized by a distressing absence of sexual fantasies and desire for sexual activity, lasting for an extended period of time. If this presumption is correct, then asexual individuals may be referred to sex therapy clinics and administered treatments designed to increase their sexual desire, particularly if they are partnered with a sexual person who has a higher interest in sex. In the current climate of sexual pharmaceuticals and intolerance of waning sexual desire (Snabes & Simes, 2009), the lustless individual might be diagnosed with HSDD and prescribed an off-label investigational medication.

Asexual individuals do not experience distress directly in relation to their lack of sexual desire (Brotto, Knudson, Inskip, Rhodes, & Erskine, 2010; Pagan Westfall, 2004), making asexuality fundamentally different from HSDD—the latter of which requires marked distress or interpersonal difficulty for a clinical diagnosis (American Psychiatric Association, 2000). The largest online web-community of asexuals, the Asexuality Visibility and

Education Network (AVEN), also rejects the categorization of asexuality as a sexual dysfunction and instead prefers to describe asexuality as a sexual orientation or sexual identity, along with heterosexuality, bisexuality, and homosexuality (Jay, 2008). This view has received widespread support among the asexual community, who further believe that asexuality is biologically determined and is not the result of social forces. AVEN members have voiced their belief that, if asexuality were to be accepted as a sexual orientation, stigma against those who express a lack of sexual attraction would decrease, because this would be "explained" by their asexual orientation (Brotto et al., 2010). Scholars (Bogaert, 2006b) share this perspective of asexuality as a sexual orientation.

In a direct test of whether asexuality might be explained by a dysfunctional sexual arousal response, asexual, heterosexual, lesbian, and bisexual women were compared and found not to differ from one another in the genital sexual arousal response to erotic films (Brotto & Yule, 2011). This lack of group difference in genital response is consistent with a growing body of evidence that women, regardless of stated sexual preferences and type of erotic material, respond in a similar manner with regard to their genital sexual response (Chivers, Rieger, Latty, & Bailey, 2004; Chivers, Seto, & Blanchard, 2007; Chivers, Seto, Lalumière, Laan, & Grimbos, , 2010). Moreover, Brotto and Yule (2011) found that women's subjective sexual arousal to the same heterosexual clips did not differ between the groups, although the asexual women did not experience an increase in sexual attraction during the film whereas the other three groups did. That asexual individuals showed the same automatic and robust genital sexual response as the other sexual groups suggested that "category non-specificity," or the finding that women's genital response can be evoked from a variety of preferred and non-preferred stimuli, may be a feature of all women, independent of whether they have sexual attractions or not. It is true, however, that lesbian women did show more category specificity in their genital responses than heterosexual women (Chivers et al., 2007), suggesting that category non-specificity is not ubiquitous among all women.

Bogaert (2004) found evidence suggesting that biological pathways may play a role in the development of asexuality. Late menarche, shorter stature, and health problems in women, and shorter stature and health problems in men, were predictors of asexuality. Evidence for more health problems was also found in a more recent American national probability study of asexuals (Poston & Baumle, 2010). In light of evidence that the development of sexual attraction may be prenatally biologically determined (Bogaert, 1998, 2003; Bogaert & Blanchard, 1996; Mustanski, Bailey, & Kaspar, 2002a), and given the association of physical development and sexual orientation, Bogaert (2004) concluded that asexuality may also result from prenatal events.

Three biomarkers have emerged as strong correlates of sexual orientation development in epidemiological studies. Findings indicate that: (1) homosexuality is associated with a higher incidence of non-right-handedness in both males and females, (2) a greater number of older brothers increase the odds of homosexuality in males, and (3) homosexuality is associated with specific finger length ratios, such that lesbian women have been found to have lower 2D:4D than heterosexual woman (Grimbos, Dawood, Buriss, Zucker, & Puts, 2010). As a test of the prenatal development theory of asexuality as a sexual orientation, the present study examined these markers of atypical prenatal development in asexual women and men.

Handedness

Handedness is a biological measure that reflects prenatal influences and differentiates sexual orientation groups. Aspects of cerebral lateralization, externally manifested as handedness, may be etiological factors accounting for homosexuality (Blanchard, 2008). Homosexual men and women have atypical handedness patterns, with gay men showing greater odds of non-right-handedness (i.e., preferential use of the left hand, or equal use of both hands, in common tasks) (Bogaert, 2007) compared to heterosexual groups. In a large meta-analysis of 20 studies that examined handedness and sexual orientation in men and women, Lalumière, Blanchard, and Zucker (2000) concluded that homosexual individuals were more likely to be non-right-handed than heterosexual individuals. This finding was replicated using data from the British Broadcasting Corporation (BBC) Sex Differences Survey (Reimers, 2007) of over 255,000 participants to conclude that non-right-handedness was associated with homosexuality in both men and women (Blanchard & Lippa, 2007).

There are different mechanisms by which handedness might be related to sexual orientation development. Prenatal hormone theory posits that handedness (as well as digit ratios) and sexual orientation are linked to prenatal androgen levels, such that exposure to higher levels of androgens leads to more male-typical patterns of development, including increased incidence of left-handedness and smaller 2D:4D ratios. Evidence for this theory comes from a large, widely-cited meta-analysis by Seddon and McManus (1991), which concluded that men are significantly more likely to be non-right-handed than women, and this was attributed to elevated levels of prenatal testosterone. According to a linear version of this theory, in which prenatal androgen levels masculinize behavior within each sex, non-right-handedness should be associated with homosexuality in women, but not in men (Lippa, 2003b). Large-scale reviews, however, suggest that the prenatal hormone theory may hold for women, but not for men (Lalumière et al., 2000), indicating that some other factor may be operating. According to developmental instability theory, perturbations during normal development would give rise to a greater incidence of non-right-handedness as well as other neurodevelopmental differences (e.g., minor physical anomalies, neuropsychological deficits). This theory would hold for both men and women (given that it does not depend on potential masculinizing effects of testosterone) and also may apply to asexuals.

