Alone in the Crowd: The Structure and Spread of Loneliness in a Large Social Network

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The discrepancy between an individual's loneliness and the number of connections in a social network is well documented, yet little is known about the placement of loneliness within, or the spread of loneliness through, social networks. The authors use network linkage data from the population-based Framingham Heart Study to trace the topography of loneliness in people's social networks and the path through which loneliness spreads through these networks. Results indicated that loneliness occurs in clusters, extends up to 3 degrees of separation, is disproportionately represented at the periphery of social networks, and spreads through a contagious process. The spread of loneliness was found to be stronger than the spread of perceived social connections, stronger for friends than family members, and stronger for women than for men. The results advance understanding of the broad social forces that drive loneliness and suggest that efforts to reduce loneliness in society may benefit by aggressively targeting the people in the periphery to help repair their social networks and to create a protective barrier against loneliness that can keep the whole network from unraveling.

Keywords: loneliness, social network, social isolation, contagion, longitudinal study

> Human social isolation is recognized as a problem of vast importance. (Harlow, Dodsworth, & Harlow, 1965, p. 90)

Social species do not fare well when forced to live solitary lives. Social isolation decreases the lifespan of the fruit fly, *Drosophilia melanogaster* (Ruan & Wu, 2008); promotes the development of obesity and Type 2 diabetes in mice (Nonogaki, Nozue, & Oka, 2007); delays the positive effects of running on adult neurogenesis in rats (Stranahan, Khalil, & Gould, 2006); increases the activation of the sympatho-adrenomedullary response to an acute immobilization or cold stressor in rats (Dronjak, Gavrilovic, Filipovic, & Radojcic, 2004); decreases the expression of genes regulating glucocorticoid response in the frontal cortex of piglets (Poletto, Steibel, Siegford, & Zanella, 2006); decreases open field activity, increases basal cortisol concentrations, and decreases lymphocyte proliferation to mitogens in pigs (Kanitz, Tuchscherer, Puppe, Tuchscherer, & Stabenow, 2004); increases the 24-hr urinary catecholamines levels and evidence of oxidative stress in the aortic arch of the Watanabe heritable hyperlipidemic rabbit (Nation et al., 2008); increases the morning rises in cortisol in squirrel monkeys (Lyons, Ha, & Levine, 1995); and profoundly disrupts psychosexual development in rhesus monkeys (Harlow et al., 1965).

Humans, born to the longest period of abject dependency of any species and dependent on conspecifics across the lifespan to survive and prosper, do not fare well, either, whether they are living solitary lives or whether they simply perceive that they live in isolation. The average person spends about 80% of waking hours in the company of others, and the time with others is preferred to the time spent alone (Emler, 1994; Kahneman, Krueger, Schkade, Schwarz, & Stone, 2004). Social isolation, in contrast, is associated not only with lower subjective well-being (Berscheid, 1985; Burt, 1986; Myers & Diener, 1995) but also with broad-based morbidity and mortality (House, Landis, & Umberson, 1988).

Humans are an irrepressibly meaning-making species, and a large literature has developed showing that *perceived* social isolation (i.e., loneliness) in normal samples is a more important predictor of a variety of adverse health outcomes than is objective social isolation (e.g., (Cole et al., 2007; Hawkley, Masi, Berry, & Cacioppo, 2006; Penninx et al., 1997; Seeman, 2000; Sugisawa, Liang, & Liu, 1994). In an illustrative study, Caspi, Harrington, Moffitt, Milne, & Poulton (2006) found that loneliness in adolescence and young adulthood predicted how many cardiovascular

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risk factors (e.g., body mass index, waist circumference, blood pressure, cholesterol) were elevated in young adulthood and that the number of developmental occasions (i.e., childhood, adolescence, young adulthood) at which participants were lonely predicted the number of elevated risk factors in young adulthood. Loneliness has also been associated with the progression of Alzheimer's disease (Wilson et al., 2007), obesity (Lauder, Mummery, Jones, & Caperchione, 2006), increased vascular resistance (Cacioppo, Hawkley, Crawford, et al., 2002), elevated blood pressure (Cacioppo, Hawkley, Crawford, et al., 2002; Hawkley et al., 2006), increased hypothalamic pituitary adrenocortical activity (Adam, Hawkley, Kudielka, & Cacioppo, 2006; Steptoe, Owen, Kunz-Ebrecht, & Brydon, 2004), less salubrious sleep (Cacioppo, Hawkley, Berntson, et al., 2002; Pressman et al., 2005), diminished immunity (Kiecolt-Glaser et al., 1984; Pressman et al., 2005), reduction in independent living (Russell, Cutrona, de la Mora, & Wallace, 1997; Tilvis, Pitkala, Jolkkonen, & Strandberg, 2000), alcoholism (Akerlind & Hornquist, 1992), depressive symptomatology (Cacioppo et al., 2006; Heikkinen & Kauppinen, 2004), suicidal ideation and behavior (Rudatsikira, Muula, Siziya, & Twa-Twa, 2007), and mortality in older adults (Penninx et al., 1997; Seeman, 2000). Loneliness has even been associated with gene expression: specifically, the under-expression of genes bearing anti-inflammatory glucocorticoid response elements and over-expression of genes bearing response elements for proinflammatory NF-κB/Rel transcription factors (Cole et al., 2007).

Adoption and twin studies indicate that loneliness has a sizable heritable component in children (Bartels, Cacioppo, Hudziak, & Boomsma, 2008; McGuire & Clifford, 2000) and in adults (Boomsma, Cacioppo, Muthen, Asparouhov, & Clark, 2007; Boomsma, Cacioppo, Slagboom, & Posthuma, 2006; Boomsma, Willemsen, Dolan, Hawkley, & Cacioppo, 2005). Social factors have a substantial impact on loneliness, as well, however. For instance, freshmen who leave family and friends behind often feel increased social isolation when they arrive at college, even though they are surrounded by large numbers of other young adults (e.g., Cutrona, 1982; Russell, Peplau, & Cutrona, 1980). Lower levels of loneliness are associated with marriage (Hawkley, Browne, & Cacioppo, 2005; Pinquart & Sorenson, 2003), higher education (Savikko, Routasalo, Tilvis, Strandberg, & Pitkala, 2005), and higher income (Andersson, 1998; Savikko et al., 2005), whereas higher levels of loneliness are associated with living alone (Routasalo, Savikko, Tilvis, Strandberg, & Pitkala, 2006), infrequent contact with friends and family (Bondevik & Skogstad, 1998; Hawkley et al., 2005; Mullins & Dugan, 1990), dissatisfaction with living circumstances (Hector-Taylor & Adams, 1996), physical health symptoms, chronic work and/or social stress (Hawkley et al., 2008), small social network (Hawkley et al., 2005; Mullins & Dugan, 1990), lack of a spousal confidant (Hawkley et al., 2008), marital or family conflict (Jones, 1992; Segrin, 1999), poor quality social relationships (Hawkley et al., 2008; Mullins & Dugan, 1990; Routasalo et al., 2006), and divorce and widowhood (Dugan & Kivett, 1994; Dykstra & de Jong Gierveld, 1999; Holmen, Ericsson, Andersson, & Winblad, 1992; Samuelsson, Andersson, & Hagberg, 1998).

