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A Twin Registry Study of Male and Female Sexual Orientation

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Monozygotic (MZ), same-sex dizygotic (DZ), and opposite-sex (OS) twins from the Minnesota Twin Registry responded to a sexual orientation survey. Using the relative frequencies of heterosexuals, bisexuals, and homosexuals responding to the survey and generalizing these frequencies to the entire Registry, the prevalence of bisexuality among women was estimated as 1.58% and among men, 2.08%. For homosexuality, prevalence rates for women and men were 1.68% and 2.49%, respectively. Homosexual and heterosexual attraction, behavior, and self-identification were significantly more heritable in women than men. For men, no significant genetic effects were found for number of opposite- and same-sex sexual encounters, nor for sexual orientation. No evidence was found for different genes influencing the sexual orientation of men and women.

Biological approaches to the etiology of individual differences in human sexual orientation have received significant empirical support during the last few years. One impetus for this work has been the desire to explain the continual occurrence throughout time and place of homosexuality despite its apparent selective disadvantages (Ruse, 1988). The approaches have been diverse: Support has been obtained from neuroendocrine (LeVay, 1991), molecular genetic (Hamer, Hu, Magnuson, Hu, & Pattatucci, 1993), and behavioral genetic (Bailey & Pillard, 1991) perspectives. Arguably, behavioral genetic studies have provided the strongest evidence to date in affirming the role biology plays in influencing human sexual behavior (Bailey, 1995).

Behavioral genetic studies rely on the relative similarity of family members of differing genetic resemblance to estimate the heritability and environmentality underlying a phenotype. Most commonly, behavioral genetic studies compare the similarity of monozygotic (MZ) and dizygotic (DZ) twins. My primary purpose for this article is to report the results of a twin study of sexual orientation to evaluate the influence of heredity in both men and women.

Table 1 presents the pairwise concordances found for sexual orientation in MZ and same-sex DZ twins from seven of the largest twin studies. Although the magnitude of heritability suggested by the studies varies greatly, most suggest the presence of some genetic influence on sexual orientation. The only exception appears to be King and McDonald (1992). To date, the Bailey, Pillard, Neale, and Agyei (1993) study has been the only published, noncase study of female twin concordance for sexual orientation.

Another difference among these studies is the method used to obtain participants, a possible source for the different heritabilities implied by the studies. As the phrase suggests, no attempt is made to obtain a representative sample of gay/lesbian probands when a "word-of-mouth" approach is used. Four sexual orientation twin studies were advertised in homophile publications to request volunteers, a strategy that could lead to nonrandom participation. It is not known how well the characteristics of volunteer participants approximate the characteristics of individuals who do not volunteer for sexual orientation studies and who, further, never have the opportunity of volunteering because they do not read these publications. These readers may be more affluent, more open about their sexual orientation, or more educated. If more open, the co-twins may be more knowledgeable about their twins' sexual orientation, facilitating greater rates of participation by them than for twins

Table 1

Probandwise Concordances From Twin Studies of Sexual Orientation

Study	*MZ*[a]	%	*DZ*[a]	%	Ascertainment
Males:					
Kallmann, 1952[a,b]	37/37	100	4/26	15	Word of mouth
Heston & Shields, 1968[b]	2/4	50	1/7	14	Serial admission
Buhrich, Bailey, & Martin, 1991	8/17	47	0/3	0	Twin registry
Bailey & Pillard, 1991	29/56	52	12/54	22	Advertisement
King & McDonald, 1993	2/16	13	2/16	13	Advertisement
Whitam, Diamond, & Martin, 1993	22/34	65	4/14	29	Advertisement
Females:					
Bailey et al., 1993	34/71	48	6/37	16	Advertisement

[a]Number of pairs concordant/total number of pairs; [b]Excludes a schizophrenic MZ proband confused about sexuality.

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who are less knowledgeable concerning their co-twin's sexual orientation.

Two strategies may be used to mitigate but not completely remove bias in obtaining participants. The first strategy, used commonly in studies of psychiatric disorders, is to obtain systematically a diagnosis for each individual passing through a site such as a hospital and to recruit for the study those who are eligible. The individuals who come to the site must be representative, and those who have the disorder and those who do not cannot differ in their rates of participation. Heston and Shields (1968) obtained participants using this strategy, examining serial admissions to a psychiatric hospital for schizophrenia. They did not, of course, systematically sample for sexual orientation. A second strategy is to gather a sample of participants representative of the general population and then query them as to their sexual orientation. If no differences exist in the response rates of individuals who are positive for the phenotype compared to individuals who are not positive, then the results may be generalized to the population represented by the sample. Provided that they truly represent the population they are supposed to, twin registries can be useful here. However, both serial admissions and twin registries as methods of ascertainment suffer if twins who are more alike tend to volunteer for participation more frequently than twins who are less alike. Further, if this effect is stronger for MZs than DZs, spuriously high heritability estimates may be obtained (Kendler & Eaves, 1989; Neale, Eaves, Kendler, & Hewitt, 1989).

MZ and DZ twins from the Minnesota Twin Registry (Lykken, Bouchard, McGue, & Tellegen, 1990) were used in this study to obtain evidence for genetic influence on sexual orientation. From previous research, we hypothesized that genetic effects would be significant for individual differences in sexual orientation. Our definition of sexual orientation included not only self-identification, but same-sex sexual attraction and behavior as well. An additional purpose in this study was to obtain, for the first time, evidence for genetic effects on sexual orientation for a large sample of *both* male and female twins, examined together within the same study.