Fraternal Birth Order

Number of older brothers has also been associated with sexual orientation, such that a greater number of older brothers increases the probability of homosexuality in men (Blanchard, 2008; Blanchard & Bogaert, 1996). This pattern is not evident in women (Blanchard & Lippa, 2007; Blanchard, Zucker, Siegelman, Dickey, & Klassen, 1998; Bogaert, 1997; Ellis & Blanchard, 2001) and may be present only in right-handed men (Blanchard, 2008). This effect is limited to the number of biological brothers and maternal half-brothers, even if they were raised in separate households, whereas having paternal step-brothers or adoptive brothers had no effect on sexual orientation (Bogaert, 2006a).

Fraternal birth order (FBO) effect can be explained by the maternal immune hypothesis, which proposes that maternal antibodies to male-specific antigens (most likely proteins or peptides) may affect the development of male but not female fetuses (Blanchard & Bogaert, 1996). The theory suggests that male fetal cells (or fragments of cells) enter the maternal circulation and are recognized as foreign by the mother's immune system, triggering the production of antibodies against them. During subsequent male pregnancies, these anti-male antibodies cross the placental barrier and act on the development of the fetal brain, diverting it from the male-typical developmental pathway, such that the individual will later experience sexual attraction to men rather than women. The strength of this maternal immunization is thought to increase with each subsequent male pregnancy and thus the probability of homosexuality increases with each older brother (Blanchard, 2008). The maternal immune hypothesis operates in parallel with Ellis and Ames' (1987) long-standing theory that sexual orientation in men is related to prenatal testosterone, proposing that the development of sexual orientation depends both on a main system driven by testosterone and a supplementary system driven by male-specific proteins (Blanchard, 2008), as well as being influenced by other etiological factors such as atypical hormone levels at critical stages of fetal development (Mustanski, Chivers, & Bailey, 2002b), and cerebral lateralization, which is thought to have a genetic influence (Geschwind, Miller, DeCarli, & Carmelli, 2002) and also affects handedness.

Previous research has identified an interaction between handedness and number of older brothers in predicting homosexuality in men (Blanchard, Cantor, Bogaert, Breedlove, & Ellis, 2006; Blanchard & Lippa, 2007; Bogaert, Blanchard, & Crosthwait, 2007). Specifically, number of older brothers increased the probability of homosexuality only in men who reported being right-handed. These findings run counter to the meta-analytic data that suggested non-right-handed men have a greater likelihood of homosexuality (Lalumière et al., 2000); however, the data may be interpreted such that non-right-handed men with no older brothers might be more likely to be homosexual due to decreased lateralization of the brain, that non-right-handers may be less sensitive to maternal anti-male antibodies, or that non-right-handedness is actually a proxy for some feature of the mother that makes her less susceptible to developing anti-male antigens. Therefore, current theorizing is that the FBO effect on sexual orientation is present only among right-handers (Blanchard, 2008).

Finger Length Ratio

The ratio of the length of the index finger (2D) compared to the fourth finger (4D) is known as the 2D:4D ratio, and sex differences on this measure are thought to reflect a prenatal influence of androgens (Williams et al., 2000; for a more detailed discussion, see Manning, 2002). In women, the 2D is almost the same length as the 4D; in men, the 2D is typically shorter than the 4D. However, some studies show that lesbian women exhibit 2D:4D ratios more similar to heterosexual men, suggesting potentially greater prenatal exposure to androgens, and homosexual men show 2D:4D ratios more similar to heterosexual women, suggesting potentially lower prenatal exposure to androgens (McFadden et al., 2005). In a recent meta-analysis, Grimbos et al. (2010) determined lesbians to have a lower (more masculine) 2D:4D than heterosexual women, but found no significant difference between heterosexual and gay men.

Objectives of the Study

If putative markers of prenatal development, such as handedness, number of older brothers, and finger-length ratios, were to co-vary with sexual orientation, then this would support the proposed association between prenatal developmental events and sexual orientation (Lippa, 2003b). To date, there are no data on handedness patterns, FBO or digit ratios in asexuals. The aim of the current study was to compare asexual, non-heterosexual (bisexual and homosexual), and heterosexual individuals on these measures, where we hypothesized that asexuals would differ from other sexual orientation groups. Although the FBO effect has focused on male participants and their brothers, as an exploratory analysis, we also tested for FBO in female participants and number of older sisters in all participants.

Method

Participants

A total of 1,283 individuals between the ages of 19 and 72 years participated in this study, including 314 men and 969 women. Participants were asked to select which option of four sexual orientation types best described them: heterosexual, homosexual, bisexual, or asexual. Among the men, there were 190 heterosexual, 64 non-heterosexual (homosexual and bisexual), and 60 asexual participants. Among the women, there were 500 heterosexual, 204 non-heterosexual (homosexual and bisexual), and 265 asexual participants. They were recruited through several

separate and concurrent avenues, including postings on local websites (e.g., Craigslist), on the AVEN online web-community general discussion board, and through our university's human subject pool.

The average age of participants was 24.3 years for asexual women ($SD = 6.7$), 22.8 years for heterosexual women ($SD = 6.3$), and 29.1 years for non-heterosexual women ($SD = 9.4$), and there was a significant group difference in age, $F(2, 966) = 56.25$, $p < .001$, with non-heterosexual women being significantly older than both asexual and heterosexual women, and asexual women being significantly older than heterosexuals. The average age of male participants was 26.9 years for asexual men ($SD = 10.5$), 25.2 years for heterosexual men ($SD = 8.5$), and 28.8 years for non-heterosexual men ($SD = 9.9$), and there was a significant group difference in age, $F(2, 311) = 3.66$, $p = .027$, with non-heterosexual men being significantly older than heterosexuals.