The discrepancy between an individual's subjective report of loneliness and the reported or observed number of connections in their social network is well documented (e.g., see Berscheid & Reis, 1998), but few details are known about the placement of loneliness within or the spread of loneliness through a social network. The association between the loneliness of individuals connected to each other, and their clustering within the network, could be attributed to at least three social psychological processes.

First, the *induction* hypothesis posits that the loneliness in one person contributes to or causes the loneliness in others. The emotional, cognitive, and behavioral consequences of loneliness may contribute to the induction of loneliness. For instance, emotional contagion refers to the tendency for the facial expressions, vocalizations, postures, and movements of interacting individuals to lead to a convergence of their emotions (Hatfield, Cacioppo, & Rapson, 1994). When people feel lonely, they tend to be shyer, more anxious, more hostile, more socially awkward, and lower in self-esteem (e.g., Berscheid & Reis, 1998; Cacioppo et al., 2006). Emotional contagion could therefore contribute to the spread of loneliness to those with whom they interact. Cognitively, loneliness can affect and be affected by what one perceives and desires in their social relationships (Peplau & Perlman, 1982; Rook, 1984; Wheeler, Reis, & Nezlek, 1983). To the extent that interactions with others in an individual's social network influence a person's ideal or perceived interpersonal relationship, that person's loneliness should be influenced. Behaviorally, when people feel lonely, they tend to act toward others in a less trusting and more hostile fashion (e.g., Rotenberg, 1994; cf. Berscheid & Reis, 1998; Cacioppo & Patrick, 2008). These behaviors, in turn, may lower the satisfaction of others with the relationship or lead to a weakening or loss of the relationship and a consequent induction of loneliness in others.

Second, the *homophily* hypothesis posits that lonely or nonlonely individuals choose one another as friends and become connected (i.e., the tendency of like to attract like; McPherson, Smith-Lovin, & Cook, 2001). Byrne's (1971) law of attraction specifies that there is a direct linear relationship between interpersonal attraction and the proportion of similar attitudes. The association between similarity and attraction is not limited to attitudes, and the characteristics on which similarity operates move from obvious characteristics (e.g., physical attractiveness) to less obvious ones (social perceptions) as relationships develop and deepen (e.g., Neimeyer & Mitchell, 1988). Although feelings of loneliness can be transient, stable individual differences in loneliness may have sufficiently broad effects on social cognition, emotion, and behavior to produce similarity-based social sorting.

Finally, the *shared environment* hypothesis posits that connected individuals jointly experience contemporaneous exposures that contribute to loneliness. Loneliness, for instance, tends to be elevated in matriculating students, because for many, their arrival at college is associated with a rupture of normal ties with their family and friends (Cutrona, 1982). People who interact within a social network may also be more likely to be exposed to the same social challenges and upheavals (e.g., coresidence in a dangerous neighborhood, job loss, retirement).

To distinguish among these hypotheses requires repeated measures of loneliness, longitudinal information about network ties, and information about the nature or direction of the ties (e.g., who nominated whom as a friend; Carrington, Scott, & Wasserman, 2005; Fowler & Christakis, 2008b). With the recent application of innovative research methods to network linkage data from the population-based Framingham Heart Study (FHS), these data are now available and have been used to trace the distinctive paths through which obesity (Christakis & Fowler, 2007), smoking

(Christakis & Fowler, 2008), and happiness (Fowler & Christakis, 2008a) spread through people's social networks. We sought here to use these methods and data to determine the role of social network processes in loneliness, with an emphasis on determining the topography of loneliness in people's social networks, the interdependence of subjective experiences of loneliness and the observed position in social networks, the path through which loneliness spreads through these networks, and factors that modulate its spread.

Method

Assembling the FHS Social Network Dataset

The FHS is a population-based, longitudinal, observational cohort study that was initiated in 1948 to prospectively investigate risk factors for cardiovascular disease. Since then, it has come to be composed of four separate but related cohort populations: (1) the "Original Cohort," enrolled in 1948 (n = 5,209); (2) the "Offspring Cohort" (the children of the Original Cohort and spouses of the children), enrolled in 1971 (n = 5,124); (3) the "Omni Cohort," enrolled in 1994 (n = 508); and (4) the "Generation 3 Cohort" (the grandchildren of the Original Cohort), enrolled beginning in 2002 (n = 4,095). The Original Cohort actually captured the majority of the adult residents of Framingham in 1948, and there was little refusal to participate. The Offspring Cohort included offspring of the Original Cohort and their spouses in 1971. The supplementary, multiethnic Omni Cohort was initiated to reflect the increased diversity in Framingham since the inception of the Original Cohort. For the Generation 3 Cohort, Offspring Cohort participants were asked to identify all their children and the children's spouses, and 4,095 participants were enrolled beginning in 2002. Published reports provide details about sample composition and study design for all these cohorts (Cupples & D'Agnostino, 1988; Kannel, Feinleib, McNamara, Garrison, & Castelli, 1979; Quan et al., 1997).

Continuous surveillance and serial examinations of these cohorts provide longitudinal data. All of the participants are personally examined by FHS physicians and nurses (or, for the small minority for whom this is not possible, evaluated by telephone) and watched continuously for outcomes. The Offspring study has collected information on health events and risk factors roughly every 4 years. The Original Cohort has data available for roughly every 2 years. It is important to note that even participants who migrate out of the town of Framingham (to points throughout the United States) remain in the study and, remarkably, come back every few years to be examined and to complete survey forms; that is, there is no necessary loss to follow-up because of out-migration in this dataset, and very little loss to follow-up for any reason (e.g., only 10 cases out of 5,124 in the Offspring Cohort have been lost).

For the purposes of the analyses reported here, exam waves for the Original Cohort were aligned with those of the Offspring Cohort, so that all participants in the social network were treated as having been examined at just seven waves (in the same time windows as the Offspring, as noted in Table 1).

The Offspring Cohort is the key cohort of interest here, and it is our source of the *focal participants* (FPs) in our network. However, individuals to whom these FPs are linked—in any of the four cohorts—are also included in the network. These linked individuals are termed *linked participants* (LPs). That is, whereas FPs come only from the Offspring Cohort, LPs are drawn from the entire set of FHS cohorts (including also the Offspring Cohort itself). Hence, the total number of individuals in the FHS social network is 12,067, because LPs identified in the Original, Generation 3, and Omni Cohorts are also included, as long as they were alive in 1971 or later. Spouses who list a different address of residence than the FP are termed noncoresident spouses. There were 311 FPs with noncoresident spouses in Exam 6 and 299 in Exam 7.

Table 1
Survey Waves and Sample Sizes of the Framingham Offspring Cohort (Network Focal Participants)

Survey wave/ physical exam	Time period	No. alive	No. alive and 18+	No. examined	% of adults participating
Exam 1	1971–1975	5,124	4,914	5,124	100.0
Exam 2	1979–1982	5,053	5,037	3,863	76.7
Exam 3	1984–1987	4,974	4,973	3,873	77.9
Exam 4	1987–1990	4,903	4,903	4,019	82.0
Exam 5	1991–1995	4,793	4,793	3,799	79.3
Exam 6	1996–1998	4,630	4,630	3,532	76.3
Exam 7	1998–2001	4,486	4,486	3,539	78.9

The physical, laboratory, and survey examinations of the FHS participants provide a wide array of data. At each evaluation, participants complete a battery of questionnaires (e.g., the Center for Epidemiological Studies Depression Scale [CES–D; Radloff, 1977] measure of depression and loneliness, as described below), a physician-administered medical history (including review of symptoms and hospitalizations), a physical examination administered by physicians on site at the FHS facility, and a large variety of lab tests.