Method

Participants

The Minnesota Twin Registry (Lykken et al., 1990) consists of about 10,500 twin individuals, found in Minnesota birth records for 1936 through 1955, then located and recruited by mail between 1985 and 1990 when the twins were from 30 to 50 years old. Participants completed a Biographical Questionnaire (BQ) that included questions (e.g., "How does your eye color compare with your twin's?") from which zygosity could be diagnosed with at least 96% confidence based on comparison with blood assay results (Cohen, Dibble, Grawe, & Pollin, 1973). The BQ also determined marital status.

For the current study, never-married twins were recruited as most likely to be homosexually oriented. All 144 Registry pairs of which both twins reported they had never been married (NN pairs) were recruited, together with the first 500 of 594 NM pairs (in which one twin reported having never married), and as a control group, the 471 MM pairs (both twins married) that followed in the database an NM pair. Sexual orientation surveys were mailed to these 2,230 twin individuals, of whom 1,314, or 59%, responded. Of the 1,115 twin pairs recruited, 858 or 77% were represented by either responses from one or both twins. Participants included 57% of the men (594/1,046) and 61% of the women (720/1,184) recruited, as well as 62% of the married (887/1,442), and 54% of the never-married (427/788) twins.

The Questionnaire

A one-page, two-sided questionnaire headed Special Survey (Confidential) was mailed to each of the 2,230 individuals with a cover letter explaining the need for a better scientific understanding of sexual orientation and stressing the confidentiality with which responses would be treated. (The questionnaire is provided in the Appendix.) The questionnaire asks respondents to indicate their degree of attraction to opposite-sex and same-sex persons, their frequency of sexual contact with both opposite- and same-sex partners, their self-identified sexual orientations, each before and after 25 years of age, and the orientations of their co-twin and non-twin brothers and sisters. One hundred nine of the 427 respondents who had never married when first recruited had married during the several years since these twins filled out their BQs, giving a sample of 986 married twins and 328 who are still unmarried. Ten of the 887 twins who were previously heterosexually married reported that they are living as married with a same-sex partner.

Sex-Limitation Behavioral Genetic Model Fitting

According to the model underlying quantitative genetic theory, the variance in a phenotype may be partitioned into genetic and environmental components (Plomin, DeFries, & McClearn, 1990). When data are available from both same-sex and opposite-sex twins, it becomes possible to determine whether the heritability and environmentality of the phenotype differ between the sexes, and whether there are genetic and environmental effects specific to only one sex (Neale & Cardon, 1992).

To conduct a quantitative genetic analysis, the correlations between relatives of varying genetic relatedness are required. In this study, the relatives are monozygotic (identical) twins (MZ), same-sex dizygotic (fraternal) twins (DZ), and opposite-sex twins (OS). Three basic parameters were estimated in this study from the twin correlations. The first parameter, additive genetic effects (A), represents the additive (or summative) influence of multiple genes affecting the phenotype. Identical twins share all their genetic effects and thus have a unit correlation for additive genetic effects; fraternal twins share, on the average, 50% of their genes and are correlated .50 for additive genetic effects. Only results for models with additive genetic effects are reported in this article; models with nonadditive genetic effects were also estimated but could not be distinguished from additive models in terms of fit. Generally, additive and nonadditive genetic parameters were estimated to be the same value. This is not surprising: Unless the sample size of each twin group numbers in the hundreds, the power of behavioral genetic models to distinguish additivity from nonadditivity is low (Eaves, Eysenck, & Martin, 1989).

The second parameter, shared rearing environmental effects (*C*), refers to those environmental factors that produce similarities in siblings reared together. By definition, when reared together in the same home, both MZ and DZ twins are assigned a correlation of 1.00 for shared environmental effects. The third parameter, nonshared environmental effects (*E*), refers to those environmental effects that contribute to a lack of twin resemblance. The correlation for MZ and DZ twins because of nonshared environmental effects is therefore zero. This parameter includes variance because of unreliability of measurement.

Figure 1 presents a path diagram for the general sex-limitation model for opposite-sex DZ twins. In this model, the phenotypes of both female (DZ_f) and male (DZ_m) twins are influenced by a common set of genetic and environmental effects: E_f, A_f, and C_f for women and E_m, A_m, and C_m for men. Although the phenotypes of both men and women are hypothesized to be influenced by additive genetic, shared environmental, and nonshared environmental effects, the magnitude of their influence is allowed to differ for the sexes. For example, even though the same set of genes may influence female and male sexual orientation, the heritability (a^2) of sexual orientation may not be the same for men and women: $a^2_m \neq a^2_f$. Yet it is also reasonable to assume that at least some genetic effects on sexual orientation are not the same for men and women; some genes influencing sexual orientation affect only one sex and are not held in common between men and women. In Figure 1, additive genetic effects specific or limited to one sex are denoted by a prime (i.e., *A'*m). If these sex-specific effects are significant, then the genetic (r_A) correlation between men and women will be significantly less than 1.00. Sex-specific effects have been incorporated for men only. In this model, it is possible to solve for sex-limited effects for only one sex. The decision as to which sex should be defined as having unique effects is completely arbitrary in terms of answering the general question as to whether there is complete overlap in genetic effects for men and women.

Two basic simplifications may be made to the sex-limitation model. If the sex-specific parameter (*A'*m) is not significant, it may be deleted from the model. Further, the remaining additive genetic, shared, and nonshared environmental effects may affect men and women equally; in this model, these effects are hypothesized to be identical both in kind and magnitude for men and women.