There were no significant group differences in highest level of education achieved, $\chi^2(2) = 3.55$, with the majority of participants (89 % asexual, 84 % heterosexual, 87 % non-heterosexual) having received at least some post-secondary education. Fourteen percent of asexual, 53 % of heterosexual, and 57 % of non-heterosexual individuals indicated that they were in a relationship, either committed or non-committed, and these proportions differed significantly, $\chi^2(2) = 158.20$, $p < .001$, with asexual participants being least likely to be in a relationship.

Procedure

The University of British Columbia Behavioral Research Ethics Board approved all procedures. Data were collected between September and December 2010 via a web-based survey hosted by SurveyMonkey (Gordon, 2002). Data were collected using questionnaires that assessed demographic, physical and mental health, sexual functioning, and sexual behaviors that took an average of 60 min to complete.

Measures

Demographic Information

Participants reported their ethnicity as: Caucasian/White, East Asian (Chinese, Japanese or Korean), South Asian, African American/Canadian, First Nations/Aboriginal, Hispanic, or "other." Ninety-three percent of asexual men and 86 % of asexual women, 59 % of heterosexual men and 45 % of heterosexual women, and 61 % of non-heterosexual men and 74 % of non-heterosexual women identified as Caucasian. The asexual samples were more likely to be Caucasian than the heterosexual or non-heterosexual samples, and 32 % of the heterosexual participants identified as East Asian. The ethnic make-up of our sample was of significance given the finding that 2D:4D ratios vary widely across ethnic groups (Manning, 2002; Manning, Churchill, & Peters, 2007).

Edinburgh Handedness Inventory (EHI)

The Edinburgh Handedness Inventory (Oldfield, 1971) is a measurement scale widely used to assess the dominance of a person's right or left hand in everyday activities ranging from writing to opening a box. This 10-item measure produces scores ranging from -100 (indicating strong left-handedness) to +100 (strong right-handedness), and a designation of left-handedness is usually assigned to those who score less than -40, ambidextrous to those who score between -40 and +40, and right-handed to those who score more than +40 on this measure. The EHI has good test–retest reliability. We pooled left-handed and ambidextrous participants as non-right-handed, according to the widely accepted definition of handedness put forward by Rife (1940).

Number of Older Brothers and Sisters

Participants responded to three questions that assessed their number of older brothers and sisters: "Do you have any biological siblings?" and "If you answered yes to the previous question, how many older brothers (sisters) do you have?"

Finger Length Measurement

Finger lengths were self-measured following the methodology reported by Manning, Scutt, Wilson, and Lewis-Jones (1998). Participants were provided with a link to an online ruler (http://iruler.net) and the instructions "Hold your right hand in front of you. Look at where your ring finger joins the palm of your hand. Find the bottom crease. Put the 0 of your ruler exactly on the middle of the bottom crease. Make sure the ruler runs straight up the middle of your finger. Measure to the tip of your finger (not your nail) in millimetres. It is important to do this as accurately as possible, every millimetre counts! Enter your finger-length measurements into the appropriate boxes below. Repeat for your right-hand index finger. Repeat measurements for the ring and index fingers of your left hand."

Statistical Analysis

Baseline group comparisons used analysis of covariance (ANCOVA), with age included as the covariate, followed by Tukey's multiple comparisons test in cases of a significant overall effect. As 2D:4D finger-length ratios and handedness appear to be stable over time, and do not seem to be affected by postnatal variations in hormone levels (Manning, 2002), and because age did not affect 2D:4D ratios in men or women, we did not control for age in these analyses.

Results

Handedness

There were 1,270 participants who provided information on handedness. We first analyzed sex differences in handedness. For heterosexual participants alone, there was no statistically significant relationship between sex and handedness, $\chi^2(1) < 1$ (see below). In contrast, non-heterosexual participants showed a sex difference in handedness that approached significance, $\chi^2(1) = 3.82, p = .051$, with the percentage of non-right-handed non-heterosexual women (20 %) being greater than the percentage of non-right-handed non-heterosexual men (10 %). There were no significant sex differences in handedness among asexual participants alone, $\chi^2(1) < 1$. A 2 (Handedness) × 3 (Sexual Orientation) Chi square test revealed an overall significant effect between sexual orientation groups, $\chi^2(2) = 8.49, p = .014$ for men, and $\chi^2(2) = 23.06, p < .001$ for women.

Handedness in Women as a Function of Sexual Orientation

A series of 2 × 2 Chi square tests revealed asexual and non-heterosexual women to be significantly more likely to be non-right-handed than heterosexual women, $\chi^2(1) = 22.24, p < .001$, odds ratio = 2.51, and $\chi^2(1) = 8.40$, $p < .01$, odds ratio = 1.89, respectively. However, there was no statistically significant difference between asexual and non-heterosexual women on this measure. Twenty-five percent of asexual women, 20 % of non-heterosexual women, and 12 % of heterosexual women reported being non-right-handed (Fig. 1).

Handedness in Men as a Function of Sexual Orientation

A series of 2 x 2 Chi square tests revealed asexual men to be significantly more likely to be non-right-handed than both non-heterosexual and heterosexual men, $\chi^2(1) = 6.38, p = .012$, and $\chi^2(1) = 6.01, p = .014$, respectively (odds ratio = 2.39 compared to heterosexual men). Heterosexual men did not differ from non-heterosexual men on measures of handedness (odds ratio = 0.68).