To ascertain the network ties, we computerized information from archived, handwritten documents that had not previously been used for research purposes, namely, the administrative tracking sheets used by the FHS since 1971 by personnel responsible for calling participants to arrange their periodic examinations. These sheets record the answers when all 5,124 of the FPs were asked to comprehensively identify relatives, friends, neighbors (based on address), coworkers (based on place of employment), and relatives who might be in a position to know where the FPs would be in 2 to 4 years. The key fact here that makes these administrative records so valuable for social network research is that, given the compact nature of the Framingham population in the period from 1971 to 2007, many of the nominated contacts were themselves also participants of one or another FHS cohort.

We have used these tracking sheets to develop network links for FHS Offspring participants to other participants in any of the four FHS cohorts. Thus, for example, it is possible to know which participants have a relationship (e.g., spouse, sibling, friend, coworker, neighbor) with other participants. Of note, each link between two people might be identified by *either party* identifying the other; this observation is most relevant to the "friend" link, as we can make this link either when A nominates B as a friend, or when B nominates A (and, as discussed below, this directionality is methodologically important and might also be substantively interesting). People in any of the FHS cohorts may marry or befriend or live next to each other. Finally, given the high quality of addresses in the FHS data, the compact nature of Framingham, the wealth of information available about each participant's residential history, and new mapping technologies, we determined who is whose neighbor, and we computed distances between individuals (Fitzpatrick & Modlin, 1986).

The measure of loneliness was derived from the CES–D administered between 1983 and 2001 at times corresponding to the fifth, sixth, and seventh examinations of the Offspring Cohort. The median year of examination for these individuals was 1986 for Exam 5, 1996 for Exam 6, and 2000 for Exam 7. Participants are asked how often during the previous week they experienced a particular feeling, with four possible answers: 0–1 days, 1–2 days, 3–4 days, and 5–7 days. To convert these categories to days, we recoded these responses at the center of each range (0.5, 1.5, 3.5, and 6). Factor analyses of the items from the CES–D and the University of California, Los Angeles loneliness scales indicate that they represent two separate factors, and the "I felt lonely" item from the CES–D scale loads on a separate factor from the depression items (Cacioppo et al., 2006). The face-valid nature of the item also supported the use of the "How often I felt lonely" item to gauge loneliness.

Table 2 shows summary statistics for loneliness, network variables, and control variables we use to study the statistical relationship between feeling lonely and being alone.

Statistical Information and Sensitivity Analyses

To distinguish among the induction, homophily, and shared environment hypotheses requires repeated measures of loneliness, longitudinal information about network ties, and information about the nature or direction of the ties (e.g., who nominated whom as a friend; Carrington et al., 2005; Fowler & Christakis, 2008b). For the analyses in Table 3, we averaged across waves to determine the mean number of social contacts for people in each of the four loneliness categories. For the analyses in Tables 4 and 5, we considered the prospective effect of LPs, social network variables, and other control variables on FP's future loneliness. For the analyses in Tables 6–12, we conducted regressions of FP loneliness as a function of FP's age, gender, education, and loneliness in the prior exam and of the gender and loneliness of an LP in the current and prior exam. The lagged observations for Wave 7 are from Wave 6 and the lagged observations for Wave 6 are from Wave 5. Inclusion of FP loneliness at the prior exam eliminates serial correlation in the errors and also substantially controls for FP's genetic endowment and any intrinsic, stable tendency to be lonely. LP's loneliness at the prior exam helps control for homophily (Carrington et al., 2005), which has been verified in Monte Carlo simulations (Fowler & Christakis, 2008b).

Table 2
Summary Statistics for the Framingham Offspring Cohort (Network Focal Participants)

Variable	*M*	*SD*	Min	Max
Current no. of days per week feeling lonely	0.853	0.964	0.5	6
Prior wave no. of days per week feeling lonely	0.940	1.086	0.5	6
Current no. of family members	2.819	3.071	0	23
Prior wave no. of family members	3.035	3.255	0	26
Current no. of close friends	0.897	0.894	0	6
Prior wave no. of close friends	0.951	0.911	0	6
Female	0.549	0.498	0	1
Years of education	13.573	2.409	2	17
Age (years)	63.787	11.848	29.667	101.278

Note. Min = minimum; Max = maximum.

The key coefficient in these models that measures the effect of induction is on the variable for LP contemporaneous loneliness. We used generalized estimating equation (GEE) procedures to account for multiple observations of the same FP across waves and across FP–LP pairings (Liang & Zeger, 1986). We assumed an independent working correlation structure for the clusters (Schildcrout & Heagerty, 2005). These analyses underlie the results presented in Figure 4.

The GEE regression models in the tables provide parameter estimates that are approximately interpretable as effect sizes, indicating the number of extra days of loneliness per week the FP experiences given a one-unit increase in the independent variable. Mean effect sizes and 95% confidence intervals (CIs) were calculated by simulating the first difference in LP contemporaneous loneliness (changing from 0.5 days feeling lonely to 1.5 days) using 1,000 randomly drawn sets of estimates from the coefficient covariance matrix and assuming all other variables are held at their means (King, Tomz, & Wittenberg, 2000). We also checked all results using an ordered logit specification, and none of these models changed the significance of any reported result; we therefore decided to present the simpler and more easily interpretable linear specifications.

The regression coefficients have mostly the expected effects, such that, for example, FP's prior loneliness is the strongest predictor for current loneliness. The models in the tables include exam fixed effects, which, combined with age at baseline, account for the aging of the population. The sample size is shown for each model, reflecting the total number of all such ties, with multiple observations for each tie if it was observed in more than one exam, and allowing for the possibility that a given person can have multiple ties. As previously indicated, repeated observations were handled with GEE procedures.

We evaluated the possibility of omitted variables or contemporaneous events explaining the associations by examining how the type or direction of the social relationship between FP and LP affects the association between FP and LP. If unobserved factors drive the association between FP and LP friendship, then directionality of friendship should not be relevant. Loneliness in the FP and the LP move up and down together in response to the unobserved factors. In contrast, if an FP names an LP as a friend but the LP does not reciprocate, then a causal relationship indicates that the LP significantly affects the FP, but the FP does not necessarily affect the LP.[1] The Kamada-Kawai algorithm used to prepare the

[1] We explored the sensitivity of our results to model specification by conducting numerous other analyses, each of which had various strengths and limitations, but none of which yielded substantially different results than those presented here. For example, we experimented with different error specifications. Although we identified only a single close friend for most of the FPs, we studied how multiple observations on some FPs affected the standard errors of our models. Huber-White sandwich estimates with clustering on the FPs yielded very similar results. We also tested for the presence of serial correlation in the GEE models using a Lagrange multiplier test and found none remaining after including the lagged dependent variable (Beck, 2001).

images in Figure 1 generates a matrix of shortest network path distances from each node to all other nodes in the network and repositions nodes so as to reduce the sum of the difference between the plotted distances and the network distances (Kamada & Kawai, 1989). The fundamental pattern of ties in a social network (known as the "topology") is fixed, but how this pattern is visually rendered depends on the analyst's objectives.

