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ORIGINAL RESEARCH

Sensation Seeking in Females from Opposite- Versus Same-Sex Twin Pairs: Hormone Transfer or Sibling Imitation?

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Abstract The aims of this study were to replicate the results of a previous study (Resnick et al. 1993) and to extend them by examining the evidence for prenatal exposure to androgens versus sibling imitation as a potential cause of group differences in levels of sensation seeking. Participants were members of the Australian Twin Registry who had participated in a structured interview study and completed the Zuckerman Sensation-Seeking Scale. Three sets of group comparisons were conducted: (1) the sensation seeking scores of females from same-sex twin pairs ($n = 1{,}947$) were compared to females from opposite-sex twin pairs ($n = 564$), (2) females from same-sex twin pairs without a brother ($n = 580$) were compared to same-sex females with a close-in-age older brother ($n = 300$), and (3) same-sex females who had a close-in-age older brother ($n = 300$) were compared to females from opposite-sex twin pairs ($n = 564$). Females from opposite-sex twin pairs obtained significantly higher scores than females from same-sex twin pairs on the experience-seeking ($d = 0.12$) and thrill and adventure seeking ($d = 0.10$) subscales, but not the boredom susceptibility ($d = -0.01$) or disinhibition ($d < 0.01$) subscales of the Sensation-Seeking Scale. The modest effects obtained could not be explained by the psychosocial effect of having a close-in-age brother. Considering these effects alongside the overall sex differences in the Sensation-Seeking Scales of experience-seeking ($d = 0.12$ vs. $d = 0.18$) and thrill and adventure-seeking ($d = 0.10$ vs. $d = 0.83$) suggests that prenatal androgens may actually play a large role in the sex difference in the personality trait of experience seeking, and a smaller role in thrill and adventure-seeking; there was no evidence from this study that prenatal androgens are important for explaining sex differences in the traits of boredom susceptibility or disinhibition.

Keywords Sensation-seeking · Twins · Prenatal androgens · Sibling imitation · Sex differences

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Sensation seeking is a personality construct generally described as the tendency towards varied, novel and intense sensations, and related to engaging in risk-taking behaviors such as gambling, drinking, smoking and illicit drug use (Zuckerman 1974, 2007). Males tend to have higher mean scores on measures of sensation seeking than females (Zuckerman et al. 1978), and this difference suggests that some causes of sensation seeking may be related to factors associated with biological sex and/or psychological gender. One factor associated with biological sex that could plausibly influence sensation seeking and explain the higher levels of sensation seeking amongst males is testosterone (Zuckerman et al. 1978). Past research has suggested that plasma levels of testosterone are related to individual differences in sensation seeking within samples of men (Daitzman et al. 1978; Aluja and Torrubia 2004). Although the majority of research has focused on the effects of postnatal testosterone exposure, prenatal exposure to testosterone may also be important (Becker et al. 2005). The purpose of this study is to examine the possible role of prenatal androgens on sensation seeking.

Prenatal androgen exposure has been studied in rats and other litter-bearing mammals such as swine and cattle (vom Saal 1989). One approach for examining the effect of differing levels of intrauterine testosterone in non-human mammals is based on what researchers have termed the intrauterine position effect (vom Saal 1989). Litter-bearing mammals tend to carry multiple offspring during each gestation period, and researchers have discovered that levels of testosterone can vary in both males and females based on their position in the womb. A female fetus lying between two male fetuses is quite often hypermasculinized in adulthood (i.e. mounting other females, having a delayed estrus cycle, and exhibits more aggressive behavior than other female counterparts) (vom Saal 1989).

Twins provide a window into whether the effects observed among rats, swine, and cattle might also apply to humans. Comparison of females from same-sex twin pairs with those from opposite-sex dizygotic (DZ) twin pairs (females in utero with a male co-twin) can provide a test of the theory that prenatal hormone transfer from the male co-twin may masculinize the behavior of the female in later development (Ryan and Vandenbergh 2002). The process by which androgens can be transferred from a male twin to the female co-twin is called amniotic diffusion. This increased prenatal exposure to androgens may result in the masculinization of females such that these females display higher levels of male-dominated traits, such as sensation seeking or rule breaking behavior (Loehlin and Martin 2000; Resnick et al. 1993). Therefore, if prenatal androgens influence levels of sensation seeking, females from opposite-sex twin pairs should have higher levels of sensation seeking than females from same-sex twin pairs.

Resnick et al. (1993) examined levels of sensation seeking in females from opposite-sex twin pairs in comparison to females from same-sex twin pairs. Females from opposite-sex twin pairs scored significantly higher on two of the four subscales of Zuckerman's Sensation Seeking Scale (experience seeking and disinhibition) than females from same-sex twin pairs. Although these results are consistent with the hypothesis that prenatal exposure to androgens were responsible for this difference, an alternative explanation for higher levels of sensation seeking among females from opposite-sex compared to same-sex twin pairs is that of a psychosocial effect: females from opposite-sex twin pairs may imitate their male co-twin. In order to evaluate the viability of this psychosocial explanation, females from same-sex twin pairs with and without a brother close in age could be compared on their levels of sensation seeking.