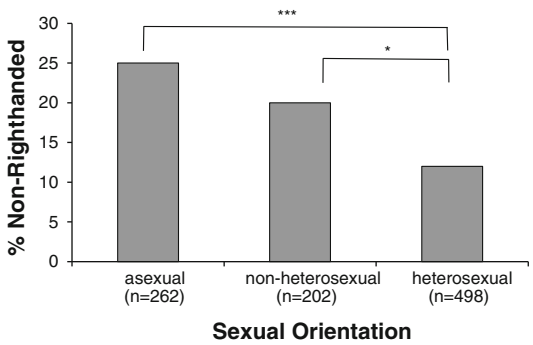

Fig. 1 Percentage of non-right-handed participants by sexual orientation in women. *$p < .05$, ***$p < .001$

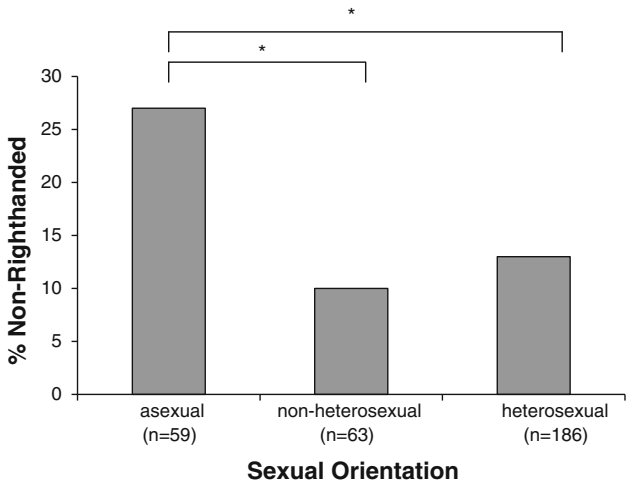

Fig. 2 Percentage of non-right-handed participants by sexual orientation in men. *$p < .05$

Twenty-seven percent of asexual men, 10 % of non-heterosexual men, and 13 % of heterosexual men reported being non-right-handed (Fig. 2).

Birth Order Effects: Older Brothers

Older Brothers in Men as a Function of Sexual Orientation

There was a statistically significant difference in number of older brothers between sexual orientation groups for men, $F(2, 311) = 3.48, p = .032$. Post-hoc tests showed that asexual men had more older brothers than their heterosexual counterparts, $p = .028$. All other comparisons were non-significant (Fig. 3a). There was a statistically significant difference between sexual orientation groups for right-handed men, $F(2, 258) = 5.55, p < .01$, but not for non-right-handed men, $F(2, 44) = 1.11$ (Fig. 3b, c). Post-hoc tests showed that right-handed asexual men had significantly more older brothers than their right-handed heterosexual counterparts, $p < .01$.

Older Brothers in Women as a Function of Sexual Orientation

There was also a statistically significant difference in number of older brothers between sexual orientation groups for women, $F(2, 966) = 3.20, p = .041$. Post-hoc tests showed asexual women had fewer older brothers than their non-heterosexual counterparts, $p = .036$. All other comparisons were non-significant (Fig. 4a). There was no statistically significant difference between sexual orientation groups for right-handed women, $F(2, 793) = 1.19$, but there was a marginally significant difference for non-right-handed women, $F(2, 163) = 2.69, p = .07$ (Fig. 4b, c). Post-hoc tests showed that non-right-handed asexual women had fewer older brothers than their non-heterosexual counterparts, $p = .056$. There was no statistically significant difference between non-right-handed asexual women and their heterosexual counterparts.

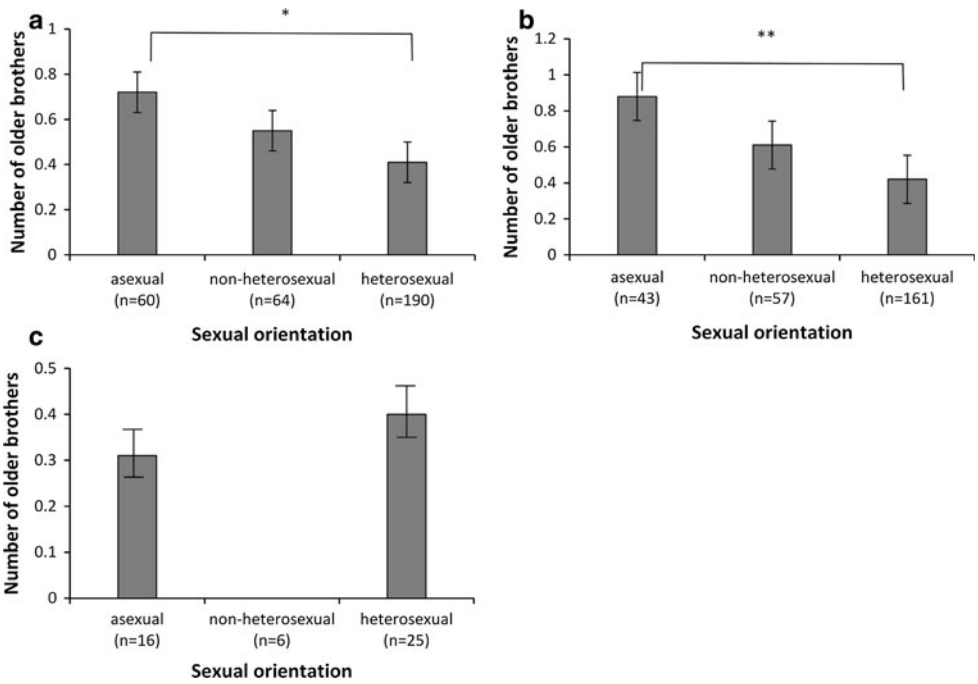

Fig. 3 Number of older brothers by sexual orientation for **a** all men, **b** right-handed men only, and **c** non-right-handed men only. *$p < .05$, **$p < .01$

Birth Order Effects: Older Sisters

Older Sisters in Men as a Function of Sexual Orientation

There was a statistically significant difference in number of older sisters between sexual orientation groups for men, $F(2, 311) = 7.66$, $p = .001$. Post-hoc tests showed that asexual men were less likely to have older sisters than their non-heterosexual counterparts, $p < .01$. Non-heterosexual men were more likely to have older sisters than their heterosexual counterparts, $p < .001$. There was no significant difference in number of older sisters between asexual and heterosexual men (Fig. 5a). There was a statistically significant difference in number of older sisters between sexual orientation groups for right-handed men, $F(2, 258) = 6.25$, $p < .01$, but not for non-right-handed men, $F(2, 44) = 1.37$ (Fig. 5b, c). Post-hoc tests showed that right-handed asexual men had fewer older sisters than their non-heterosexual counterparts, $p = .043$, while non-heterosexual men had more older sisters than their heterosexual counterparts, $p < .01$.

