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Geographic proximity is associated with transmission of suicidal behavior among siblings

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Abstract

Objective: The aim of this study was to clarify the role of “contagion”, or social transmission, in risk of suicidal behavior (SB) among siblings.

Methods: We followed Swedish sibling pairs until one of them (S1; N=111,848) was registered for a suicide attempt or completion. We tested the effect of geographical proximity between siblings on risk of a first SB registration of S1’s sibling (S2). To control for familial confounding, we conducted complementary analyses of sibling trios (N=701), comparing risk in different siblings as a function of their respective proximity to S1.

Results: The best fitting model across sibling pairs included an effect of distance between siblings (HR=0.96, 95% CI=0.93–0.99). Hazard ratios declined quickly up to 25km and largely stabilized beyond 150km. Across all pairs, a larger age difference between siblings was associated with reduced SB risk (HR=0.96 95% CI=0.93–0.98). Findings were consistent within the sibling trios.

Conclusions: Consistent with the concept of suicide contagion, risk of suicidal behavior subsequent to a sibling’s suicide completion or attempt is higher as a function of sibling closeness. These findings are robust to potentially confounding familial factors.

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Introduction

Suicidal behavior (SB) has been observed to cluster in social, spatial, or spatial-temporal networks (1–4), a phenomenon that may be attributable to “contagion,” (2, 5), sometimes termed social transmission or suicide suggestion (6). The underlying premise is that exposure to suicidal behavior, for example through personal networks, or media coverage (7), results in increased rates of suicide attempts or completions in a temporally and/or geographically limited manner. Clarification of the mechanism(s) that contribute to clustering has the potential to inform the response to suicide, for example by determining whether individuals in the social network of a suicide attempter or decedent are indeed at increased risk for SB themselves due to their exposure to the index incident of suicidal behavior.

Two key complicating factors in the study of clustering of suicidal behavior are: i) homophily, in which individuals with similar behavioral features seek one another out and belong to the same social network, and ii) assortative susceptibility, wherein individuals are aggregated in a common geographic area whose features confer risk (though they may be unknown to one another). Homophily could contribute to the appearance of clustering even when the underlying risk factors on which members of the social network assort (e.g., impulsive propensities, depressive symptoms) are the true risk factors for suicidal behavior. For example, within a putative SB cluster of high school students, individuals exhibiting SB subsequent to index cases were more likely to have had a history of SB or depression relative to exposed peers who did not exhibit SB after the index cases (5). It is also possible that individuals exhibiting risk-conferring features are more susceptible to SB exposure, i.e., that both intrinsic and extrinsic factors interact.

In the case of assortative susceptibility, clusters may seem to exist where the features of the area are the true risk factors (e.g., neighborhood deprivation, low educational opportunities, high levels of crime, etc.). These models are not mutually exclusive and may act in concert, but they would be independent of a true contagion effect. Determining whether exposure to suicidal behavior is the true risk factor in apparent clusters is critical for prevention and risk assessment: intervention and the provision of social support in the wake of a local suicide may not represent the best use of resources if SB exposure *per se* is not the true underlying problem.

Some evidence suggests that younger individuals may be more susceptible to contagion (1, 3, 8, 9), with some suggesting that contagion is actually *limited to* younger individuals (5, 10). Suicide is a leading cause of death among adolescents, and suicide attempts are far more common among US adolescents and younger adults than among older adults (11). The apparent increased vulnerability to contagion in young people may reflect a higher prevalence of other risk factors (e.g., impulsive behaviors, low self-esteem, compromised executive function, immature social support networks) (12, 13), or an interaction between

these factors and SB exposure. Many prior studies are limited to examining the incidence of SB subsequent to one or a few publicized SB cases, an approach that precludes generalization to SB overall. More empirical evidence is needed to clarify the extent to which adolescents and young adults may warrant additional prevention efforts after SB exposure.

SB also strongly aggregates within families, likely as a result of genetic and shared environmental risk factors (14–17). We are unaware of prior efforts to examine, using precise measures of geographical proximity, whether the transmission of SB within relatives—that is, exposure to SB within one’s familial network—contributes to this aggregation. However, we recently examined a similar etiologic research question in the context of drug abuse (DA), which is also familial (18–20) and for which clustering has been observed (21, 22). We examined DA among parent-offspring, sibling, and cousin pairs in Sweden, and found stronger transmission in those living together versus those residing in the same town, which in turn was stronger than those living only in same large metropolitan area (23).