Since the publication of Resnick et al. (1993) only one other study has compared the sensation seeking scale scores of opposite- and same-sex female twins. Cohen-Bendahan et al. (2005a) studied a small sample of 13-year old female twins; the only significant difference obtained was that the opposite-sex girls had significantly *lower* scores on the experience seeking subscale of the Zuckerman Sensation Seeking Scale than did the same-sex girls. This result is inconsistent with both the hormone transfer and the sibling imitation explanations of group differences.

The aims of this study were to replicate the results of the earlier study of Resnick et al. (1993) and to extend them by examining the evidence for hormone transfer versus sibling imitation as a potential cause of sibling differences in levels of sensation seeking. First, we compared the sensation seeking scores of females from same-sex twin pairs versus females from opposite-sex twin pairs; higher scores among the opposite-sex females would be consistent with either hormone transfer or sibling imitation. Second, females from same-sex twin pairs without a brother were compared to same-sex females with a close-in-age older brother; higher scores among females with a brother would be most consistent with sibling imitation. Third, same-sex females who had a close-in-age older brother were compared to females from opposite-sex twin pairs (who also have a brother—the male cotwin); higher scores among the opposite-sex females would be most consistent with hormone transfer. The goal was to elucidate which environment, prenatal or psychosocial, has an influence on sensation seeking behavior.

Method

Participants

The participants for this study were members of the national community-based Australian Twin Registry (ATR) (Slutske et al. 2009). The data for this study was collected during 2004–2007, when participants were between 32 and 43 years old ($M = 37.66$, $SD = 2.31$). Participants completed a structured diagnostic telephone interview and were mailed a paper-and-pencil personality questionnaire with a postage-paid return envelope. Of the 4,764 participants who completed the telephone interview, 4,355 (91%) returned the personality questionnaire. These 4,355 individual twins included 1,139 monozygotic females (MZF), 761 monozygotic males (MZM), 864 dizygotic females (DZF), 576 dizygotic males (DZM), 576 opposite-sex females (OSF), and 439 opposite-sex males (OSM). (For more details about sample characteristics, participation rates, potential sampling biases, and zygosity determination, see Slutske et al. 2009.)

Measures

Sensation seeking

The Zuckerman Sensation Seeking Scale-Form V (SSS-V) was used as a measure of sensation seeking. There are four subscales of the SSS-V, which include: boredom susceptibility (BS), experience seeking (ES), disinhibition (DIS), and thrill and adventure seeking (TAS). Each subscale includes a series of ten questions resulting in 40 items for the full SSS. A review of all of the available published data on the internal consistency reliability (α) of the SSS-V found that the mean reliabilities were $\alpha = 0.62$ for BS, $\alpha = 0.69$ for ES, $\alpha = 0.69$ for DIS, and $\alpha = 0.75$ for TAS (Deditius-Island and Caruso 2002); the authors noted the particularly low reliability of the BS scale. In the present study the internal consistency reliabilities were $\alpha = 0.55$ for BS, $\alpha = 0.61$ for ES, $\alpha = 0.73$ for DIS, and $\alpha = 0.80$ for TAS. Consistent with the review of previous studies, the reliability of the boredom susceptibility scale was also low in the present study. Subscales with more than three of the ten items missing were considered missing; 4,276 of the 4,355 participants (98%) had complete data for all four subscales of the SSS-V. Scores on subscales with 1–3 missing items were pro-rated based on responses to the remaining non-missing items. Pro-rated scores were computed as the number of endorsed items divided by the number of non-missing items; this resulted in scale score values that ranged from 0 to 1.0.

Infrequency scale

Eleven items from the Infrequency Scale (Chapman and Chapman 1983) were used to identify SSS profiles that may have been invalid. Data from participants who tallied a score greater than 3 on this modified Infrequency Scale were excluded from analyses. Based on potentially invalid questionnaire responses as indicated by the Infrequency Scale, data from 53 participants were excluded from analysis, which left a final sample size of 4,223 participants (1,111 MZF; 732 MZM; 836 DZF; 557 DZM; 423 OSM; and 564 OSF).

Presence of non-twin brothers

Information about the siblings of the twins was obtained from two sources: a previous telephone interview conducted with the twins in 1996–2000 (see Slutske et al. 2009), and a comprehensive twin-family demographic database maintained at the Queensland Institute of Medical Research (QIMR) Genetic Epidemiology Unit. The 1996–2000 interviews included questions about the number of full older and younger brothers and sisters and half-, step-, or adopted older and younger brothers and sisters. These interview data were supplemented with information from the QIMR database about the birthdates of many of the siblings. These birthdates were used to determine the age difference between the twins and their siblings.