Older Sisters in Women as a Function of Sexual Orientation

There was a statistically significant difference in number of older sisters between sexual orientation groups for women, $F(2, 966) = 5.72$, $p < .01$. Post-hoc tests showed that asexual women had fewer older sisters than both their heterosexual and non-heterosexual counterparts, $p = .030$ and $p < .01$ respectively. All other comparisons were non-significant (Fig. 6a). There was a statistically significant difference between sexual orientation groups for right-handed women, $F(2, 793) = 5.88$, $p < .01$. Post-hoc tests showed that right-handed asexual women had fewer older sisters than both their right-handed heterosexual and non-heterosexual counterparts, $p = .015$ and $p < .01$, respectively (Fig. 6b). Finally, there was no statistically significant difference in number of older sisters between sexual orientation groups for non-right-handed women, $F(2, 163) < 1$ (Fig. 6c).

Older Siblings in Men as a Function of Sexual Orientation

There was a significant difference in number of older siblings between sexual orientation groups in men, $F(2, 217) = 5.20$, $p < .01$. Post-hoc tests showed that both asexual and non-heterosexual men had a greater number of older siblings than heterosexual men, $p = .034$ and $p = .027$, respectively, making them more likely to be later-born. However, there was no significant difference in number of older siblings between asexual and non-heterosexual men.

Older Siblings in Women as a Function of Sexual Orientation

Similarly, there was a significant difference in number of older siblings between sexual orientation groups in women, $F(2, 746) = 6.65$, $p = .001$. Asexual women had fewer older siblings than non-heterosexual women, $p = .001$, and thus were more likely to be earlier-born. Asexual and non-heterosexual women did not differ in the number of older siblings from heterosexual women; however, non-heterosexual women tended to have a greater number of older siblings than heterosexual women, $p = .054$.

Finger Length Ratios (2D:4D)

To reduce potential variance in 2D:4D ratios due to ethnicity, we restricted analyses to those who self-identified as Caucasian/

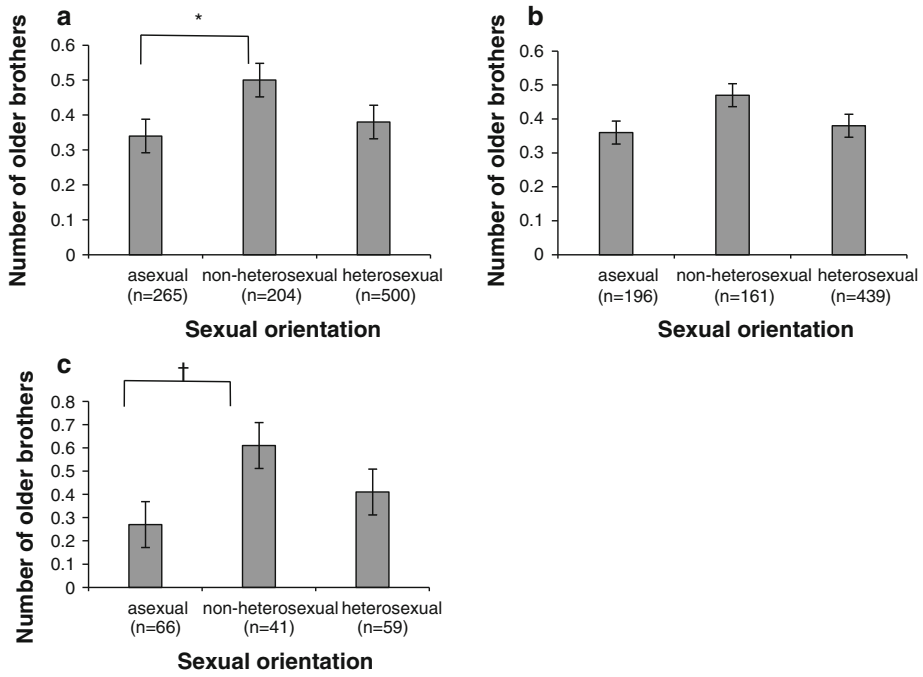

Fig. 4 Number of older brothers by sexual orientation for **a** all women, **b** right-handed women only, and **c** non-right-handed women only. $^{*}p < .05$, $^{\dagger}p = .056$

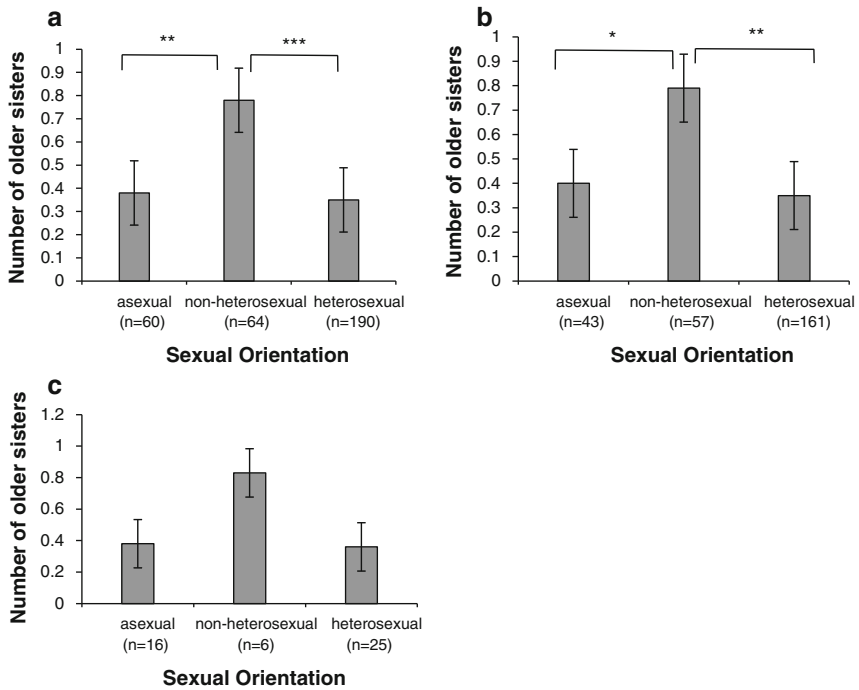

Fig. 5 Number of older sisters by sexual orientation for **a** all men, **b** right-handed men only, and **c** non-right-handed men only. $^{*}p < .05$, $^{**}p < .01$, $^{***}p < .001$