Results

In Figure 1, we show a portion of the social network, which demonstrates a clustering of moderately lonely (green nodes) and very lonely (blue nodes) people, especially at the periphery of the network. In the statistical models, the relationships between loneliness and number of social contacts proved to be negative and monotonic, as illustrated in Figure 1 and documented in Table 3.

To determine whether the clustering of lonely people shown in Figure 1 could be explained by chance, we implemented the following permutation test: We compared the observed network with 1,000 randomly generated networks in which we preserved the network topology and the overall prevalence of loneliness but in which we randomly shuffled the assignment of the loneliness value to each node (Szabo & Barabasi, 2007). For this test, we dichotomized loneliness to be zero if the respondent said they were lonely 0–1 days the previous week, and one otherwise. If clustering in the social network is occurring, then the probability that an LP is lonely, given that an FP is lonely, should be higher in the observed network than in the random networks. This procedure also allows us to generate confidence intervals and measure how far, in terms of social distance, the correlation in loneliness be-

Table 3
Mean Total Number of Social Contacts for People in Each of the Four Loneliness Categories

Variable	*M* no. of social contacts (friends and family combined)	*SE*
Felt lonely 0–1 days last week	4.03	0.05
Felt lonely 1–2 days last week	3.88	0.11
Felt lonely 3–4 days last week	3.76	0.21
Felt lonely 5–7 days last week	3.42	0.28

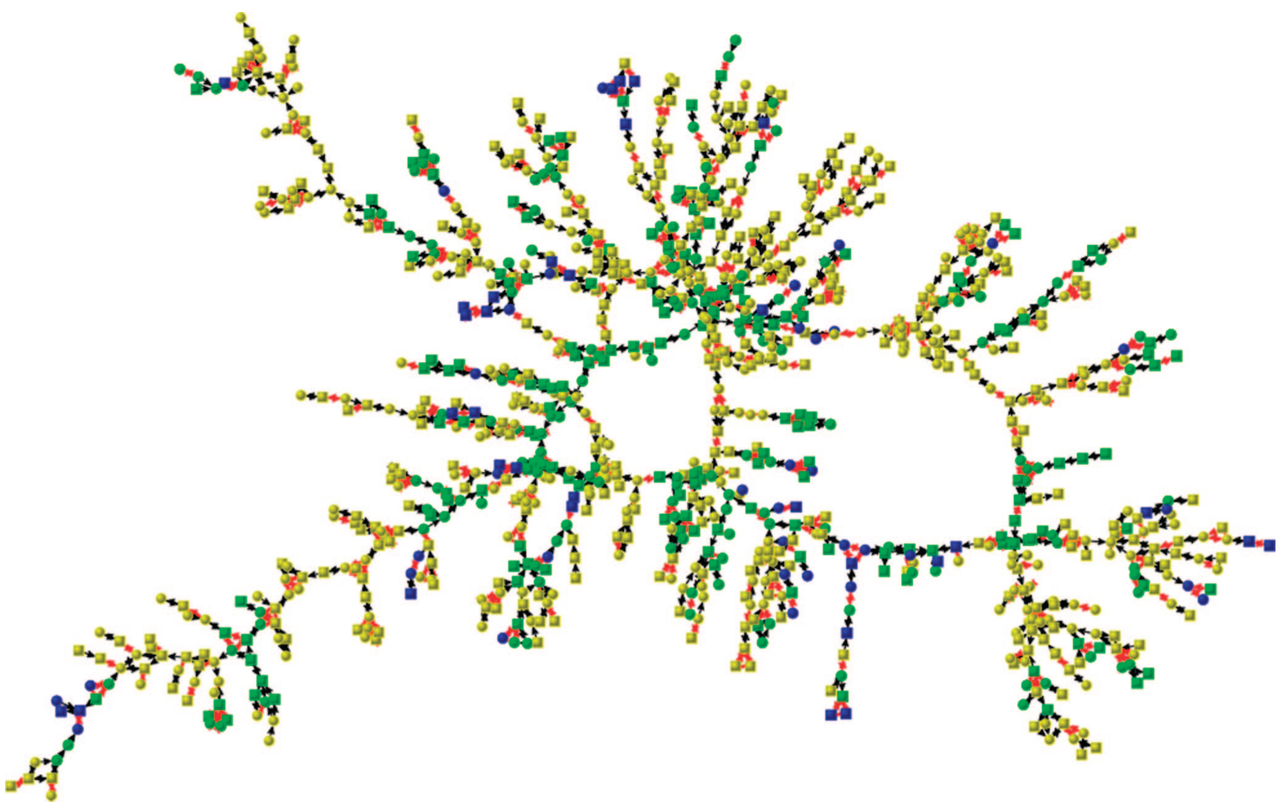

Figure 1. Loneliness clusters in the Framingham Social Network. This graph shows the largest component of friends, spouses, and siblings at Exam 7 (centered on the year 2000). There are 1,019 individuals shown. Each node represents a participant, and its shape denotes gender (circles are female, squares are male). Lines between nodes indicate relationship (red for siblings, black for friends and spouses). Node color denotes the mean number of days the focal participant and all directly connected (Distance 1) linked participants felt lonely in the past week, with yellow being 0–1 days, green being 2 days, and blue being greater than 3 days or more. The graph suggests clustering in loneliness and a relationship between being peripheral and feeling lonely, both of which are confirmed by statistical models discussed in the main text.

tween FP and LP reaches. As described below and illustrated in Figure 2, we found a significant relationship between FP and LP loneliness, and this relationship extends up to three degrees of separation. In other words, a person's loneliness depends not just on his friend's loneliness but also extends to his friend's friend and his friend's friend's friend. The full network shows that participants are 52% (95% CI = 40% to 65%) more likely to be lonely if a person to whom they are directly connected (at one degree of separation) is lonely. The size of the effect for people at two degrees of separation (e.g., the friend of a friend) is 25% (95% CI = 14% to 36%), and for people at three degrees of separation (e.g., the friend of a friend of a friend), it is 15% (95% CI = 6% to 26%). At four degrees of separation, the effect disappears (2%; 95% CI = −5% to 10%), in keeping with the "three degrees of influence" rule of social network contagion that has been exhibited for obesity, smoking, and happiness (e.g., Christakis & Fowler, 2007, 2008; Fowler & Christakis, 2008a).

The first model in Table 4, depicted in the first three columns, shows that (a) loneliness in the prior wave predicts loneliness in the current wave, and (b) current feelings of loneliness are much more closely tied to our networks of optional social connections, measured at the prior wave, than to those that are handed to us upon birth or to demographic features of the individuals. People with more friends are less likely to experience loneliness in the future, and each extra friend appears to reduce the frequency of feeling lonely by 0.04 days per week. That may not seem like much, but there are 52 weeks in a year, so this is equivalent to about 2 extra days of loneliness per year; because, on average (in our data) people feel lonely 48 days per year, having a couple of extra friends decreases loneliness by about 10% for the average person. The same model shows that the number of family members has no effect at all.