For the purpose of this study, which focussed on the masculinizing effect of prenatal testosterone compared to that of the psychosocial effect of being reared with a brother, only data pertaining to the full (older and younger) brothers of the twins was used. Of the 4,223 participants described above, 4,046 had information on both male and female siblings from the previous interview, and 2,635 (62%) reported that they had at least one full brother. Of these, 1,880 (71%) had birthdate information in the QIMR database.

Although data were available on half/step/adopted siblings of the twins we decided not to use these siblings in our analyses. This was because it was not possible to definitively know when these types of siblings began living with the twins, nor was it possible to identify for how long they lived together. Therefore, inferences about the sibling psychosocial effect would have been ambiguous.

Data analysis

Two different data analytic approaches were used: standard *t* tests of mean differences (to most closely match the previous study) and structural equation modeling (to parse differences in means vs. differences in variances). Following Resnick et al. (1993) the primary data analyses were comparisons of mean levels of sensation seeking for: (1) same-sex (SS) MZ and DZ males versus SS MZ and DZ females and (2) SS MZ and DZ females versus opposite-sex (OS) females. We also conducted analyses restricted to SS and OS DZ females. Altogether, there were data available from 1,289 (557 DZ) SS males, 1,947 (836 DZ) SS females, and 564 OS females for these analyses.

We defined “brother” several different ways for tests of the sibling imitation hypothesis: (1) we compared SS females without a brother versus SS females with a brother, (2) we compared SS females without a brother versus SS females with an older brother, and (3) we compared SS females without a brother versus SS females with a close-in-age (no more than 3 years) older brother. Altogether, there were data available from 580 (246 DZ) female twins without a brother, 1,235 (527 DZ) female twins with a brother, 832 (397 DZ) female twins with an older brother, and 300 (121 DZ) female twins with a close-in-age older brother.

We opted to specifically focus on comparisons of females without a brother to females with an older or close-in-age older brother, rather than a younger or close-in-age younger brother. This was because the main purpose of these analyses was to simulate the brother-sister relationship in OS twin pairs as closely as possible. Older siblings are present from birth (as are co-twins) whereas younger siblings are not. Also, nearly all of the previous studies of sibling imitation have focussed on the effects of older on younger siblings rather than the effects of younger on older siblings (e.g. Pomery et al. 2005; Rowe and Gulley 1992; Slomkowski et al. 2001). This is based in part on influential studies of early child development demonstrating that younger siblings are much more likely to imitate an older sibling's behavior than the reverse (e.g. Abramovitch et al. 1979).

In all of the analyses, the data were treated as clustered, with the family unit (that is, the twin pair) serving as the cluster. The analyses employed Taylor series (linearization) variance estimation to obtain correct sampling errors from the clustered data. In order to facilitate comparisons between statistical tests that vary in their sample sizes (and therefore statistical power), we focus primarily on the estimation of effect sizes in addition to null hypothesis significance testing. For example, the tests comparing OS versus SS female twins had sample sizes of 564 and 1,947, and the tests comparing female SS twins without a brother to female SS twins with a close-in-age older brother had sample sizes of 580 and 300. The effect sizes were calculated from parameters estimated from the clustered regression analyses (t values) along with their corresponding degrees of freedom (Rosenthal and Rosnow 1991) using the formula $d = 2t/\text{sqrt(df)}$. The focus on effect sizes is consistent with the recommendations made by the APA Task Force on Statistical Inference (Wilkinson and the Task Force on Statistical Inference 1999).

Whenever group differences are of interest it is important to be mindful of variance as well as mean differences because differences in variances can affect the interpretation of mean differences (Feingold 1995). For example, it is possible that the effects of exposure to prenatal androgens may lead to greater variability of scores on the sensation-seeking scales of OS female compared to SS female twins even when there are no mean differences. Also, it has long been recognized by behavioral genetic experts that the influence of sibling imitation can affect the variance as well as the mean of a trait (Carey 1986; Eaves 1976). Therefore, a secondary set of structural equation modeling analyses using the statistical software program Mplus (Muthén and Muthén 2004) were conducted to compare the means and variances of SSS scores of SS versus OS females. Four models were tested for each SSS subscale: (1) a model in which the means and variances for SS and OS female twins were free to vary, (2) a model in which the means were constrained to be equal but the variances for SS and OS female twins were free to vary, (3) a model in which the means were free to vary but the variances for SS and OS female twins were constrained to be equal, and (4) a model in which the means and variances were constrained to be equal for SS and OS female twins. The fits of nested models were compared via χ^2 difference tests to determine the better fitting model.

Results

As expected, SS males had significantly higher means than SS females on all four of the sensation seeking scales, with effect sizes (d) of 0.46 for BS, 0.18 for ES, 0.69 for DIS, and 0.83 for TAS (all $ps < 0.0001$; see Fig. 1).