White.[1] Further, while Caswell and Manning (2009) found self-reported 2D:4D measurements to be a reliable method of digit-ratio measurement, we followed their suggestion to remove extreme outliers (e.g., those measurements which were unlikely to be accurate). Based on criteria put forward by Manning, Churchill, and Peters (2007), we restricted the range of 2D:4D to values from .80 to 1.20, which resulted in the removal of 1 % of

[1] Identical analyses performed on all ethnicities in this sample revealed a similar pattern of results.

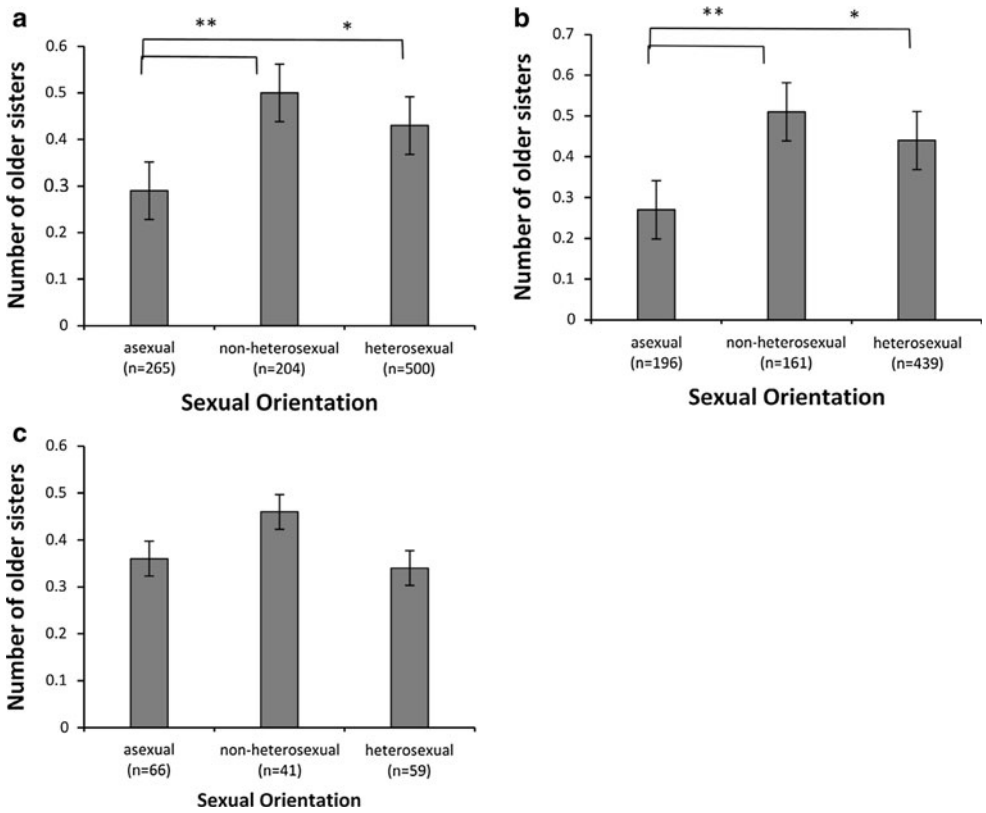

Fig. 6 Number of older sisters by sexual orientation for **a** all women, **b** right-handed women only, and **c** non-right-handed women only. *$p < .05$, **$p < .01$

the participants' data ($n = 7$; 2 men and 5 women). This resulted in 622 participants who reported finger-length measurements allowing a calculation of 2D:4D ratios.

For heterosexual participants only, a 2 (Sex) x 2 (Hand: Right vs. Left) repeated-measures analysis of variance (ANOVA) was conducted for 2D:4D ratios, with sex of participant a between-subjects factor and hand a within-subjects factor. There were no significant main effects for Sex, $F(1, 261) < 1$ or for Hand, $F(1, 261) < 1$, nor was there a significant Sex x Hand interaction, $F(1, 261) < 1$.

For male participants only, a 3 (Sexual Orientation Group) x 2 (Hand) repeated-measures ANOVA was conducted for 2D:4D ratios. There were no significant main effects for Sexual Orientation Group, $F(2, 149) = 1.09$, or for Hand, $F(1, 149) < 1$, nor was there an interaction between Sexual Orientation Group and Hand, $F(2, 149) < 1$. The equivalent repeated-measures ANOVA for women similarly revealed no significant main effects for Sexual Orientation Group, $F(2, 464) < 1$, or for Hand, $F(1, 464) = 1.35$, nor was there an interaction between Sexual Orientation Group and Hand, $F(2, 149) < 1$ (Table 1).

Discussion

Summary of Findings

This study used three putative biological markers of sexual orientation (handedness, birth order, and digit ratios) to investigate the notion that asexuality could be conceptualized as a sexual orientation. We found that asexual men and women were significantly more likely to be non-right-handed than their heterosexual counterparts. Also novel to this study, there were significant differences between sexual orientation groups on number of older siblings, both sisters and brothers, for all asexuals. Specifically, asexual men had significantly more older brothers and significantly fewer older sisters compared to the other groups, and asexual women had significantly fewer older brothers and sisters than the other groups. There were no significant differences between sexual orientation groups on measures of finger length ratio in Caucasian participants.