Two approaches are taken in determining which model best fits the data. First, the models may be compared with respect to their Chi-squares and degrees of freedom: If the Chi-square for the more parsimonious model does not differ significantly from the Chi-square of the less parsimonious model, then the parameters absent from the more parsimonious model are not significant. Second, models may be compared with respect to the number of parameters that are fit to the model. When two models are very similar in fit but differ in number of parameters, the more parsimonious of the models is preferred. We used the Consistent Akaike Information Criterion (CAIC, Bozdogan, 1987) as a measure of parsimony: Models that minimize CAIC are considered preferable. Most modeling in this article was conducted with the LISREL 8 program (Jöreskog & Sörbom, 1993).

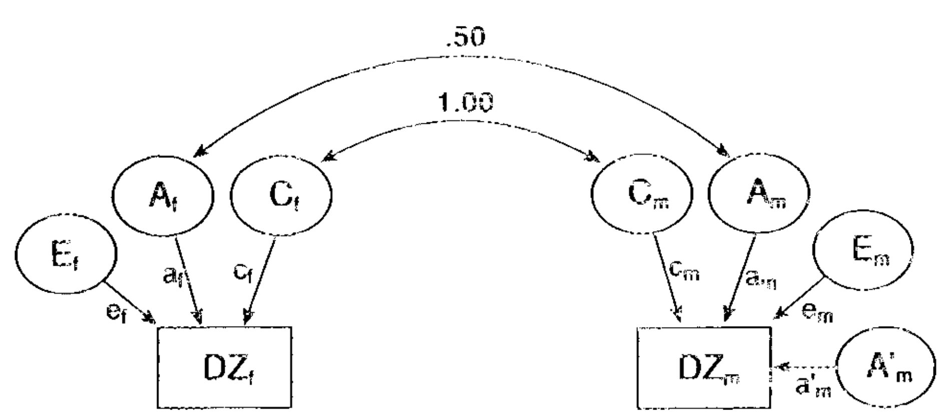
Results

The results are presented in two sections. The first section is concerned with estimating the prevalence of bisexuality and homosexuality in the twin registry. The second section describes the results of the behavioral genetic model fitting for sexual orientation, behavior, and attraction phenotypes.

Prevalence of Same-Sex Orientation

The sexual orientation and age characteristics of the twin sample

Figure 1. General Sex-Limitation Model



Note: E = nonshared environmental effects; A = additive genetic effects; C = shared rearing environmental effects; A' = sex-specific additive genetic effects; f = female; m = male are presented in Table 2. The data provide several bases for estimating the incidence of bisexual and homosexual orientation in the Minnesota Twin Registry. We have, first, the self-classification of the twin respondents. Second, we might infer orientation from the respondents' ratings of their heterosexual and homosexual attraction. Third, we have the respondents' reports of the orientation of their co-twins. Finally, we have the respondents' estimates of the sexual orientation of their non-twin siblings.

Twins' self-reported orientation. The sample was not a random sampling of the entire Registry but consisted of two groups, the twins who were unmarried when first recruited and their co-twins, plus a random sample of the twin pairs concordant for having been married when first recruited. For example, the unmarried men included 6.8% gays and 15.1% bisexuals, compared to 2.9% and 8.6%, respectively, for the unmarried women. This might suggest at first that the incidence of same-sex interest might be twice as high in men as in women generally. But these data are for just those men and women who had not yet married when they joined the Registry. Because the sexes presumably differ both in age of first marriage and their reasons for remaining single, these samples do not represent their respective sexes in the same way. Therefore, it is necessary to compute prevalence separately for MM, NM, and NN individuals and then to extrapolate to the entire Registry.

For example, the 310 women in MM pairs are selected to represent the 4,143 MM women in the Registry, the 296 women in NM pairs are selected to represent the 609 NM women in the Registry, and the 72 women in NN pairs are selected to represent the 132 NN women in the Registry. Because 2 of the 310 (0.65%) MM women now report they are lesbian, we can estimate that .0065(4,143) = 26.93 of the total group of MM women would make this report. Similarly, 11 of the 296 (3.72%) NM women report that they are lesbian, indicating that about .0372(296) = 22.65 of the NM Registry women would make this report. Further, 10 of the 72 (13.89%) NN women report they are lesbian, indicating that about .1389(132) = 18.33 of the NN Registry women would make this report. Altogether, this yields a total estimate of 67.91 (26.93 + 22.65 + 18.33) lesbians among all 4,884 female twins, yielding an estimated prevalence of 67.91/4,884 = 1.39% of all female twins who are lesbian. No significant age differences existed among the marital groups, nor between men and women.

Applying this method led to the results in Table 3, which shows the estimated prevalence of homosexuality and bisexuality among the Registry twins based in part on the twins' report of their orientation since age 25 or their orientation ever. Orientation was also defined in terms of the twins' reported degree of homosexual

Table 2

Characteristics of the Sample

Current Sexual Orientation[a]	*N*	Percentage of Total Sample	Mean (*SD*) Age
Men			
None	7	.54	39.68 (2.19)
Heterosexual	529	40.98	42.20 (5.06)
Bisexual	18	1.39	45.06 (5.95)
Gay	29	2.25	42.00 (4.41)
Total	583	45.16	42.25 (5.05)
Women			
None	27	2.09	44.00 (5.20)
Heterosexual	647	50.12	42.62 (5.48)
Bisexual	10	.77	43.80 (6.65)
Lesbian	24	1.86	42.82 (4.96)
Total	708	54.84	42.70 (5.47)
Sample total	1291	100.00	42.49 (5.29)

[a]Current sexual orientation refers to sexual orientation after 25 years of age.