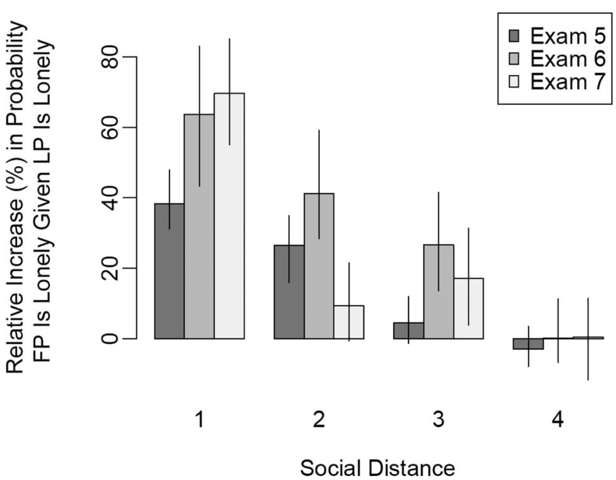

Figure 2. Social distance and loneliness in the Framingham Social Network. This figure shows for each exam the percentage increase in the likelihood a given focal participant (FP) is lonely if a friend or family member at a certain social distance is lonely (where lonely is defined as feeling lonely more than once a week). The relationship is strongest between individuals who are directly connected, but it remains significantly greater than zero at social distances up to three degrees of separation, meaning that a person's loneliness is associated with the loneliness of people up to three degrees removed from them in the network. Values are derived by comparing the conditional probability of being lonely in the observed network with an identical network (with topology and incidence of loneliness preserved) in which the same number of lonely participants are randomly distributed. Linked participant (LP) social distance refers to closest social distance between the LP and FP (LP = Distance 1, LP's LP = Distance 2, etc.). Error bars show 95% confidence intervals.

Analyses also showed that loneliness shapes social networks. Model 2 in Table 4, depicted in the middle three columns, shows that people who feel lonely at an assessment are less likely to have friends by the next assessment. In fact, compared with people who are never lonely, they lose about 8% of their friends on average by the time they take their next exam in roughly 4 years. For comparison, and not surprisingly, the results depicted in the third model in Table 4 (last three columns) show that loneliness has no effect on the future number of family members a person has. These results are symmetric to both incoming and outgoing ties (not shown; available on request). Lonely people tend to receive fewer friendship nominations, but they also tend to name fewer people as friends. What this means is that loneliness is both a cause and a consequence of becoming disconnected. These results suggest that our emotions and networks reinforce each other and create a rich-gets-richer cycle that benefits those with the most friends. People with few friends are more likely to become lonelier over time, which then makes it less likely that they will attract or try to form new social ties.

We also find that social connections and the loneliness of the people to whom these connections are directed interact to affect how people feel. Figure 3 shows the smoothed bivariate relationship between the fraction of a person's friends and family who are lonely at one exam and the number of days per week that person feels lonely at the following exam. The relationship is significant and adds an extra quarter day of loneliness per week to the average person who is surrounded by other lonely people, compared with those who are not connected to anyone who is lonely. In Table 5, we present a statistical model of the effect of lonely and nonlonely LPs on future FP loneliness that includes controls for age, education, and gender. This model shows that each additional lonely LP significantly increases the number of days a FP feels lonely at the next exam ($p < .001$). Conversely, each additional nonlonely LP significantly *reduces* the number of days a participant feels lonely at the next exam ($p = .002$). But these effects are asymmetric: Lonely LPs are about two and a half times more influential than nonlonely LPs, and the difference in these effect sizes is itself significant ($p = .01$). Thus, the feeling of loneliness seems to spread more easily than a feeling of belonging.

To study person-to-person effects, we examined the direct ties and individual-level determinants of FP loneliness. In the GEE models we present in Tables 6–12, we control for several factors, as noted earlier, and the effect of social influence from one person on another is captured by the "Days/Week LP Currently Lonely" coefficient in the first row. We have highlighted in bold the social influence coefficients that are significant. Figure 4 summarizes the results from these models for friends, spouses, siblings, and neighbors. Each extra day of loneliness in a "nearby" friend (who lives within 1 mile) increases the number of days FP is lonely by 0.29 days (95% CI = 0.07 to 0.50; see the first model in Table 6). In contrast, more distant friends (who live more than 1 mile away) have no significant effect on FP, and the effect size appears to decline with distance (see the second model in Table 6). Among

Table 4
Prospective Influence of Friends and Family on Loneliness and Vice Versa

	Current wave								
	Days/week feel lonely			No. of friends			No. of family		
Variable	Coef	*SE*	*p*	Coef	*SE*	*p*	Coef	*SE*	*p*
Prior wave days/week feel lonely	**0.257**	**0.021**	**.000**	**−0.010**	**0.004**	**.010**	−0.007	0.006	.227
Prior wave no. of friends	**−0.040**	**0.013**	**.002**	0.900	0.007	.000	−0.029	0.007	.000
Prior wave no. of family	−0.001	0.004	.797	−0.003	0.002	.046	0.933	0.003	.000
Age	0.006	0.001	.000	−0.002	0.000	.000	0.002	0.001	.003
Years of education	−0.014	0.006	.019	0.003	0.002	.145	−0.005	0.003	.033
Female	0.124	0.024	.000	−0.016	0.009	.067	0.014	0.012	.240
Exam 7	0.043	0.022	.057	0.007	0.009	.419	0.041	0.012	.001
Constant	0.112	0.196	.569	0.092	0.075	.223	−0.275	0.089	.002
Deviance	5,065			720			1,288		
Null deviance	5,656			4,866			57,349		
N	6,083			6,083			6,083		

Note. Coef = coefficient. Results for linear regression of focal participant's loneliness, number of friends, and number of family members at current exam on prior loneliness, number of friends, and number of family, plus other covariates. Models were estimated using a general estimating equation with clustering on the focal participant and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002). The main results (coefficients in bold) show that number of friends is associated with a decrease in future loneliness, and loneliness is associated with a decrease in future friends.

friends, we can distinguish additional possibilities. Because each person was asked to name a friend, and not all of these nominations were reciprocated, we have FP-perceived friends (denoted "friends"), "LP-perceived friends" (LP named FP as a friend, but not vice versa) and "mutual friends" (FP and LP nominated each other). Nearby mutual friends have a stronger effect than nearby FP-perceived friends; each day they are lonely adds 0.41 days of loneliness for the FP (95% CI = 0.14 to 0.67; see the third model

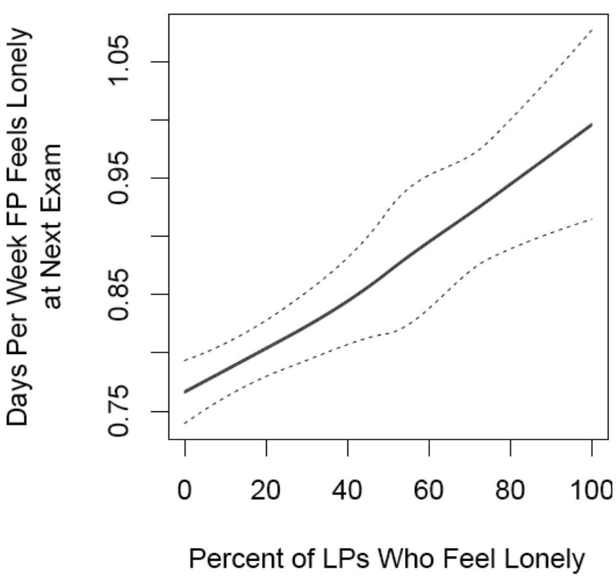

Figure 3. Lonely linked participants (LPs) in the Framingham Social Network. This plot shows that the number of days per week a person feels lonely in Exams 6 and 7 is positively associated with the fraction of their friends and family in the previous exam who are lonely (those who say they are lonely more than one day a week). The solid line shows smoothed relationship based on bivariate LOESS regression, and dotted lines indicate 95% confidence intervals. The results show that people surrounded by other lonely people are themselves more likely to feel lonely in the future.