Handedness

The current results supported previous findings (Lalumière et al., 2000; Lippa, 2003b; Mustanski et al., 2002a; Rahman & Wilson, 2003) of an association between handedness and sexual orientation, with non-heterosexual women being significantly more likely to be non-right-handed than heterosexual women. We found non-heterosexual men not to differ on measures of handedness from their heterosexual counterparts; however, this lack of effect may be accounted for by our relatively small sample size of 59 non-heterosexual men who completed this measure. Importantly, and novel to this study, both asexual men and asexual women were significantly more likely to display non-right-handedness than their heterosexual counterparts, with odds ratios

Table 1 Digit ratio (2D:4D) data for Caucasian participants by sexual orientation

Variable	Asexuals *M* (*SD*)	Non-heterosexual *M* (*SD*)	Heterosexuals *M* (*SD*)
Women	($n = 186$)	($n = 106$)	($n = 177$)
Right	.995 (.054)	.999 (.049)	.996 (.062)
Left	.992 (.050)	.997 (.058)	.995 (.054)
Men	($n = 41$)	($n = 26$)	($n = 86$)
Right	.989 (.050)	.972 (.041)	.989 (.065)
Left	.997 (.053)	.978 (.057)	.987 (.055)

n = number of participants

All $ps > .05$

of 2.39 and 2.51, respectively, compared to the heterosexual groups. A large proportion of our asexual sample were non-right-handed (25 % of asexual women, and 27 % of asexual men), a proportion that is three times higher than the estimated incidence of non-right-handedness in the general population, which ranges from 9 to 11 % (Corballis, 1991).

According to the linear prenatal hormone theory of sexual orientation, non-right-handedness is associated with hyper-androgenization in the prenatal environment. If this theory were true for asexuality, it would suggest that asexual individuals may have been exposed to *higher* levels of prenatal androgens. Clearly, this is not the case given their lack of, as opposed to excess of, sexual attraction. A non-linear prenatal hormone theory, which posits that androgens may masculinize structures up to a certain point, but once androgens reach a critical threshold, they then lead to feminization of these same structures (Lippa, 2003a), may be more suitable to account for the development of asexuality. It has also been theorized that the effects of prenatal androgens are dependent on the timing of surges and declines of androgen levels and/or the individual's ability to utilize these androgens (Berenbaum, 2002; McFadden, 2002). Further, it has been proposed that handedness is genetically determined (Klar, 2003; Rife, 1940) and thus may be independent from prenatal hormones. Hence, while the current study revealed a significant relationship between handedness and asexuality, the underlying mechanisms remain unknown. Because scholars have argued that the increased rate of non-right-handedness within a group establishes a clear link between brain development and the variable of interest (Cantor et al., 2004), it is likely that neurodevelopmental processes are also involved in the development of asexuality.

Of note, the high prevalence of non-right-handedness in asexuals does not, in itself, establish asexuality as a sexual orientation given that similarly high proportions of left-handedness have been found in pedophiles and hebephiles (Blanchard et al., 2007; Bogaert, 2001; Cantor et al., 2004, 2005) (although, notably, an argument has recently been made for conceptualizing pedophilia as a sexual orientation) (Seto, 2012). It is possible that a third-variable model may account for the relationship between these two phenomena; namely, that a perturbation in early brain development causes both non-right-handedness and pedophilic interests. Thus, non-right-handedness is a marker, not a causal agent, of pedophilia. The same might apply to asexuality.

Birth Order

Previous research has consistently found evidence for the FBO effect: that having a greater number of older brothers increases the odds of homosexuality in men (Blanchard & Lippa, 2007). This pattern has not been previously observed in women nor has it been shown true for number of older sisters, younger brothers, or younger sisters (Blanchard, 2004; Camperio-Ciani, Corna, & Capiluppi, 2004; Green, 2000). As discussed earlier, because the FBO effect holds true even for biological brothers raised in separate households, but not for step-brothers or adoptive brothers, it is hypothesized to be due to effects of the prenatal milieu and possibly to the progressive production by some mothers of anti-male antibodies in response to each successive male fetus, which then have an effect on the sexual differentiation of a later born male fetus (Blanchard & Bogaert, 1996).

Novel to this study was the finding of a significant relationship between number of older siblings, both sisters and brothers, and asexuality. Although our findings were not statistically significant for non-heterosexual men, the current findings support the observation (Blanchard & Lippa, 2007) that the effect of older brothers on sexual orientation is true for right-handed men only and extends these findings to asexual men. We could speculate based on previous theories, such as the maternal immune hypothesis, that the prenatal environment is influenced by older male siblings, which in turn influences the development of sexual attraction in the asexual male. However, there may be multiple influences on the development of sexual orientation and this would apply also to asexuality. Further complicating matters, our unexpected finding that non-right-handed asexual women had significantly fewer older brothers than sexual women, as well as our finding of a statistically significant relationship between older sisters and asexuality in both men and women (asexuals had fewer older sisters than other groups), makes it more difficult to speculate on a unified hypothesis as to the mechanism that might link number of older siblings and asexuality.

It is possible that prenatal stress might play a role, given the speculation that both left-handedness and homosexuality are correlated with stressful prenatal conditions in general (Lalumière et al., 2000). The maternal immune hypothesis implies prenatal stress and this may be an explanation for the association between handedness, birth order, and sexual orientation. It has been hypothesized that because later-born children are likely born to older mothers, they may have been exposed to prenatal stressors directly as a result of having an older mother (Bogaert, 2003). It may be hypothesized that the current findings were due to number of older siblings in general, which may be a proxy for maternal age. Asexual men, for example, had a significantly greater number of older siblings than heterosexual men, which may suggest elevated

maternal age. Unfortunately, mother's age at participant's birth was not assessed in this study.