Table 3

Prevalence of Homosexual and Bisexual Orientation Based on Twins' Self-Report, Co-twin's Report, and By Male and Female Twins' Report of the Orientation of Their Non-Twin Brothers and Sisters

Basis of Estimate	*N*	Prevalence Gay/Lesbian	Bisexual	Total
		Men		
Twins' orientation now	3690	1.57%	1.70%	3.27%
Twins' orientation ever	3690	1.71%	3.59%	5.30%
Twins' attraction now	3690	3.01%	.69%	3.70%
Twins' attraction ever	3690	3.06%	.92%	3.98%
Orientation or attraction now	3690	3.06%	1.71%	4.77%
Orientation or attraction ever	3690	3.24%	2.87%	6.11%
Brothers' orientation (by men)	6147	3.23%	1.37%	4.60%
Brothers' orientation (by women)	7905	1.06%	3.79%	4.85%
Unweighted *M*		2.49%	2.08%	4.57%
		Women		
Twins' orientation now	4884	1.39%	.65%	2.04%
Twins' orientation ever	4884	1.39%	1.82%	3.21%
Twins' attraction now	4884	1.56%	.67%	3.68%
Twins' attraction ever	4884	1.91%	1.14%	3.05%
Orientation or attraction now	4884	1.76%	1.38%	4.49%
Orientation or attraction ever	4884	2.11%	2.38%	4.77%
Sisters' orientation (by men)	6107	.55%	1.56%	2.11%
Sisters' orientation (by women)	7845	1.33%	3.06%	4.39%
Unweighted *M*		1.68%	1.58%	3.26%

and heterosexual attraction either before or after age 25. Those who reported their homosexual attraction as 5 ("strong") or 4 (where 3 is "moderate") were classified here as gay/lesbian if their heterosexual attraction is reported as 3 or less. If both homosexual and heterosexual attraction is 4 or 5, they were classified as bisexual. Table 3 shows that the estimated prevalence of self-reported gay/lesbian orientation in the Registry ranges from about .65% to 3.59%, with men having an overall slightly higher incidence of homosexuality and bisexuality than women.

Twins' report of co-twins' and siblings' sexual orientation. Using the same method described for twins' self-report of sexual orientation, twins' report of co-twins' sexual orientation was also used to estimate the prevalence of homosexuality and bisexuality. These prevalence rates based on the co-twins' orientation are provided in Table 3.

In addition, twins' report of siblings' sexual orientation was used to estimate sexual prevalence in the Registry. To compute prevalence of gays and bisexuals among the brothers of female twins, for example, we established first that the 317 MM women in the sample reported 509 brothers, or 1.61 brothers per respondent. For the 4,143 MM female twins in the Registry, we then estimated 1.61(4,143) = 6,670 brothers. The MM women in the sample reported that 3, or .10%, of their 509 brothers were gay, suggesting that, among all 6,670 brothers of MM female Registry twins, there should be about 0.01(6,670) = 66.03 gays among those brothers. In a similar way, the 300 female twins from NM pairs in the sample reported 495 brothers, suggesting 1,005 brothers for all 579 NM women in the Registry. Based on the report of the 300 sampled NM women, 5, or 1.70%, of their brothers are gay, giving .017(1,005) = 17.08 gays among these brothers. Finally, the 72 sampled women from NN pairs reported 125 brothers, or 1.74 per twin, suggesting 1.74(132) = 230 brothers. These women said that 2, or 2.80%, of their brothers were gay, suggesting a total of .028(230) = 6.43 gays among all brothers of NN women. Summing the brothers of the MM, NM, and NN women in the Registry, we get an estimated total of (60.3 + 17.08 + 6.43) = 83.54 gays among the 7,905 brothers, yielding finally the estimate that 83.54/7,905 = 1.06% of the non-twin brothers of all Registry female twins are gay.

Two aspects of the method used for determining the prevalence of homosexual and bisexuality using non-twin siblings require explanation. First, the number of siblings and the proportion who are gay/lesbian or bisexual are estimated separately for the MM, NM, and NN twins because the NM and NN twins reported somewhat fewer siblings per twin, but a higher proportion of those siblings are said to be gay/lesbian or bisexual. If there is a familial influence on homosexuality, one would expect such a difference. Second, many siblings have been counted twice, because about half of the twin pairs are represented by both co-twins. The degrees of freedom are only about two thirds what they would be if each twin was from a different family. However, the estimated incidence of gays/lesbians and bisexuals among the siblings is unaffected by this method unless there is reason to suppose that the twins who both participated have different sibling characteristics than the twins whose co-twins did not participate. As can be seen in Table 3, reported prevalence of gay/lesbian and bisexual orientation among non-twin siblings of Registry twins ranges from 0.55% (lesbian sisters reported by male twins) to 3.79% (bisexual brothers reported by female twins).

The different prevalence estimates in Table 3 are in reasonably good agreement, suggesting a prevalence of about 1% to 3% in this sample of middle aged adults. The prevalence does not seem to be different for twins versus non-twin siblings, and the mean prevalence for men is only slightly higher than for women.

Behavioral Genetic Model Fitting

Table 4 presents the means and standard deviations by sex of the variables that were fit to behavioral genetic models. Sex differences, both before and after 25 years of age, emerge on sexual attraction toward the opposite and same sex, with men showing a higher attraction toward persons of the opposite and same sex, and on the proportion of the sample self-identified as homosexual or bisexual, men having a greater frequency than women.