Tests of overall effect

Females from OS twin pairs scored significantly higher than females from SS twin pairs on the ES ($d = 0.12$, $p = 0.01$; Table 2, row 2) and TAS ($d = 0.10$, $p = 0.04$; Table 4, row 2) subscales, but not the BS ($d = -0.01$, $p = 0.83$; Table 1, row 2) or DIS ($d < 0.01$, $p = 0.95$; Table 3, row 2) subscales (see Fig. 2, panel a). (Note that the comparison group for these effect sizes were OS female twins; a positive effect size indicates that the mean was higher in the OS than the SS female twins, a negative effect size indicates that the mean was higher in the SS than the OS female twins.) When the analyses were restricted to DZ twin pairs only, ES was the only subscale for which the group differences remained significant (Tables 1, 2, 3, 4, row 8). These comparisons of females from SS and OS twin pairs confound hormone transfer and sibling imitation effects—the following two sets of analyses were an attempt to disentangle these effects.

Tests of sibling imitation effect

In order to isolate a potential sibling imitation effect, SS females without a brother were compared on all four sensation seeking subscales to: (1) SS females with a brother (all $ps > 0.2$, $d \geq -0.05$; Tables 1, 2, 3, 4, row 4), (2) SS females with an older brother (all $ps > 0.2$, $d \geq -0.03$; Tables 1, 2, 3, 4, row 5), and (3) SS females with a close-in-age older brother (all $ps > 0.5$, $d \geq -0.04$; Tables 1, 2,

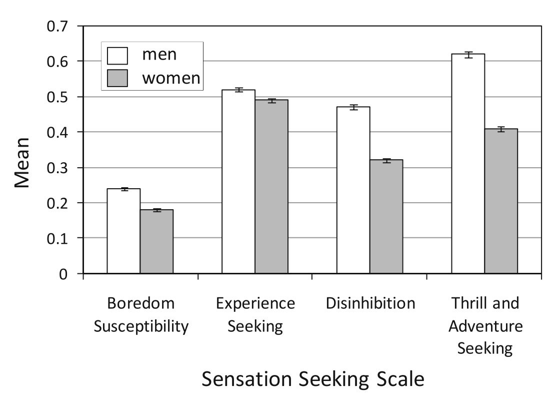

Fig. 1 Mean sensation-seeking scale scores for same-sex male versus female twins. *Error bars* represent one standard error above and below the mean. All scales scores significantly differ for men and women at $p < 0.0001$

Table 1 Means, variances, and group comparisons for Zuckerman's Sensation Seeking Scale: Boredom Susceptibility Subscale

Row number	Group	*n*	Mean	Variance	Groups compared	*t*	*p*	*d*
Females from opposite-sex twin pairs								
1	OSF	564	0.17	0.028	–	–	–	–
Females from same-sex twin pairs (MZ and DZ)								
2	SSF	1947	0.18	0.028	1 vs. 2	0.21	0.83	−0.01
3	SSF without a brother	580	0.17	0.027	–		–	–
4	SSF with a brother	1235	0.18	0.027	3 vs. 4	0.90	0.37	−0.05
5	SSF with older brother	883	0.17	0.026	3 vs. 5	0.39	0.69	−0.03
6	SSF with CIA older brother	300	0.18	0.028	3 vs. 6	0.51	0.61	−0.04
7		–	–	–	1 vs. 6	0.12	0.91	−0.01
Females from same-sex twin pairs (DZ only)								
8	SSF	836	0.18	0.029	1 vs. 8	0.62	0.54	−0.04
9	SSF without a brother	246	0.17	0.029	–		–	–
10	SSF with a brother	527	0.18	0.028	9 vs. 10	0.69	0.49	−0.06
11	SSF with older brother	407	0.17	0.025	9 vs. 11	0.13	0.85	−0.01
12	SSF with CIA older brother	121	0.18	0.023	9 vs. 12	0.14	0.89	−0.02
13		–	–	–	1 vs. 12	0.10	0.92	−0.01

Note: *MZ* monozygotic, *DZ* dizygotic, *OSF* opposite-sex female, *SSF* same-sex female, *CIA* close in age

3, 4, row 6). (Note that the comparison group for these effect sizes were SS female twins without a brother; a positive effect size indicates that the mean was higher in the SS female twins without a brother than the SS female twins with a brother, a negative effect size indicates that the mean was higher in the SS female twin with a brother than the SS female twins without a brother.) This comparison showed no significant differences on any of the SSS subscales (see Fig. 2, panel b).

When the sample was restricted to DZ participants only, there was still no evidence of sibling imitation effects, that is, higher levels of sensation seeking in SS females with versus without a brother. In fact, there was evidence of the opposite. On the ES subscale, SS females without a brother actually had higher levels of sensation-seeking than SS females with a brother ($d = 0.17$, $p = 0.06$; Table 2, row 10) and SS females with an older brother ($d = 0.19$, $p = 0.05$; Table 2, row 11). On the DIS subscale SS females without a brother had higher mean scores than SS females with a brother ($d = 0.17$, $p = 0.06$; Table 3, row 10).