Table 5
Influence of Number of Lonely Linked Participants on Focal Participant Loneliness

	Current wave days/week feel lonely		
Variable	Coef	*SE*	*p*
Prior wave number of lonely LPs	**0.064**	**0.017**	**.000**
Prior wave number of nonlonely LPs	**−0.024**	**0.008**	**.002**
Prior wave days/week feel lonely	0.230	0.022	.000
Age	0.003	0.002	.030
Years of education	−0.003	0.006	.641
Female	0.121	0.025	.000
Exam 7	0.053	0.024	.027
Constant	0.037	0.206	.858
Deviance	3,487		
Null deviance	3,831		
N	4,879		

Note. Coef = coefficient; LP = linked participant. Results for linear regression of focal participant's loneliness, on prior loneliness, number of lonely friends and family (>1 day of loneliness per week), number of nonlonely friends and family (0–1 days of loneliness per week), and other covariates. Models were estimated using a general estimating equation with clustering on the focal participant and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002). The main results (coefficients in bold) show that number of lonely LPs is associated with an increase in future loneliness and the number of nonlonely LPs is associated with a decrease in future loneliness. Moreover, the lonely LP effect is significantly stronger than the nonlonely LP effect (p = .01, calculated by drawing 1000 pairs of coefficients from the coefficient covariance matrix produced by the model).

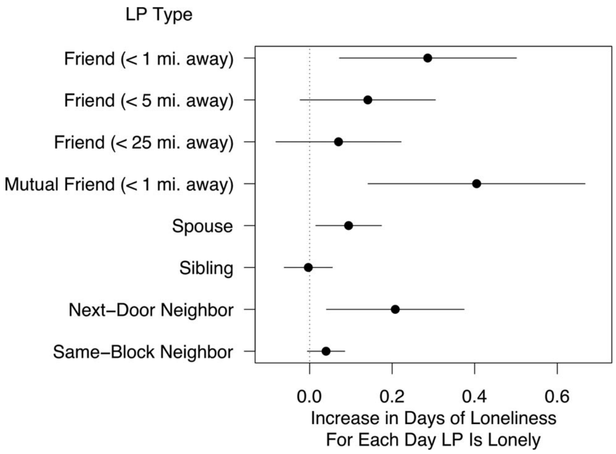

Figure 4. Linked participant (LP) type and loneliness in the Framingham Social Network. This figure shows that friends, spouses, and neighbors significantly influence loneliness, but only if they live very close to the focal participant. Effects are estimated using generalized estimating equation linear models on several different subsamples of the Framingham Social Network (see Tables 6 and 7).

in the third column of Table 6). In contrast, the influence of nearby LP-perceived friends is not significant (p = .25; see the fourth model in the fourth column of Table 6). If the associations in the social network were merely due to confounding, the significance and effect sizes for different types of friendships should be similar. That is, if some third factor were explaining both FP and LP loneliness, it should not respect the directionality or strength of the tie.

We also find significant effects for other kinds of LPs. Each day a coresident spouse is lonely yields 0.10 extra days of loneliness for the FP (95% CI = 0.02 to 0.17; see the fifth model in Table 6), whereas noncoresident spouses have no significant effect (see the sixth model). Next-door neighbors who experience an extra day of loneliness increase FP's loneliness by 0.21 days (95% CI = 0.04 to 0.38; see the third model in the third column of Table 7), but this effect quickly drops close to zero among neighbors who live on the same block (within 25 m; see the fourth model in Table 7). All these relationships indicate the importance of physical proximity, and the strong influence of neighbors suggests that the spread of loneliness may possibly depend more on frequent social contact in older adults. But siblings do not appear to affect one another at all (even the ones who live nearby; see the first model in Table 7), which provides additional evidence that loneliness in older adults is about the relationships people choose, rather than the relationships they inherit. And spouses appear to be an intermediate category; Table 8 shows that spouses are significantly less influential than friends in the spread of loneliness from person to person (as indicated by the significant interaction term in the first row of Table 8).

Analyses separated by gender suggested that loneliness spreads more easily among women than among men and that this holds for both friends and neighbors. As shown in the coefficients in the first row of Tables 9 and 10, women are more likely to be affected by the loneliness of both their friends (see Table 9) and neighbors (see Table 10), and their loneliness is more likely to spread to other people in their social network. The coefficients in bold show that social influence is greatest when the FP or the LP is female. Women also reported higher levels of loneliness than did men. We are reporting estimates from a linear model, however, so the baseline rate of loneliness should not affect the absolute differences that we observed. (We would be more concerned about this possible effect if we were reporting odds ratios or risk ratios that are sensitive to the baseline.) In a linear model, any additive differences in baseline should be captured by the sex variable in the model, which does show a significantly higher baseline for women. However, because we include this control, the baseline

Table 6
Association of LP Loneliness and FP Loneliness

	LP type					
Variable	Nearby friend	Distant friend	Nearby mutual friend	Nearby LP: Perceived friend	Coresident spouse	Noncoresident spouse
Days/week LP currently lonely	**0.29 (0.11)**	−0.08 (0.05)	**0.41 (0.13)**	0.35 (0.30)	**0.10 (0.04)**	0.08 (0.05)
Days/week LP lonely in prior wave	0.12 (0.05)	0.11 (0.05)	0.16 (0.09)	0.02 (0.08)	0.03 (0.02)	0.06 (0.05)
Days/week FP lonely in prior wave	0.31 (0.13)	0.39 (0.09)	0.28 (0.14)	0.10 (0.05)	0.21 (0.04)	0.04 (0.05)
Exam 7	0.11 (0.09)	0.05 (0.07)	0.04 (0.16)	−0.07 (0.09)	0.08 (0.03)	0.01 (0.08)
FP's age	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)	0.00 (0.00)	−0.01 (0.00)
FP female	0.18 (0.09)	0.06 (0.08)	0.17 (0.14)	0.12 (0.14)	0.11 (0.03)	0.04 (0.08)
FP's years of education	0.00 (0.01)	−0.01 (0.02)	0.01 (0.02)	0.05 (0.03)	0.00 (0.01)	−0.05 (0.02)
Constant	−0.30 (0.43)	−0.04 (0.60)	−0.78 (0.60)	−0.89 (0.71)	0.48 (0.20)	1.65 (0.51)
Deviance	236	677	138	122	1,575	275
Null deviance	375	899	285	145	1,734	290
N	472	1,014	214	274	3,716	592

Note. LP = linked participant; FP = focal participant. Coefficients and standard errors in parentheses for linear regression of days per week FP feels lonely on covariates are shown. Observations for each model are restricted by type of relationship (e.g., the leftmost model includes only observations in which the FP named the LP as a "friend" in the previous and current period, and the friend is "nearby," i.e., lives no more than 1 mile away). Models were estimated using a general estimating equation with clustering on the FP and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002).