Table 4

Means and Standard Deviations of Measures By Sex

	Before 25 Years					After 25 Years				
	Men		Women			Men		Women		
Variable	*M*	*SD*	*M*	*SD*	*t*	*M*	*SD*	*M*	*SD*	*t*
Sexual attraction toward opposite sex	4.32	1.00	3.92	1.04	6.97*	4.14	1.06	3.76	1.04	6.53*
Sexual attraction toward same sex	1.40	1.02	1.27	.75	2.67	1.41	1.07	1.29	.83	2.11
Number of opposite-sex sexual encounters	4.06	1.45	3.95	1.51	1.31	4.41	1.22	4.37	1.24	.59
Number of same-sex sexual encounters	1.26	.83	1.14	.65	2.88	1.25	.92	1.20	.80	1.17
[a]Sexual orientation (heterosexual/bisexual, gay, lesbian)	.08	.27	.04	.19	2.95	.08	.27	.05	.22	2.24

[a]Heterosexual = 0; bisexual, gay, lesbian = 1. All other scales scored: 1 = none to 5 = strong/many
*$p < .005$

Table 5

Correlations Between Variables Before and After 25 Years of Age

Variable	Men *r*	Men *N*	Women *r*	Women *N*
Sexual attraction toward opposite sex	.78	580	.70	714
Sexual attraction toward same sex	.94	584	.91	718
Number of opposite-sex sexual encounters	.57	584	.56	714
Number of same-sex sexual encounters	.72	581	.71	713
[a]Sexual orientation (heterosexual/bisexual, gay, lesbian)	.88	573	.85	670

Note: In all correlations, $p < .001$.
[a]Heterosexual = 0; bisexual, gay, lesbian = 1. All other scales scored: 1 = none to 5 = strong/many

Table 6

Twin Intraclass Correlations

Variable	Before 25 Years *r*	Before 25 Years *SD*	Before 25 Years *N*	After 25 Years *r*	After 25 Years *SD*	After 25 Years *N*
Sexual attraction toward opposite sex:						
MZM	.04	.97	76	.13	1.03	76
MZF	.29**	1.04	101	.24*	1.07	101
DZM	.14	.95	61	.14	1.04	60
DZF	.01	1.06	91	.04	1.03	89
OS	–.03	1.07	116	.05	1.10	114
Sexual attraction toward same sex:						
MZM	.15	1.05	76	.23	1.12	75
MZF	.40***	.82	101	.55***	.93	101
DZM	–.12	1.13	63	–.16	1.13	62
DZF	.07	.69	93	.11	.75	92
OS	–.03	.90	118	.06	.92	118
Number of opposite-sex sexual encounters:						
MZM	.25*	1.37	76	.08	1.29	76
MZF	.27**	1.56	102	.42***	1.37	101
DZM	.28*	1.47	63	–.14	1.14	61
DZF	–.11	1.65	92	–.01	1.31	92
OS	.25	1.39	117	.05	1.18	118
Number of same-sex sexual encounters:						
MZM	.29*	.89	76	.14	1.06	75
MZF	.24*	.74	101	.50***	.92	98
DZM	.01	.85	63	–.06	.85	60
DZF	–.03	.61	92	.18	.88	91
OS	–.05	.75	117	–.05	.75	117
[a]Sexual orientation (heterosexual/bisexual, gay, lesbian)						
MZM	.22	.33	76	.16	.31	73
MZF	.22*	.21	91	.52***	.24	92
DZM	.16	.26	63	.10	.29	62
DZF	–.03	.17	81	.18	.23	84
OS	–.04	.20	110	–.05	.21	107

Note: MZM = male monozygotic twins; MZF = female monozygotic twins; DZM = male dizygotic twins; DZF = female dizygotic twins; OS = opposite-sex twins. *N* refers to number of pairs.
[a]Heterosexual = 0; bisexual, gay, lesbian = 1. All other scales scored: 1 = none to 5 = strong/many
$*p < .05$ $**p < .01$ $***p < .001$

The sexual orientation variable was scored dichotomously, heterosexual = 0 and bisexual/gay, lesbian = 1. Bisexuals have been grouped with gays and lesbians because of the relatively low endorsement frequency of these categories by respondents, and because our primary interest is the quantitative genetic analysis of any homosexual self-identification or behavior. Both men and women showed significantly less attraction toward persons of the opposite sex after age 25 than before: respectively, $t(579) = -6.04$, $p < .001$, and $t(713) = -5.36$, $p < .001$. Both men and women also increased their number of opposite-sex sexual encounters after 25 years of age: respectively, $t(583) = 6.61$, $p < .001$, and $t(712) = 8.67$, $p < .001$. The number of respondents endorsing a gay/lesbian identification did not increase significantly from before to after 25 years of age, and in general, measures of same-sex sexual behavior and attraction showed more stability than opposite-sex sexual behavior and attraction. This greater stability of same-sex sexual behavior is also supported by the higher correlations shown in Table 5 for same-sex sexual behavior before and after 25 years of age as compared to opposite-sex sexual behavior.

Twin intraclass correlations for these variables are shown in Table 6. These twin correlations have not been corrected for the effects of age because of the negligible correlation of age with the current status (after 25 years of age) for each variable for both sexes: sexual attraction toward opposite sex (men: $r = -.07$; women: $r = .05$); sexual attraction toward same sex (men: $r = .06$; women: $r = -.01$); number of opposite-sex sexual encounters (men: $r = .00$; women: $r = -.06$); number of same-sex sexual encounters (men: $r = .03$; women: $r = -.01$); and sexual orientation (men: $r = .05$; women: $r = .02$).

An important issue to consider is whether the pattern of twin correlations differs before versus after 25 years of age. Such a difference could imply different heritabilities, different environmentalities, or both. For each variable the pattern of intraclass correlations did not differ significantly from before to after 25 years of age; respectively, $\chi^2 = 1.96$, 3.63, 7.69, 7.16, and 8.97, all $df = 15$, all ns. Thus, modeling was only conducted with the data from after 25 years of age.