Tests of hormone transfer effect

Though there was no evidence of a sibling imitation effect on sensation seeking, we sought to control for this possible effect while testing the hormone transfer theory. Thus, we compared OS females to SS females with a close-in-age older brother. Although none of these comparisons yielded statistically significant differences for any of the SSS scales (BS: $d = -0.01$, $p = 0.91$, Table 1, row 7; ES: $d = 0.10$, $p = 0.17$, Table 2, row 7; DIS: $d = 0.01$, $p = 0.92$, Table 3, row 7; TAS: $d = 0.06$, $p = 0.42$, Table 4, row 7), the effect sizes were approximately equal to the effect sizes obtained when the females from SS and OS twin pairs were compared in row 2 (see Fig. 2, panel c). (Note that the comparison group for these effect sizes were OS female twins; a positive effect size indicates that the mean was higher in the OS than the SS female twins with a close-in-age older brother, a negative effect size indicates that the mean was higher in the SS female twins with a close-in-age older brother than the OS female twins.) When the analyses were restricted to data from DZ twins only, the effect sizes obtained were nearly identical (Tables 1, 2, 3, 4, row 13).

Tests of variance differences

Prior to looking for variance differences between SS and OS female twins, we tested whether there were variance differences between men and women. Tests of variance differences in Mplus yielded significant sex differences in variances for the BS ($\Delta\chi^2 = 10.35$, df = 1, $p = 0.001$) and DIS ($\Delta\chi^2 = 10.75$, df = 1, $p = 0.001$), but not for the ES ($\Delta\chi^2 = 0.22$, df = 1, $p = 0.64$) or TAS ($\Delta\chi^2 = 2.99$, df = 1, $p = 0.08$) subscales. For both the BS and DIS subscales the variances were greater among men than among women.

There were no significant differences in means or variances between SS and OS female twins for the BS and DIS scales. For the ES subscale, when the model of constrained means and variances was compared to the model of free means and variances, there was a significant deterioration

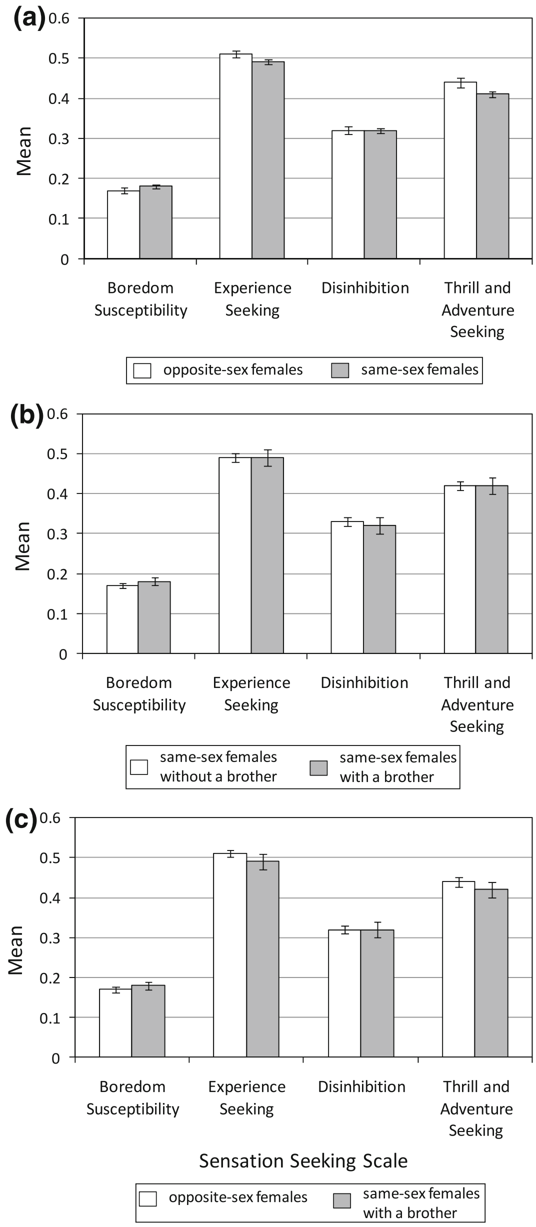

Fig. 2 Mean sensation-seeking scale scores for **a** opposite-sex versus same-sex female twins (overall effect), **b** same-sex female twins without a brother versus same-sex female twins with a close-in-age older brother (test of sibling imitation effect), and **c** opposite-sex female twins versus same-sex female twins with a close-in-age older brother (test of hormone transfer effect). The same-sex female twin groups include both monozygotic and dizygotic twins. *Error bars* represent one standard error above and below the mean

in fit ($\Delta\chi^2 = 8.43$, df = 2, $p = 0.01$). This appeared to be due to differences in the means ($\Delta\chi^2 = 6.59$, df = 1, $p = 0.01$), rather than the variances ($\Delta\chi^2 = 0.83$, df = 1, $p = 0.36$). The same results were obtained when the sample was restricted to SS and OS DZ twins.