The central research question of the current study is whether exposure to SB, here defined as a suicide attempt or completion, within a personal network increases an individual’s SB risk; that is, can SB be socially transmitted? Because we employ Swedish national registries rather than self-reported data to address this important topic, we restrict our analyses to siblings to ensure the existence of an interpersonal relationship between index cases and exposed individuals. To capture the impact of proximity on SB risk, we extend and modify our earlier efforts in the realm of DA, empirically testing the role of geographical proximity between sibling pairs as a risk factor for SB. While our earlier report on DA was restricted to residences within the same metropolitan area, the current analyses examine sibling pairs throughout the country, utilizing information in Sweden on the geographical location of all individuals’ residence known to within 250 meters. There is prior evidence that, among adult siblings, physical proximity is associated with frequency of contact (24–28) and emotional closeness (24, 25, 27–32). Thus, proximity of residence should act as an informative proxy for sibling interpersonal closeness, an integral component of our research question.

Aims of the study.

We utilize Swedish national registry data to empirically investigate the role of contagion on risk of suicidal behavior in siblings, using proximity of residence between siblings as a proxy for exposure. We further test whether any observed association between geographic proximity and risk is robust to controlling for familial factors, through the use of families with more than two siblings. Evidence for contagion could inform future efforts at risk assessment and prevention.

Method

Sample.

This study utilized several Swedish population-based registers with national coverage, the availability and content of which have been described previously (33). Records are linked using unique personal identification numbers, which are replaced by serial numbers to

maintain confidentiality. The study was approved by the Regional Ethical Review Board of Lund University. From the Swedish Multigenerational register, we included all possible full-sibling pairs, where both individuals within the pair were born between 1932 and 1990, and differed in age by a maximum of 10 years. Records were available for individuals aged 15 years and older. For all individuals, we included yearly information from 1987 to 2012 on location of residence at a resolution of 250 meters. This enabled us to examine the distance between places of sibling residence at the time of S1's registration.

Outcome.

Suicidal behavior included both suicide attempts and completions, as determined from national medical registers and the Swedish mortality register. The following ICD codes were used to identify cases from the mortality and medical registers: ICD-9—E950-E959; ICD-10—X60-X84. Events of undetermined intent are coded differently across Swedish municipalities; we therefore excluded these events to avoid potentially confounding the effect of distance.

Statistical analyses.

We selected sibling pairs where at least one in the pair (sibling 1 or S1) was registered for SB for the first time during the observation period (1987–2012), at which point follow-up began for sibling 2 (S2) until registration for the SB, death, emigration or end of follow-up (3 years after S1's registration or the end of 2012). We used Cox proportional hazards models, where the primary predictor of interest was distance (kilometers) between siblings at the time of S1's registration. We tested several models allowing the relationship between distance and the outcome variable to differ (e.g., the natural log of distance, different splines) (Table 2). Here, a spline indicates the point (distance) at which the linear effect of the predictor (S1's SB) shifts.

The models controlled for age at S1's registration, S1-S2 age differences, gender composition, and the density of SB within S2's Small Areas for Market Statistics (SAMS) residence (hereafter, *SB density*). Defined by Statistics Sweden to represent geographically distinct communities, there are approximately 9,200 SAMS throughout Sweden, with an average population of 1,000. SAMS are designed to be relatively homogenous with respect to type of housing and are therefore also relatively homogenous with respect to household income and educational attainment. SB density reflected, within the SAMS where S2 resided at S1's registration, the proportion of SB registrations in individuals with ± 5 years age difference to S2 within a 3-year interval around that registration; it is included as a proxy for assortative susceptibility. For the analysis of larger sibships (those with at least three siblings), the Cox proportional hazards model included a separate stratum for each sibship that allowed each sibship to have a separate baseline hazard function. The best fitting models were selected by Akaike's Information Criterion (AIC) (34), which balances model fit and parsimony.