Model fitting results are presented in Table 7. Standardized maximum likelihood parameter estimates from the model and the model's goodness of fit to the data (as indicated by χ^2) are reported, along with CAIC and χ^2_{diff} values for comparing models. For each variable, two models are compared: the first a "full" model, incorporating all the parameters of the general sex-limitation model, and the second, a "reduced" model, a more parsimonious representation of the data that does not differ significantly in fit from the full model. Because of its greater parsimony, the reduced model CAIC should also be substantially lower than the CAIC of the full model.

Table 7

Standardized Maximum Likelihood Parameter Estimates and Goodness-of-Fit for Models of Sexual Orientation and Behavior

Variable	a^2_m	a^2_f	r_a	c^2_m	c^2_f	e^2_m	e^2_f	χ^2	*df*	χ^2_{diff}	*df*	CAIC
Sexual attraction toward opposite sex												
Full model	.03*	.21**	1.00	.11*	.00	.79**	.86**	1.44	3	—	—	51.05
Reduced model ($a^2_m = a^2_f$; $e^2_m \neq e^2_f$; $c^2_m = c^2_f = 0$)	.18**	.18**	1.00[b]	—	—	.82**	.82**	2.95	8	1.51	5	17.13
Sexual attraction toward same sex												
Full model	.03*	.49**	1.00	.00	.00	.86**	.51**	20.14**	3	—	—	69.84
Reduced model ($a^2_m = a^2_f$; $e^2_m \neq e^2_f$; $c^2_m = c^2_f = 0$)	.31**	.36**	1.00[b]	.00	—	.77**	.55**	24.49**	7	4.05	4	45.80
Number of opposite-sex sexual encounters												
Full model	.06*	.28**	1.00	.00	.00	.86**	.72**	10.48*	3	—	—	60.21
Reduced model ($a^2_m = 0$; $c^2_m \neq e^2_f$; $c^2_m = c^2_f = 0$)	—	.34**	—	—	—	1.00**	.66**	10.85	7	.37	4	32.16
Number of same-sex sexual encounters												
Full model	.00	.45**	.00	.00	.00	.92**	.55**	24.09**	3	—	—	73.72
Reduced model ($a^2_m = 0$; $e^2_m \neq e^2_f$; $c^2_m = c^2_f = 0$)	—	.45**	—	—	—	1.00*	.55**	25.15**	7	1.06	4	46.42
[a]Sexual orientation (heterosexual/bisexual, gay, lesbian)												
Full model	.00	.48**	.00	.06	.00	.86**	.52**	26.59**	3	—	—	75.83
Reduced model ($a^2_m = 0$; $e^2_m \neq e^2_f$; $c^2_m = c^2_f = 0$)	—	.48**	—	—	—	1.00**	.52**	29.14**	7	2.55	4	50.24

Note: a = additive genetic effects; c = shared environmental effects; e = nonshared environmental effects; r_a = additive genetic correlation between men and women.
[a]Heterosexual = 0; bisexual, gay, lesbian = 1. All other scales scored: 1 = none to 5 = strong/many
[b]Parameter fixed to one
*$p < .05$ **$p < .001$

Four general conclusions concerning the genetic and environment structure of the variables may be drawn from the results reported in Table 7. First, for no variable were shared environmental effects significant, either for men or women. Second, the single largest effect for both males and females was the nonshared environment, although as mentioned previously, this effect includes random measurement error. Third, for no variable were sex-specific additive genetic effects found: Either the additive genetic correlation between men and women was 1.00 (when additive genetic effects were significant for men and women) or zero (when additivity was significant for only one sex, thus forcing the correlation to be zero by definition). Fourth, for each variable, the heritability was either the same for men and women (i.e., sexual attraction toward the opposite sex) or the heritability was greater for women than men (i.e., the remaining four variables). Indeed, for each variable the heritability for women was significant, ranging from .18 to .48, whereas for men, the heritability was zero for three variables and was .18 and .31 for two others. Perhaps most significantly, the heritability of sexual orientation for men was zero, for women, .48.

The Registry data enable a more extensive analysis of the familiality of self-identified sexual orientation than provided in Table 7. The twin intraclass correlations used for the analysis of sexual orientation in Table 7 were calculated from the self-report of the twins. However, each twin reported the perceived sexual orientation of the co-twin, as well as the perceived sexual orientation of non-twin brothers and sisters. The twin was also requested to rate the certainty of this knowledge. If confidence can be placed in the accuracy of the report given by the twin concerning sibling sexual orientation, then it is possible to increase the number of twin pairs contributing to the analysis (by substituting missing twin responses with the report of the co-twin)

Table 8

Intraclass Correlations for Sexual Orientation (Heterosexual/Bisexual, Gay, Lesbian)[a] Using Extended Family Data

Relationship	*r*	*SD*	*N* Pairs
MZ male	.24*	.26	135
MZ female	.60***	.21	147
DZ male	.05	.26	119
DZ female	.17*	.18	152
DZ opposite sex	−.04	.20	177
Siblings male	.24***	.13	231
Siblings female	.43***	.14	227
Siblings opposite sex	.19***	.13	308
MZ male—Sibling male	−.07	.24	81
DZ male—Sibling male	−.01	.09	63
DZ opposite-sex male—Sibling male	−.07	.24	41
MZ female—Sibling male	.13	.24	88
DZ female—Sibling male	.38***	.17	86
DZ opposite-sex female—Sibling male	−.03	.16	59
MZ male—Sibling female	−.04	.18	74
DZ male—Sibling female	−.02	.12	66
DZ opposite-sex male—Sibling female	−.03	.18	47
MZ female—Sibling female	.26*	.19	91
DZ female—Sibling female	−.01	.08	75
DZ opposite-sex female—Sibling female	−.02	.13	55

[a]Heterosexual = 0; bisexual, gay, lesbian = 1
$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

and to add non-twin brothers and sisters to the analysis. One measure of how much confidence can be placed in the reports of twins is the degree of correspondence that exists between the self-report of a twin and the report given about the twin by the co-twin, when data exist for both the twin and co-twin. The correlation between these reports when a rating of "definite" was given was .90(701), $p < .001$. Notably, a majority of individuals (90%) rated their knowledge of the co-twin's orientation as "definite"; when the correlation was computed for the remaining 10% of the sample, it decreased to .66 (104), $p < .001$.