For the TAS subscale, a model that constrained both the means and variances had a marginally worse fit than the model that allowed both the means and variances to differ ($\Delta\chi^2 = 5.51$, df = 2, $p = 0.06$) in SS versus OS female twins. This appeared to be due to differences in the means ($\Delta\chi^2 = 4.21$, df = 1, $p = 0.04$), rather than the variances ($\Delta\chi^2 = 0.04$, df = 1, $p = 0.83$). When the sample was restricted to SS and OS DZ female twins only, there were no longer significant differences in the means for the TAS subscale.

Discussion

In a large study of adult female twin pairs, we obtained evidence consistent with a small but significant impact of prenatal androgens on sensation-seeking tendencies in females from OS pairs. Opposite-sex females had significantly higher scores than SS females on measures of ES and TAS, with effect sizes of $d = 0.12$ and $d = 0.10$, respectively. This may be due to either hormone transfer or sibling imitation. In order to identify possible sibling imitation effects, SS females without a brother were compared to SS females with a close-in-age older brother. There were no significant differences between these groups on either ES or TAS, with effect sizes of $d < 0.01$ and $d = -0.01$, respectively. In order to distinguish a possible hormone transfer effect, OS females were compared to SS females with a close-in-age older brother; the effect sizes of the differences between these groups for ES and TAS were $d = 0.10$ and $d = 0.06$, respectively. Although not statistically significant, these effect sizes were similar to those obtained in the comparisons of the OS females to the much larger sample of all SS females (see Fig. 3).

The preceding results were based on SS female twins from both MZ and DZ twin pairs. When the analyses were restricted to only the DZ twin pairs, the evidence for a possible hormone transfer effect for ES and TAS was largely unchanged, while the evidence for sibling imitation was further weakened by obtaining large negative relations between having an older brother and scores on the two sensation seeking scales (see Fig. 3). The effect sizes for the comparison of OS and SS females were $d = 0.14$ and $d = 0.09$, the effect sizes for the comparison of SS females with and without a close-in-age older brother were $d = 0.17$ and $d = 0.12$ (indicating that the scores were higher among the females *without* a close-in-age older brother), and the effect sizes of the comparisons of OS and SS females with a close-in-age older brother were $d = 0.12$ and $d = 0.08$ for ES and TAS, respectively. Including females from MZ pairs was mainly done for comparison with the previous paper of Resnick et al. (1993) in which the same-sex twins came from both MZ and DZ pairs. Ideally, one would only include SS DZ twins in comparisons with OS twins because there are important differences

Table 2 Means, variances, and group comparisons for Zuckerman's Sensation Seeking Scale: Experience Seeking Subscale

Row number	Group	*n*	Mean	Variance	Groups compared	*t*	*p*	*d*
Females from opposite-sex twin pairs								
1	OSF	564	0.51	0.041	–	–	–	–
Females from same-sex twin pairs (MZ and DZ)								
2	SSF	1947	0.49	0.043	1 vs. 2	2.59	0.01	0.12
3	SSF without a brother	580	0.49	0.045	–		–	–
4	SSF with a brother	1235	0.49	0.043	3 vs. 4	0.33	0.74	0.02
5	SSF with older brother	883	0.48	0.042	3 vs. 5	0.70	0.48	0.05
6	SSF with CIA older brother	300	0.49	0.047	3 vs. 6	0.05	0.96	0.00
7		–	–	–	1 vs. 6	1.39	0.17	0.10
Females from same-sex twin pairs (DZ only)								
8	SSF	836	0.49	0.043	1 vs. 8	2.32	0.02	0.14
9	SSF without a brother	246	0.51	0.043	–		–	–
10	SSF with a brother	527	0.48	0.043	9 vs. 10	1.88	0.06	0.17
11	SSF with older brother	407	0.47	0.040	9 vs. 11	1.96	0.05	0.19
12	SSF with CIA older brother	121	0.47	0.053	9 vs. 12	1.31	0.19	0.17
13		–	–	–	1 vs. 12	1.53	0.13	0.12

Note: *MZ* monozygotic, *DZ* dizygotic, *OSF* opposite-sex female, *SSF* same-sex female, *CIA* close in age

Table 3 Means, variances, and group comparisons for Zuckerman's Sensation Seeking Scale: Disinhibition Subscale

Row number	Group	*n*	Mean	Variance	Groups compared	*t*	*p*	*d*
Females from opposite-sex twin pairs								
1	OSF	564	0.32	0.053	–		–	–
Females from same-sex twin pairs (MZ and DZ)								
2	SSF	1947	0.32	0.053	1 vs. 2	0.06	0.95	0.00
3	SSF without a brother	580	0.33	0.050	–		–	–
4	SSF with a brother	1235	0.31	0.053	3 vs. 4	1.27	0.20	0.08
5	SSF with older brother	883	0.31	0.052	3 vs. 5	1.07	0.29	0.07
6	SSF with CIA older brother	300	0.32	0.050	3 vs. 6	0.63	0.53	0.05
7		–	–	–	1 vs. 6	0.10	0.92	0.01
Females from same-sex twin pairs (DZ only)								
8	SSF	836	0.32	0.053	1 vs. 8	0.25	0.81	−0.02
9	SSF without a brother	246	0.35	0.053	–		–	–
10	SSF with a brother	527	0.31	0.052	9 vs. 10	1.89	0.06	0.17
11	SSF with older brother	407	0.31	0.052	9 vs. 11	1.52	0.13	0.15
12	SSF with CIA older brother	121	0.31	0.046	9 vs. 12	1.22	0.22	0.16
13		–	–	–	1 vs. 12	0.13	0.90	0.01