We conducted *post hoc* analyses to determine whether results of our primary analyses were driven by subsets of the sample. To assess the possibility that contagion was a more prominent risk factor among young people, we compared findings across those who were

<25 at S1's SB registration to those who were ≥25. We also tested whether the impact of distance differed as a function of the nature of S1's SB (attempt versus completion); whether findings differed if restricted to sibling pairs wherein S2 resided in the same area at the beginning and end of the observation period; and whether findings were robust to the inclusion of a metric of neighborhood deprivation, which reflects area educational attainment, income, employment, and social welfare receipt (35).

We tested the proportionality assumption by including an interaction term between log of time and proximity. If this interaction term is significant, it would indicate that the effect of distance differed across time. Statistical analyses were performed in SAS 9.4 software (36).

Results

We identified 111,848 sibling pairs 15 years of age and older in whom S1 was registered for SB during the observation period (Table 1 and Supplemental Table 1). Within three years of the SB of S1, N=1112 (1.0%) of S2s were registered for SB (N=998 attempts; N=114 completions). The mean distance between the siblings in the concordant (SB observed in both) and discordant (SB only in S1) pairs were 72.8 and 88.6 kilometers, respectively. The frequency of SB in the SAMS in which S2 resided was higher for siblings concordant for suicidal behavior (0.8%) than for discordant siblings (0.5%).

Controlling for SAMS density of SB for S2, age difference between S1 and S2, and age at registration in S1, the best fit model for all sibling pairs combined included a spline with a knot at 25km (AIC = 25609.821, see Supplemental Table 2). However, for both sets of same-sex sibling pairs, the model including the log of distance (rather than a spline) provided the best fit (male-male AIC = 4545.392; female-female AIC = 7596.741, see Supplemental Table 2); we have privileged the latter model and report the corresponding hazard ratios in Table 2. The estimated HR per ln of kilometers for SB in S2 ($\pm 95\%$ CIs) was 0.96 (0.93–0.99) (Figure). The risk for concordance falls rapidly for those living up to ~25 kilometers from S1, and then declines more slowly, changing little for those residing >150 kilometers away. The effect of proximity was stronger for male-male pairs (HR=0.90, 0.84–0.97) than for female-female pairs (0.95, 0.90–0.99), though this difference was not significant ($p=0.28$). For opposite-sex pairs, the addition of distance variables did not improve model fit above the other predictors (Supplemental Table 2; parameter estimates from best-fitting model reported in Table 2).

Risk for SB in S2 conditional on SB in S1 was greater under the following circumstances: i) younger age at SB for S1; ii) smaller age difference between the two siblings; and iii) greater prevalence of SB in the SAMS area of S2's residence. As seen in the Figure, S2's risk for SB began to asymptote at around 150 kilometers from S1 with a total reduction in risk of ~20%. We found no significant interaction in the prediction of SB risk in S2 between the HR of distance and time since S1's SB ($p=0.84$), indicating no violation of the model's proportionality assumption.

Next, within the context of the best-fitting model for the full sample, we tested whether younger individuals—those who were <25 years of age at S1's SB registration—were more

susceptible to the effects of distance from S1 relative to older individuals (those ≥ 25 at S1's SB registration). While SB in S2 was more common among younger individuals (1.4% versus 0.8%), the effect of the log of distance did not differ (HR [95% CI] = 0.97 [0.93, 1.02] among younger individuals versus HR [95% CI] = 0.96 [0.92, 0.99] among older individuals; p -value=0.52).

We considered the possibility that the effect of distance would differ as a function of the nature of S1's SB (attempt versus completion). We therefore added a dummy variable for S1's attempt/completion and tested the interaction between this variable and the log of distance. The resulting HR was not significant (HR=0.99, 95% confidence intervals=0.91, 1.08). Although the estimate is imprecise, it suggests that collapsing S1's attempts and completions is an appropriate approach. Complete results are presented in Supplemental Table 3.

It is possible that individuals who move more frequently are at higher SB risk, which could be reflected in the effect of distance and/or SAMS SB on S2's SB. When restricting our analysis to only pairs in which S2 resided in the same area after 3 years or at the time of their own SB registration (N=70,710), the effect of distance was reduced among women (HR=0.99, 95% CI=0.93, 1.05) but unchanged for men (HR=0.90, 95% CI=0.83, 0.98); the effect of SAMS SB was also effectively unchanged (HR=1.12, 95% CI=1.07, 1.17 for men; HR=1.06, 95% CI=1.02, 1.10 for women).