Table 7
Association of LP Loneliness and FP Loneliness

	LP type					
Variable	Nearby sibling	Distant sibling	Immediate neighbor	Neighbor within 25 m	Neighbor within 100 m	Coworker
Days/week LP currently lonely	0.00 (0.03)	−0.03 (0.01)	**0.21 (0.09)**	**0.04 (0.02)**	−0.05 (0.03)	0.00 (0.03)
Days/week LP lonely in prior wave	−0.02 (0.02)	0.03 (0.01)	0.08 (0.06)	0.03 (0.02)	−0.02 (0.03)	−0.02 (0.02)
Days/week FP lonely in prior wave	0.18 (0.05)	0.18 (0.04)	0.39 (0.19)	0.22 (0.04)	0.08 (0.06)	0.18 (0.05)
Exam 7	0.00 (0.05)	0.03 (0.04)	0.25 (0.13)	0.12 (0.06)	−0.01 (0.10)	0.00 (0.05)
FP's age	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	−0.01 (0.01)	0.00 (0.00)
FP female	0.10 (0.05)	0.06 (0.04)	0.14 (0.12)	0.17 (0.06)	0.22 (0.09)	0.10 (0.05)
FP's years of education	−0.01 (0.02)	0.00 (0.01)	0.02 (0.04)	0.00 (0.02)	0.01 (0.02)	−0.01 (0.02)
Constant	0.82 (0.43)	0.71 (0.29)	−0.33 (0.68)	−0.01 (0.34)	1.02 (0.39)	0.82 (0.43)
Deviance	1,065	3,729	205	1,618	5,738	636
Null deviance	1,140	3,954	366	1,930	6,278	665
N	2,124	6,168	364	1,904	6,888	1,330

Note. LP = linked participant; FP = focal participant. Coefficients and standard errors in parentheses for linear regression of days per week FP feels lonely on covariates are shown. Observations for each model are restricted by type of relationship (e.g., the leftmost model includes only observations in which the FP named the LP as a "sibling" in the previous and current period, and the sibling is "nearby," i.e., lives no more than 1 mile away). Models were estimated using a general estimating equation with clustering on the FP and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002).

difference in men and women should not affect the interpretation of the absolute number of days each additional day of loneliness experienced by an LP contributes to the loneliness experienced by an FP.

Finally, our measure of loneliness was derived from the "I feel lonely" item in the CES–D. To address whether our results would change if depression were included in the models, we created a depression index by summing the other 19 questions in the CES–D (dropping the question on loneliness). The Pearson correlation between the indices in our data is 0.566. If depression is causing the correlation in loneliness between social contacts, then the coefficient on LP loneliness should be reduced to insignificance when we add depression variables to the models in Tables 6 and 7. Specifically, we added a contemporaneous and lagged variable for both FP's and LP's depression. The results in Tables 11 and 12 show that there is a significant association between FP current depression and FP current loneliness (the eighth row in bold), but other depression variables have no effect, and adding them to the model has little effect on the association between FP and LP loneliness. Loneliness in nearby friends, nearby mutual friends, immediate neighbors, and nearby neighbors all remain significantly associated with FP loneliness.

Table 8
Influence of Type of Relationship on Association Between LP Loneliness and FP Loneliness

Variable	Coef	*SE*	*p*
LP is Spouse × Days/Week LP Currently Lonely	−0.274	0.138	.047
Days/week LP currently lonely	0.364	0.131	.005
LP is spouse (instead of friend)	0.165	0.092	.074
Days/week LP lonely in prior wave	0.046	0.022	.033
Days/week FP lonely in prior wave	0.227	0.046	.000
Exam 7	0.082	0.031	.009
FP's age	0.000	0.002	.914
Female	0.117	0.032	.000
FP's years of education	−0.005	0.006	.470
Constant	0.232	0.204	.255
Deviance	910		
Null deviance	1,056		
N	2,094		

Note. LP = linked participant; FP = focal participant. Results for linear regression of days per week FP feels lonely at next exam on covariates are shown. Sample includes all spouses and nearby friends (nearby = <1 mile away). The interaction term in the first row tests the hypothesis that spouses have less influence than friends on loneliness. Models were estimated using a general estimating equation with clustering on the FP and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002). The results show that spouses exert significantly less influence on each other than friends.

Discussion

The present research shows that what might appear to be a quintessential individualistic experience—loneliness—is not only a function of the individual but is also a property of groups of people. People who are lonely tend to be linked to others who are lonely, an effect that is stronger for geographically proximal than distant friends yet extends up to three degrees of separation (friends' friends' friends) within the social network. The nature of the friendship matters, as well, in that nearby mutual friends show stronger effects than nearby ordinary friends. If some third factor were explaining both focal and linked participants' loneliness, then loneliness should not be contingent on the different types of friendship or the directionality of the tie. These results, therefore, argue against loneliness within networks primarily reflecting shared environments.

Longitudinal analyses also indicated that nonlonely individuals who are around lonely individuals tend to grow lonelier over time.

Table 9
Association of LP Loneliness and FP Loneliness in Friends, By Gender

	LP type = friend within 2 miles						
Variable	FP male	FP female	LP male	LP female	FP & LP male	FP & LP female	FP & LP opposite gender
Days/week LP currently lonely	0.03 (0.03)	**0.33 (0.15)**	0.02 (0.05)	**0.25 (0.13)**	0.05 (0.04)	**0.36 (0.15)**	−0.02 (0.11)
Days/week LP lonely in prior wave	0.04 (0.04)	0.01 (0.05)	0.05 (0.07)	0.01 (0.04)	0.03 (0.06)	0.01 (0.05)	0.04 (0.07)
Days/week FP lonely in prior wave	0.35 (0.18)	0.37 (0.11)	0.36 (0.19)	0.38 (0.11)	0.15 (0.04)	0.31 (0.11)	0.79 (0.21)
Exam 7	0.16 (0.09)	0.12 (0.12)	0.15 (0.10)	0.13 (0.11)	0.07 (0.07)	0.09 (0.11)	0.41 (0.26)
FP's age	0.01 (0.01)	0.00 (0.01)	0.01 (0.01)	0.00 (0.01)	0.01 (0.01)	0.00 (0.01)	0.02 (0.02)
FP's years of education	−0.01 (0.01)	0.00 (0.02)	−0.01 (0.01)	0.01 (0.02)	−0.02 (0.01)	0.00 (0.02)	0.05 (0.03)
Constant	−0.33 (0.57)	−0.10 (0.71)	−0.46 (0.63)	0.09 (0.64)	0.09 (0.52)	0.27 (0.71)	−1.85 (1.04)
Deviance	57	142	58	144	38	123	23
Null deviance	73	218	72	221	42	190	58
N	195	194	174	215	166	186	37

Note. LP = linked participant; FP = focal participant. Coefficients and standard errors in parentheses for linear regression of days per week FP feels lonely on covariates are shown. Observations for each model are restricted by type of relationship (e.g., the leftmost model includes only observations in which the FP is a male); all LPs in this table are friends who live within two miles. Models were estimated using a general estimating equation with clustering on the FP and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002).

The longitudinal results suggest that loneliness appears in social networks through the operation of induction (e.g., contagion), rather than simply arising from lonely individuals finding themselves isolated from others and choosing to become connected to other lonely individuals (i.e., the homophily hypothesis). The present study does not permit us to identify the extent to which the emotional, cognitive, and behavioral consequences of loneliness contributed to the induction of loneliness. All three contagion processes are promoted by face-to-face communications and disclosures, especially between individuals who share close ties, and can extend to friends' friends and beyond through a chaining of these effects. The social network pattern of loneliness and the interpersonal spread of loneliness through the network therefore appear most consistent with the induction hypothesis.