Given the relatively high correspondence that was found between twin and co-twin reports of sexual orientation, the twins' report of the co-twin was used when the co-twin data were missing. In addition, although the accuracy of twin reports of non-twin sibling sexual orientation cannot be independently established, we would expect the twins to show a comparable degree of accuracy in rating their non-twin siblings. Only reports rated with a "definite" confidence level were used. Table 8 presents the twin and sibling intraclass correlations for sexual orientation (again scored as heterosexual/bisexual, gay, lesbian) using the twins' report of co-twin and non-twin sibling sexual orientation. Also included in these data are information from the twins who contributed to the sexual orientation intraclass correlations shown in Table 6 (i.e., those twins where self-report was available from both). For each type of correlation, a family contributes only once. For example, a family may include three non-twin brothers, thus providing three pairs. Only one of these pairs (i.e., using the eldest siblings) was chosen for the analysis.

Model fitting was conducted using the correlations reported in Table 8. The Mx (Neale, 1994) model-fitting program was used. The results indicate that the heritability of sexual orientation for men still does not differ significantly from zero, whereas for women the heritability is now .55 (as compared to the previous value of .45). Thus, the results from the extended family data are consistent with the previous results for sexual orientation. Using the extended family data also allows for the detection of environmental effects not possible with the more restricted twin data. One possible type of effect is a special sibling environment, which siblings of one type share and those of another type do not. For example, MZs may share a special twin environment, whereas non-twin siblings may not share a special environment or may share it to a lesser degree. Accordingly, separate special environment parameters for MZ males (s_{mt}) and MZ females (s_{ft}) were incorporated into the reduced model, along with a special sibling environment parameter specific to female nonidentical twin siblings (s_{fnt}) and a special sibling environment parameter specific to male nonidentical twin siblings (s_{mnt}). In addition, because this special sibling environment may be expected to be more powerful when both siblings are of the same sex, female opposite-sex (s_{fos}) and male opposite-sex (s_{mos}) twins were given separate parameters. In the extended model, the special sibling environment parameters accounted for the following proportions of variance: $s_{mt} = .43, p < .001$; $s_{ft} = .46, p < .001$; $s_{fnt} = .01$, ns; $s_{mnt} = .00$, ns; $s_{fos} = .28, p < .001$.; and $s_{mos} = .00$, ns. Thus, the special sibling environment was significant and large for both male and female MZs and was significant for the DZ opposite-sex female twins.

Additional evidence for the familiality of sexual orientation (which can be due to both shared genes and environments) can be found by comparing the relative number of gay/lesbian versus heterosexual siblings identified by the twins. Female homosexual twins reported an average of .25 non-twin homosexual siblings versus an average of 2.17 heterosexual siblings; male homosexual twins reported an average of .14 non-twin homosexual siblings versus an average of 2.34 heterosexual siblings; female heterosexual siblings reported an average of .02 non-twin homosexual siblings versus 2.88 heterosexual siblings; and male heterosexual siblings reported an average of .04 non-twin homosexual siblings versus 2.96 heterosexual siblings. Thus, on the average, female homosexual twins reported more homosexual non-twin siblings than male homosexual twins (.25 vs. .14), and homosexual twins of both sexes reported more homosexual non-twin siblings (.39 combined) than did heterosexual twins of both sexes (.06 combined). Conversely, heterosexual twins tended to report more heterosexual non-twin siblings (5.84 combining males and females) than did homosexual twins (4.51 combining males and females). In addition, the female homosexual twins reported more non-twin homosexual brothers (.32) and sisters (.41) than the male homosexual twins (.29 and .06, respectively). These sex differences in the co-fraternity of sexual orientation were not detected for the heterosexual twins, where both female and male heterosexual twins had an average of 1.49 non-twin heterosexual siblings of both sexes.

Discussion

Monozygotic (MZ), same-sex dizygotic (DZ), and opposite-sex dizygotic (OS) twins from the Registry provided a means to assess the significance of genetic influence for sexual orientation, as well as to detect genetic effects differing for men and women. For none of the phenotypes examined was there evidence for genetic effects specific to one sex; in other words, the same set of genes was responsible for sexual orientation in the sexes. Further, significant genetic effects were found on all phenotypes for women, whereas for men, genetic effects were nonsignificant for three phenotypes (i.e., number of opposite- and same-sex sexual encounters and sexual orientation). Therefore, genetic effects were generally greater for women than men. Special sibling environment effects were found for self-identified sexual orientation for male and female MZ twins and opposite-sex female DZ twins.