Finally, we identified 701 sibling trios informative for SB and therefore suitable for examining proximity effects while largely controlling for familial background. Given the small sample, we report only results for all siblings combined (i.e., sibships consisting of same-sex and opposite-sex siblings), which was the best-fit model in the same-sex sibling pairs. In these trios, the HR for geographic distance was modestly more pronounced than in the pair-based analyses (HR=0.92, 95% CI 0.88, 0.97). A wider age difference between siblings was associated with lower SB risk (HR=0.97, 95% CI 0.94, 1.00; effect is per one-year difference); however, the impact of SB density in the secondary sibling's SAMS was more pronounced (HR=1.50, 95% CI 1.30, 1.72) than in the sibling pair analyses.

Discussion

Contagion, or social transmission, of suicidal behavior may contribute to observed time and space clusters of SB (3, 37, 38), such that exposure to SB within one's personal network, online social network, or via media coverage, increases subsequent risk. However, many prior studies have been unable to account for potential confounding factors that could also underlie clusters, including self-selection into a social network (e.g., correlated propensities toward depressive symptoms) and/or aggregation in a risk-conferring geographical area (e.g., one of bleak employment opportunities). We leveraged nationwide data on the residences of Swedish full sibling pairs and larger sibships to examine the relationship between sibling closeness—using geographic proximity as a proxy—and subsequent risk of SB among those whose sibling had attempted or completed suicide. Our methodological approach controlled for local density of SB, and, in the sibships, for shared genetic and familial environmental factors that could increase SB liability. We found that risk of SB in

the secondary sibling(s) decreased with increasing geographic distance from the index sibling. These results are consistent with the hypothesis that exposure to SB acts as an independent risk factor within a social network, and suggest that interpersonal closeness is an important predictor above and beyond risk conferred by one's general environment.

Our findings are premised upon the notion that geographic proximity is a meaningful proxy for personal closeness, for which there is support from previous studies (24–32). Those residing closer to one another may more readily provide social support, making a sibling's SB potentially more devastating. Because we restricted our analyses to siblings, our results speak specifically to the role of personal exposure to SB. These findings do not preclude the possibility that unrelated individuals may be at increased SB risk in the wake of SB exposure within their network. Furthermore, although S2's SB risk plateaus when residing approximately 150 km or beyond from S1, risk of SB is still likely to be elevated relative to individuals not exposed to sibling SB. Additional counseling or other resources may be warranted to help reduce SB risk among those personally close to the proband.

Different aspects of these results provide insight to the various ways that closeness is related to the salience of SB exposure among siblings. First, no effect of distance was observed for opposite-sex pairs (Table 2), who may be less emotionally close than same-sex siblings, though findings are somewhat inconsistent (24, 25, 39, 40). Second, larger age differences between siblings were associated with lower SB risk; again, this may be a function of lower interpersonal closeness among siblings who are farther apart in age (41, 42). Consistent with prior reports that sibling closeness differs across genders in terms of expression but not strength/quality (43, 44), we did not observe significant differences in the effect of distance across brothers versus sisters. Our findings warrant follow-up, though elucidation of the underlying mechanisms may require interpersonal data not readily available in national registries. It is also important to consider alternative hypotheses to emotional closeness, such as identification with the suicidal proband; additional research is necessary to determine how other processes might be captured by geographic proximity, the predictor of interest in the current analyses.

Given prior reports that younger individuals are more susceptible to contagion (1, 3, 8, 9), we tested whether the effect of distance from S1 on S2's SB differed for those younger than 25 versus those 25 and older. Despite the expected higher prevalence of SB among individuals under 25, we did not observe a differential effect of distance from S1 across groups. This finding does not refute contagion among younger people *per se*. It merely excludes geographic proximity as a key feature of the observed discrepancy. Additional efforts are necessary to clarify the role of contagion across the life course.