Finger Length Ratios

There are methodological concerns when utilizing techniques such as self-reported 2D:4D measurements over the Internet. Caswell and Manning (2009) noted that minor errors in self-measurement likely result in a reduction of effect size for both sexual dimorphism of 2D:4D and for correlations of 2D:4D with target variables, such as sexual orientation. They suggested the use of very large sample sizes, such as that used in the BBC Sex Differences Survey (Reimers, 2007), which had over 250,000 participants. While the BBC Internet Survey found significant sexual dimorphism in 2D:4D such that, as expected, males had lower 2D:4D than females, and significant differences were found between male sexual orientation groups, their self-report measures did have higher than expected mean 2D:4D and lower than expected effect sizes (Caswell & Manning, 2009; Manning et al., 2007). Due to the difficulty in sampling a sufficiently large asexual sample, and the necessity of using an Internet-based methodology in finger-length measurement, it may be that the current sample was of insufficient size to detect variations in 2D:4D between sexual orientation groups. We suspect this to be the case in the current sample, as there was no evidence of sex differences, which is inconsistent with most of the existing literature (Manning, 2002). This problem was further compounded by previously observed differences in finger lengths between ethnic groups (Manning, 2002; Manning et al., 2007), which necessitated the exclusion of a number of non-Caucasian participants.

Internet surveys allow one to collect a large amount of data and are particularly useful for the study of populations that are widely dispersed and may not otherwise be accessible–asexual individuals being a particularly good example of this. Thus, although using the Internet to measure 2D:4D lengths is not without its limitations, it is an invaluable method for collecting data that may be less influenced by measurement error. Further, while there is some concern that Internet surveys may result in repeat responses, haphazard participation, or maladjusted, socially isolated samples participating, these concerns have been allayed by researchers who noted that Internet methods could actually benefit researchers in that they can result in large and diverse samples with motivated respondents (Gosling, Vazire, Srivastava, & John, 2004). Despite the potential methodological flaws with gathering finger length measurements that may have compromised our findings, we have no reason to be concerned about the data gathered on handedness and siblings.

Conceptual Model of Asexuality

As reviewed, our finding of increased rates of non-right-handedness in both male and female asexuals likely fits a non-linear prenatal hormone theory of sexual orientation development, in which low levels of prenatal androgens may masculinize structures and higher levels might lead to the feminization of these same structures. Further, it may be that the timing of surges and declines in prenatal androgen levels influences brain development in a manner that may directly contribute to the lack of sexual attraction characteristic of asexuality.

Our findings regarding number of older siblings also raise the possibility that the prenatal environment is important in the development of asexuality, and in particular, that number of older brothers plays a role. However, this interpretation is complicated by our unexpected finding of fewer older sisters in both asexual men and women, making it challenging to speculate on a single, unified hypothesis to account for how older siblings might influence development of asexuality.

As suggested by Ellis and Ames (1987), an inversion of masculinization and feminization may occur in homosexual men and women during prenatal development. How this behavioral correlate of sexual orientation manifests in asexual individuals is unknown, but it has been hypothesized that asexual individuals conform less to traditional gender roles than do heterosexual individuals, perhaps indicating an alteration in the process that produces gender identity (Bogaert, 2012). Bogaert speculated that asexual brains are neither "masculine" nor "feminine" due to a combination of atypical prenatal hormones and/or genes (e.g., certain hormone receptor genes, such as the androgen receptor, have been implicated in male-to-female transsexualism (Hare et al., 2009) and handedness (Medland et al., 2005)). An additional influencing factor might be that of the sex (both male and female) of older siblings. Clearly, linear explanations espousing increases or decreases in prenatal hormone levels are inadequate and more research is needed to adequately test mechanisms of development.

In addition, as has been noted elsewhere (Cantor, 2012), while male and female homosexuality seem to be obviously analogous, there is actually no foundation for the assertion that homosexual men are homosexual for the same reason that homosexual women are homosexual. Male homosexuality and female homosexuality are associated with different sets of correlates and thus may have different etiological pathways. It is entirely possible, therefore, that male and female asexuality may also result from different etiological and developmental pathways.

Limitations

We were unable to distinguish between maternal and paternal half-siblings due to the wording of the question assessing the number of siblings. This potentially complicates the interpretation of the sibling data, as paternal half-siblings would not be relevant to maternal immunization hypotheses whereas maternal half-siblings would influence the FBO effect. Moreover, we unfortunately did not collect any data on the number of younger siblings, thus we were not able to calculate a possible sibling ratio effect (Blanchard, 1997). Although this study focused on putative

biological correlates of the development of asexuality, this study does not address the possibility that non-biological or, in fact, post-natal events (whether biological or not) may contribute to the development of asexuality. However, it is worth noting that an earlier study found no evidence of higher rates of psychopathology in asexual individuals compared to those in the general population (Brotto et al., 2010).

Conclusion

This was the first study to test and provide empirical evidence for biological correlates of the lack of sexual attraction characteristic of asexuality and was consistent with the demonstrated link between prenatal events and homosexual orientation development. It is unclear at this point, however, how this disposition arises, or at what stage in development it may occur. In fact, even the most essentialist supporters of biological determinism of sexual orientation acknowledge the multi-factorial and complex influences that likely lead to its development, and this is likely the case for the development of lack of sexual attraction. Taken together, however, in light of the conceptual/theoretical support in favor of classifying asexuality as a sexual orientation (Bogaert, 2006b), laboratory evidence that asexual women respond physiologically similar to other sexual orientation groups (Brotto & Yule, 2011), and the current findings which illustrate some of the same biological pathways implicated in the development of homosexuality are present in asexuality, we conclude that asexuality is likely best conceptualized as a unique sexual orientation. Further research into genetic, hormonal, environmental, and social influences on asexuality is necessary, and additional large-scale studies are required to replicate the current findings on handedness and older siblings, and to gain insight into the relationship between finger-length ratios and asexuality.

Acknowledgments Funding for this study was from a University of British Columbia Hampton Research Grant awarded to L.A.B. M.A.Y. was funded by a Predoctoral Fellowship. We wish to thank Martin L. Lalumière for his generous statistical assistance.

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