The prevalence of homosexuality in the Minnesota Twin Registry was also estimated. For men, depending on the criterion used, the prevalence of homosexuality ranges from 1.06% to 3.24%, with an average of 2.49%; for women, the range is from .55% to 2.11%, with an average of 1.68%. If combined with bisexuality, the average rises to 4.57% for men and 3.26% for women. These rates of homosexuality are very similar to those found in studies using probability samples conducted in the United States and elsewhere. Further, as confirmed in this study, most studies, whether conducted inside or outside the United States, indicate a slightly higher rate of male homosexuality than female homosexuality. For example, Sell, Wells, and Wypij (1995) reported a rate of 6.2% for men and 3.3% for women for same-sex sexual contact during the last five years in the United States. Some researchers find an even narrower difference. Spira et al. (1992) provided prevalence rates of 1.4% for men and 0.4% for women in France, also for a five-year period. However, there are a number of possible limitations to the accuracy of the prevalence rates of homosexuality estimated for the Minnesota Twin Registry, thereby limiting the generalizability of these rates. First, only twins are represented in the Registry: It is not known whether the distribution of sexual orientation differs between twins and singletons. Second, the twins listed in the Registry were all born in Minnesota and not elsewhere in the United States. Third, although a substantial majority of twins born in Minnesota between 1936 and 1955 are included in the Registry, not all are included. Fourth, those twins who were never married were predicted to be most likely to be homosexually oriented and thus were singled out to receive the Special Survey. As stated previously, the sample used for this study was not a random sampling of the entire Registry. Fifth, 59% of the individuals sent the Special Survey participated, fewer than what may have been most desirable. In regard to the last point, the restricted response rate may have been due to the personal (sexual) nature of the questions.

The results of this study are also in substantial agreement with other behavioral genetic investigations of sexual orientation: Phenotypes relevant to sexual orientation are significantly influenced by genetic effects. Specifically, significant genetic effects were found for self-identified female homosexuality, but not for male homosexuality, in both the twin and extended family analyses. Although the estimates of heritability for women were very similar in both analyses, the selection of the eldest non-twin siblings for the extended family analysis may have biased the results because of the relationship between birth order and sexual orientation in men (Blanchard & Bogaert, 1996). My study went further than others in producing evidence for the unity of genetic effects of men and women. Genetic effects may have a differential impact on individual differences in men and women, but the source of the effects, the genes on the chromosomes, are the same. This contradicts, however, the recent report by Hu et al. (1995), confirming a linkage between the Xq28 chromosome and homosexuality for men but not for women. It is important to emphasize that this study provides evidence for the significance of genetic effects but provides no evidence for where these effects may be located in the genome, or even what type of genetic effects they may be. Indeed, only additive genetic effects were specified in this study, a limited assumption, given the importance of nonadditivity for many other behavioral phenotypes (Rose, 1995).

A goal in replications of this study should be the acquisition of even more twin pairs than present in this study in order to distinguish between additivity and nonadditivity. Distinguishing between additivity and nonadditivity is not a trivial question: The detection or nondetection of significant nonadditive genetic effects, given the presence of adequate power, would bear directly on whether homosexuality has been selected for some evolutionary advantage. Replication is also critical to resolving whether the same or different genes influence male and female homosexuality.

Environmental effects were also important for sexual orientation, in fact, more important in the aggregate than genetic effects for every phenotype. Of particular note was a special sibling environment parameter that was significant for male and female MZs and for opposite-sex female DZs. The existence of a special sibling environment for identical twins is not surprising; such an effect has been found, for example, for personality (Loehlin, 1992). What the nature of this special sibling environment is, of course, cannot be determined from the results of this study, but presumably these are environmental effects that arise from sharing the same environment with a like-sex co-twin. The meaning of a significant special sibling environment for only opposite-sex female twins is even less clear. In fact, the existence of a sororal (i.e., sister) effect on homosexuality in siblings, as demonstrated by the elevated rates of male and female homosexuality in the siblings of female homosexuals, would have predicted that the special sibling environment for opposite-sex female twins would *not* have been significant, because such females have male and not female co-twins. Determining conclusively the source of these special environments must await additional studies focusing on those aspects of the environment that facilitate the development of sexual orientation.

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Appendix

Special Survey (Confidential)

Sex: M F *Age:*________

1. *Marital Status (check one):*
Married ( ) Divorced ( ) Widowed ( ) Never Married ( )
Living as Married ( ) (opposite-sex partner) Living as Married ( ) (same-sex partner)

2. Please rate the strength of your sexual attraction toward good looking persons of the *opposite* sex (circle one number on each scale)

Before you reached age 25					After age 25				
1	2	3	4	5	1	2	3	4	5
none		moderate		strong	none		moderate		strong

3. Please rate the strength of your sexual attraction toward good looking persons of the *same* sex (circle one number on each scale)

Before you reached age 25					After age 25				
1	2	3	4	5	1	2	3	4	5
none		moderate		strong	none		moderate		strong

4. How many sexual encounters have you had with a person or persons of the *opposite* sex? (A married person would circle #5, "many.")

Before you reached age 25					After age 25				
1	2	3	4	5	1	2	3	4	5
none		3-5		strong	none		3-5		strong

5. How many sexual encounters have you had with a person or persons of the *same* sex?

Before you reached age 25					After age 25				
1	2	3	4	5	1	2	3	4	5
none		3-5		strong	none		3-5		strong

6. How would you describe your *own* sexual orientation? (circle one)
Before you reached age 25: gay/lesbian bisexual heterosexual no sex interest
After age 25: gay/lesbian bisexual heterosexual no sex interest

7. How would you describe your *twin's* sexual orientation? (circle one)
Twin's orientation: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful

8. Not counting your twin, how many brothers do you have? ________
Please circle the sexual orientation—and how certain you are—for each of these brothers, starting with the eldest:
#1: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful
#2: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful
#3: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful
#4: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful

9. Not counting your twin, how many sisters do you have? ________
Please circle the sexual orientation—and how certain you are—for each of these sisters, starting with the eldest:
#1: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful
#2: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful
#3: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful
#4: gay/lesbian bisexual heterosexual no sex interest
How certain are you? Definite Probable Doubtful