The density of SB in S2's SAMS (i.e., immediate neighborhood) was a prominent risk factor across analyses, even increasing in strength when genetic and familial environmental factors were accounted for in the sibship analyses. In conjunction with our other findings, we suggest that this component of risk could be attributed to assortative susceptibility rather than causality. That is, while individuals unknown but geographically close to SB cases are at higher SB risk, this relationship is likely due to confounding factors rather than to environmental exposure to SB *per se*. We also note that a *post hoc* analysis controlling for

neighborhood deprivation resulted in broadened confidence intervals around the HR estimates of distance for same-sex pairs (Supplemental Table 4). Although results were not substantively changed, a broader conceptualization of neighborhood risk may be warranted in future studies. Importantly, the current study design cannot completely disentangle whether the association between SAMS SB density and S2's SB is due to the area itself conferring risk versus "drift" by individuals into particular SAMS. For example, those at higher risk of SB may also be underemployed, and may therefore gravitate to SAMS with a lower cost of living. Further dissection of the role of SAMS SB density is beyond the scope of the current analyses, but is warranted to gain traction on the underlying mechanism(s).

These analyses parallel a similar effort to dissect the role of social contagion in drug abuse (45), which found that, among siblings of an individual registered for drug abuse, their own subsequent risk is increased as a function of closeness of residency. That study found that the risk of drug abuse associated with proximity abated over time, while we observed no such effect for SB. This indicates that the negative impact of sibling SB may be uniquely persistent, at least within a time frame of several years. This may be due to the psychological toll experienced by surviving family members of an SB case: One psychological autopsy study noted that reactions to the suicide of a family member were "severe and enduring" (46), and a review described self-blame and guilt as common among surviving family members (47). The severity and ramifications of the index event—in particular for suicide completion but also in the case of an attempt—may contribute to the persistence of SB risk in S2 beyond that observed for a sibling's drug abuse. Comparison of these outcomes is also limited by the capacity for siblings to explicitly provide one another with substances; a direct parallel does not exist for SB.

The current findings should be considered in light of a number of limitations. First, although there is empirical support for our use of geographic proximity as a proxy for interpersonal closeness between siblings, this measure is likely imprecise, as some siblings may reside close to one another and interact very little, and vice versa. The models do not include other potential SB precipitants that may more strongly impact siblings living closer to one another (e.g., death of a parent who also lived nearby). Notably, however, findings did not substantively change when siblings residing in the same household were excluded (Supplemental Table 5).

Our observation period was 1987–2012, and electronic means of communication became widespread in the second half of the 2000's, facilitating frequent communication even among family members who did not live close to one another. We were not able to explore the potential impact of online social media, which may enable strong sibling relationships even between those who are geographically distant. However, these shifting cultural practices, if they impacted our results, would likely have reduced the impact of distance on SB risk, such that the current results may actually represent an underestimation of risk.

Our use of medical registries limits the identification of suicide attempts to those that required medical attention. In addition, while suicide completions are more readily identified, we were unable to include deaths of undetermined intent due to inconsistencies in their coding across Swedish municipalities, which complicated efforts to combine that data

with measures of geographic proximity. These analyses were based on Swedish-born full sibling pairs. Although these data might not generalize to other countries, the rate of suicide is quite similar among Sweden, other western European countries, and the United States (48). Finally, while the sibship analyses enable us to account for some proportion of familial risk, the sample size is smaller than for sibling pairs and results should be considered with caution.

In summary, we present evidence consistent with the concept of suicidal behavior contagion among siblings. Specifically, risk of SB in the second sibling is a function of sibling closeness—here, using geographic proximity as a proxy. Critically, our sibship analyses, which control for potentially confounding familial influences, yielded the same results. The effect of distance did not diminish across the follow-up period. These findings suggest that, in the wake of a suicide or attempt, siblings with whom the proband was/is close are at increased risk of their own SB, potentially warranting clinical outreach and additional preventative efforts. Our analyses were restricted to siblings to ensure personal contact; future research should extend these efforts to unrelated individuals to determine whether the same phenomenon is observed among broader social networks.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Significant outcomes

- Individuals who resided closer to a sibling who had attempted or completed suicide were at higher risk for later suicidal behavior.
- In sibships, which account for confounding genetic and familial environmental factors, the sibling who resided closer to the proband was at higher risk for later suicidal behavior.
- The effect of geographic proximity to a sibling's suicidal behavior did not differ between individuals under 25 versus those 25 or older.

Limitations

- The geographic proximity measure used as a predictor is unlikely to capture important facets of sibling interpersonal closeness.
- Suicide attempts that did not result in a medical registration could not be included in the measure of suicidal behavior.