Note: *MZ* monozygotic, *DZ* dizygotic, *OSF* opposite-sex female, *SSF* same-sex female, *CIA* close in age

between MZ and DZ twins (e.g. chorionicity, sharing of blood supply) that influence the prenatal environment and potentially pre- and post-natal development.

There were similarities and differences in the results of the present study and the previous study of Resnick et al. (1993). Both studies obtained evidence for significantly higher ES scores among OS versus SS female twins. However, the effect sizes of the comparisons of OS and SS females obtained in Resnick et al. (1993) were substantially larger than those obtained in the present study: BS ($d = 0.18$ vs. $d = -0.01$), ES ($d = 0.35$ vs. $d = 0.12$), DIS ($d = 0.39$ vs. $d < 0.01$), and TAS ($d = 0.20$ vs. $d = 0.10$). The effect sizes obtained for two of the four sensation-seeking subscales in the study of Cohen-Bendahan et al. (2005a) were also substantially larger but in the opposite direction, that is, in the direction of higher scores

Table 4 Means, variances, and group comparisons for Zuckerman's Sensation Seeking Scale: Thrill and Adventure Seeking Subscale

Row number	Group	*n*	Mean	Variance	Groups compared	*t*	*p*	*d*
Females from opposite-sex twin pairs								
1	OSF	564	0.44	0.080	–	–	–	–
Females from same-sex twin pairs (MZ and DZ)								
2	SSF	1947	0.41	0.080	1 vs. 2	2.07	0.04	0.10
3	SSF without a brother	580	0.42	0.083	–		–	–
4	SSF with a brother	1235	0.41	0.079	3 vs. 4	0.45	0.66	0.03
5	SSF with older brother	883	0.41	0.080	3 vs. 5	0.56	0.58	0.04
6	SSF with CIA older brother	300	0.42	0.079	3 vs. 6	0.16	0.87	−0.01
7		–	–	–	1 vs. 6	0.80	0.42	0.06
Females from same-sex twin pairs (DZ only)								
8	SSF	836	0.42	0.083	1 vs. 8	1.56	0.12	0.09
9	SSF without a brother	246	0.44	0.087	–		–	–
10	SSF with a brother	527	0.41	0.083	9 vs. 10	1.39	0.17	0.12
11	SSF with older brother	407	0.40	0.083	9 vs. 11	1.56	0.12	0.15
12	SSF with CIA older brother	121	0.41	0.085	9 vs. 12	0.91	0.36	0.12
13		–	–	–	1 vs. 12	1.05	0.29	0.08

Note: *MZ* monozygotic, *DZ* dizygotic, *OSF* opposite-sex female, *SSF* same-sex female, *CIA* close in age

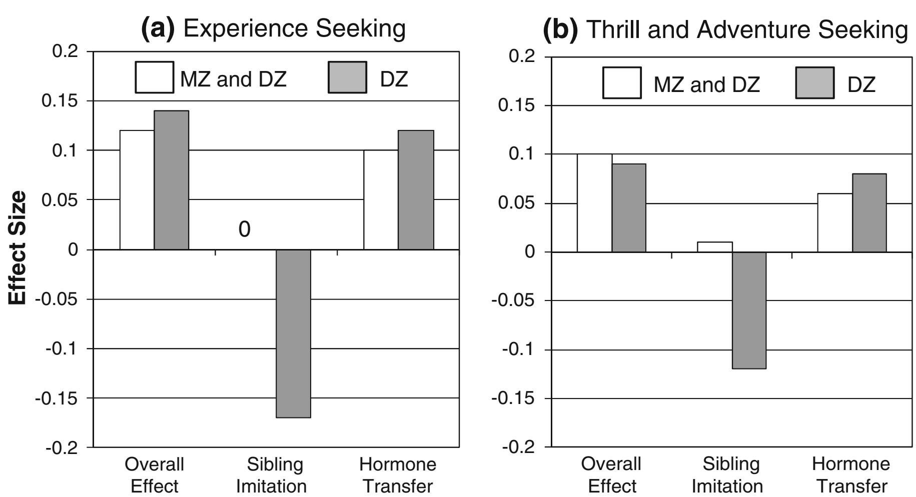

Fig. 3 Summary of results showing the effect sizes obtained for the overall effect and the tests of sibling imitation and hormone transfer for the two Zuckerman's Sensation-Seeking Scales in which there were significant overall effects: **a** the Experience Seeking Subscale, and **b** the Thrill and Adventure Seeking Subscale. Positive effect sizes represent effects that were consistent with the hypothesized relation, negative effect sizes represent effects that were in the opposite direction of the hypothesized relation (the results presented in Tables 2, 4 and in the text for the tests of the sibling imitation effects were reversed for the purpose of this figure to aid in interpretation)

among SS than OS girls: $d = -0.31$ for BS and $d = -0.37$ for ES (there was insufficient information presented in the article to calculate the effect sizes for the other two subscales).

The sex differences literature may provide insights into reasons for the differences between these three studies. Despite the fact that mean levels of sensation-seeking generally decline with age, the magnitude of the differences between men and women remain relatively stable across the adult years (Ball et al. 1984; De Moor et al. 2006; Zuckerman et al. 1978); this is consistent with a comprehensive research synthesis of the personality literature showing that sex differences are constant across age (Feingold 1994). However, a recent population-based study of 19,288 individuals ten to 60+ years of age demonstrated that sex differences for two of the four sensation-seeking subscales, BS and ES, were not evident prior to the adult years, and in some groups, the girls slightly outscored the boys (De Moor et al. 2006). The participants in the study of Cohen-Bendahan et al. (2005a) were all 13-years old, in the study of Resnick et al. (1993) the mean age of participants was 32 years (range = 16–70), and in the present study the mean age was 38 years (range = 32–43). It is possible that the effects of prenatal androgen exposure on sensation seeking may not become evident until the adult years, and this might account for the discrepant results obtained by Cohen-Bendahan et al. (2005a). This does not explain the different effect sizes obtained in the present study and Resnick et al. (1993), but given the differences in the sample sizes in the two studies (e.g. 564 vs. 51 OS twins), it is likely that the effect size estimates obtained in the present study may be more precise.

A number of experts have emphasized the importance of studying variance as well as mean level differences between the sexes (Arden and Plomin 2006; Feingold 1995; Humphreys 1988; Lehre et al. 2009). For many behavioral traits, the variability among men exceeds the variability among women, and this can occur even in the absence of mean level differences (Arden and Plomin 2006; Lehre et al. 2009). With only a few exceptions (e.g. Medland et al. 2008) nearly all previous studies of OS/SS twin differences have focussed solely on mean group differences and have not explored the possibility of group differences in variances. In the present study, in addition to significant mean sex differences for all of the sensation-seeking scales, there were also significant sex differences in variances for the BS and DIS scales. However, there were no significant differences in the variances between OS and SS females for any of the sensation-seeking scales. The finding of mean differences in the absence of variance differences leads to the unambiguous conclusion that there are (slightly) more OS than SS women in the high-scoring end of the distributions of ES and TAS scores.

Previous studies have demonstrated that individual differences in sensation-seeking are significantly correlated in brothers and sisters (e.g., Stoel et al. 2006). In this study, a different question was posed—does the presence of a male sibling (especially an older male sibling) increase the level of sensation-seeking in the sister? In the present study, the psychosocial hypothesis was tested by comparing SS female twins with and without a brother (the psychosocial impact of having a brother was defined several different ways). Regardless of how having a brother was defined, there was no evidence that females from SS twin pairs with a brother had higher levels on any of the sensation seeking scales than females from SS twin pairs without a brother. In fact, there was some evidence suggesting that females from SS DZ twin pairs with a brother actually had *lower* levels on the ES and DIS scales than SS DZ twin pairs without a brother. Thus, the possibility that differences between OS and SS twins in sensation seeking were due to the psychosocial effect of being reared with a brother was conclusively ruled out. This finding also bolsters confidence in the hormone transfer theory.

Considering the evidence obtained from comparisons of OS and SS female twins alongside the overall sex differences in sensation-seeking suggests that prenatal androgens may actually play a large role in the sex difference in the personality trait of ES ($d = 0.12$ vs. $d = 0.18$), a smaller role in TAS ($d = 0.10$ vs. $d = 0.83$), and no role in explaining sex differences in the traits of BS ($d \sim 0$ vs. $d = 0.46$) or DIS ($d \sim 0$ vs. $d = 0.69$). However, the evidence in support of the role of prenatal androgens in sex differences in ES and TAS are predicated on the premise that amniotic diffusion actually occurs in humans. A major limitation of this study is that differences in levels of prenatal testosterone were inferred from the sex of the co-twin, that is, we did not obtain actual measures of the prenatal testosterone levels of the twins. Although the intrauterine positioning effect has been widely researched in nonhuman mammals and there is definitive laboratory evidence that amniotic diffusion exists in rat pups (Even et al. 1992), similar evidence has not yet been obtained among humans. Whether amniotic diffusion occurs in humans remains an open question and matter of debate (Cohen-Bendahan et al. 2005b; Medland et al. 2008; Vuoksimaa et al. 2010).

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