Figure.
Hazard Ratio ($\pm$ 95% confidence intervals) for a first registration of suicidal behavior (SB) in a second sibling within three years of a first registration for suicidal behavior in the index sibling (S1) as a function of the distance (in kilometers) they were residing apart at the time of S1's SB registration. For details and covariates, see Table 2.

Table 1.

Descriptive statistics of sample, grouped by sex of sibling 1 (S1) and sibling 2 (S2), respectively, of the sibling pairs.

	All	Male to Male	Female to Female	Female to Male	Male to Female
N pairs	111,848	29,721	31,323	24,954	25,850
% in S2 (within 3 years)	1.0%	0.9%	1.3%	0.8%	1.0%
N in S2	1,112	226	374	261	251
Concordant - Sibling 2 affected					
Distance (KM) ^I 25 th 50 th 75 th	1–7–53	1–5–37	1–7–39	1–11–58	1–10–80
Distance (KM) Mean	72.8	60.0	69.8	81.6	79.6
Same Household	20.3%	20.7%	23.5%	18.8%	16.7%
Mean (SD) Age at S1's Registration	29.4 (9.6)	31.6 (8.8)	27.3 (9.4)	30.2 (10.0)	29.8 (9.9)
Mean (SD) Age Difference	3.9 (2.3)	4.0 (2.5)	3.8 (2.3)	4.1 (2.3)	3.8 (2.3)
Mean (SD) SAMS Density S1	1.1 (1.5)	1.1 (1.9)	1.0 (1.0)	1.1 (1.3)	1.1 (1.6)
Mean (SD) SAMS Density S2	0.8 (1.0)	0.8 (1.0)	0.8 (0.8)	0.7 (1.0)	0.8 (1.1)
Same Area at Time of S2's SB	75%	74%	75%	75%	75%
Discordant - Sibling 2 not affected					
Distance (KM) ^I 25 th 50 th 75 th	2–14–85	2–12–73	2–15–92	2–14–84	3–16–92
Distance (KM) Mean	88.6	82.6	92.1	88.2	91.4
Same Household	12.5%	12.7%	12.7%	14.8%	9.2%
Mean (SD) Age at S1's Registration	32.6 (10.0)	33.6 (9.5)	31.8 (10.4)	31.4 (10.3)	33.8 (9.5)
Mean (SD) Age Difference	4.3 (2.4)	4.3 (2.5)	4.2 (2.4)	4.2 (2.4)	4.3 (2.4)
Mean (SD) SAMS Density S1	0.9 (2.0)	0.9 (2.0)	0.9 (1.6)	0.9 (1.7)	1.0 (2.6)
Mean (SD) SAMS Density S2	0.5 (0.9)	0.5 (0.9)	0.5 (0.9)	0.5 (0.9)	0.5 (0.8)
Same Area after 3 years	63%	64%	62%	61%	66%

^I Distance between S1 and S2, in kilometers, reported at the 25th, 50th, and 75th percentile.

KM = kilometers; SAMS = Small Areas for Market Statistics; S1 = sibling 1; S2 = sibling 2

Table 2.

Hazard ratios (95% confidence intervals) from Cox proportional hazards models for concordance of suicidal behavior in full sibling pairs from the Swedish population, where sibling 1 (S1) is registered for suicidal behavior.

	All	Male to Male	Female to Female	Female to Male	Male to Female
Log of Distance	0.96 (0.93; 0.99)	0.90 (0.84; 0.97)	0.95 (0.90; 0.99)	n/a ^I	n/a ^I
Age at S1's Registration	0.98 (0.97; 0.98)	0.99 (0.98; 1.00)	0.96 (0.95; 0.97)	0.99 (0.98; 1.00)	0.96 (0.95; 0.98)
Sibling Age Difference	0.96 (0.93; 0.98)	0.96 (0.90; 1.02)	0.96 (0.91; 1.00)	0.99 (0.94; 1.04)	0.92 (0.87; 0.98)
SAMS Density	1.09 (1.06; 1.11)	1.11 (1.07; 1.16)	1.07 (1.03; 1.10)	1.12 (1.06; 1.19)	1.09 (1.05; 1.13)

^I For opposite sex pairs, no effect of distance was observed (see Supplemental Table), so this parameter is not included in the models specific to opposite sex pairs.

SAMS = Small Areas for Market Statistics; S1 = sibling 1; S2 = sibling 2