If loneliness is contagious, what, if anything, keeps the contagion in check? An observation by Harlow et al. (1965) in their studies of social isolation in rhesus monkeys offers a clue. When the isolate monkeys were reintroduced into the colony, Harlow et al., noted that most of these isolate animals were driven off or eliminated. Our results suggest that humans may similarly drive away lonely members of their species and that feeling socially isolated can lead to one becoming objectively isolated. Loneliness not only spreads from person to person within a social network but it also reduces the ties of these individuals to others within the network. As a result, loneliness is found in clusters within social networks, is disproportionately represented at the periphery of social networks, and threatens the cohesiveness of the network. The collective rejection of isolates observed in humans and other

Table 10
Association of LP Loneliness and FP Loneliness in Neighbors, By Gender

	LP type = neighbor within 25 m						
Variable	FP male	FP female	LP male	LP female	FP & LP male	FP & LP female	FP & LP opposite gender
Days/week LP currently lonely	0.05 (0.06)	**0.19 (0.08)**	−0.06 (0.04)	**0.14 (0.06)**	0.00 (0.06)	**0.24 (0.09)**	0.01 (0.06)
Days/week LP lonely in prior wave	0.00 (0.02)	0.07 (0.05)	0.05 (0.04)	0.06 (0.05)	0.02 (0.03)	0.08 (0.07)	0.02 (0.03)
Days/week FP lonely in prior wave	0.16 (0.06)	0.27 (0.07)	0.20 (0.07)	0.31 (0.07)	0.14 (0.07)	0.31 (0.08)	0.20 (0.06)
Exam 7	0.18 (0.08)	0.02 (0.19)	0.04 (0.14)	0.16 (0.11)	0.18 (0.08)	0.10 (0.17)	0.06 (0.12)
FP's age	0.00 (0.00)	−0.01 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.01)	0.00 (0.00)
FP's years of education	0.02 (0.02)	−0.03 (0.04)	−0.01 (0.03)	−0.02 (0.03)	0.03 (0.02)	−0.04 (0.05)	−0.01 (0.02)
Constant	0.04 (0.40)	1.25 (1.02)	0.84 (0.69)	0.76 (0.72)	−0.23 (0.57)	1.12 (1.23)	0.86 (0.52)
Deviance	127	571	244	473	26	350	318
Null deviance	137	684	264	574	29	454	342
N	353	535	352	536	140	323	425

Note. LP = linked participant; FP = focal participant. Coefficients and standard errors in parentheses for linear regression of days per week FP feels lonely on covariates are shown. Observations for each model are restricted by type of relationship (e.g., the leftmost model includes only observations in which the FP is a male); all LPs in this table are nonrelated neighbors who live within 25 m. Models were estimated using a general estimating equation with clustering on the FP and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002).

Table 11
Association of LP Loneliness and FP Loneliness Controlling for Depression (Compare With Table 6)

Variable	Nearby friend	Distant friend	Nearby mutual friend	Nearby LP: Perceived friend	Coresident spouse	Noncoresident spouse
	LP type					
Days/week LP currently lonely	**0.28 (0.12)**	−0.09 (0.06)	**0.37 (0.15)**	0.33 (0.28)	0.03 (0.04)	−0.05 (0.07)
Days/week LP lonely in prior wave	0.13 (0.07)	0.07 (0.05)	0.13 (0.12)	0.02 (0.07)	0.01 (0.02)	−0.03 (0.04)
Days/week FP lonely in prior wave	0.13 (0.13)	0.14 (0.07)	0.17 (0.17)	0.05 (0.06)	0.11 (0.04)	0.00 (0.06)
Exam 7	−0.03 (0.09)	−0.08 (0.09)	−0.18 (0.13)	−0.24 (0.11)	0.00 (0.03)	−0.07 (0.09)
FP's age	0.00 (0.00)	0.01 (0.01)	0.01 (0.01)	0.02 (0.01)	0.00 (0.00)	0.00 (0.00)
FP female	−0.01 (0.08)	0.01(0.07)	−0.07 (0.15)	0.11 (0.14)	0.05 (0.03)	0.00 (0.07)
FP's years of education	−0.01 (0.02)	0.01 (0.02)	0.01 (0.02)	0.04 (0.02)	0.01 (0.01)	−0.02 (0.01)
FP current depression index	**0.07 (0.02)**	**0.08 (0.01)**	**0.07 (0.04)**	**0.06 (0.02)**	**0.05 (0.01)**	**0.06 (0.02)**
FP depression index in prior wave	0.00 (0.02)	−0.01 (0.01)	−0.01 (0.02)	−0.02 (0.01)	0.00 (0.00)	0.00 (0.01)
LP current depression index	−0.01 (0.01)	0.01 (0.01)	−0.02 (0.02)	0.00 (0.01)	0.01 (0.00)	0.01 (0.01)
LP depression index in prior wave	−0.02 (0.01)	−0.01 (0.01)	−0.01 (0.01)	0.00 (0.01)	0.00 (0.00)	0.00 (0.01)
Constant	0.11 (0.41)	−0.44 (0.54)	−0.25 (0.70)	−1.23 (0.57)	−0.07 (0.20)	0.47 (0.35)
Deviance	157	405	87	80	959	146
Null deviance	353	765	266	126	1,422	219
N	396	826	182	232	3,040	492

Note. LP = linked participant; FP = focal participant. Coefficients and standard errors in parentheses for linear regression of days per week FP feels lonely on covariates are shown. Observations for each model are restricted by type of relationship (e.g., the leftmost model includes only observations in which the FP named the LP as a "friend" in the previous and current period, and the friend is "nearby," i.e., lives no more than 1 mile away). Models were estimated using a general estimating equation with clustering on the FP and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002).

primates may therefore serve to protect the structural integrity of social networks.

In the present study, the finding that loneliness spreads more quickly among friends than family further suggests that the rejection of isolates to protect social networks occurs more forcibly in networks that we select, rather than in those we inherit. This effect may be limited to older populations, however. The mean age in our sample was 64 years, and elderly adults have been found to reduce the size of their networks to focus on those relationships that are relatively rewarding, with costly family ties among those that are trimmed (Carstensen, 2001). Although a spouse's loneliness was related to an individual's subsequent loneliness, friends appeared

Table 12
Association of LP Loneliness and FP Loneliness Controlling For Depression (Compare With Table 7)

Variable	Nearby sibling	Distant sibling	Immediate neighbor	Neighbor within 25 m	Neighbor within 100 m	Coworker
	LP type					
Days/week LP currently lonely	0.00 (0.03)	−0.03 (0.01)	**0.21 (0.09)**	**0.04 (0.02)**	−0.05 (0.03)	0.00 (0.03)
Days/week LP lonely in prior wave	−0.02 (0.02)	0.03 (0.01)	0.08 (0.06)	0.03 (0.02)	−0.02 (0.03)	−0.02 (0.02)
Days/week FP lonely in prior wave	0.18 (0.05)	0.18 (0.04)	0.39 (0.19)	0.22 (0.04)	0.08 (0.06)	0.18 (0.05)
Exam 7	0.00 (0.05)	0.03 (0.04)	0.25 (0.13)	0.12 (0.06)	−0.01 (0.10)	0.00 (0.05)
FP's age	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.01 (0.00)	−0.01 (0.01)	0.00 (0.00)
FP female	0.10 (0.05)	0.06 (0.04)	0.14 (0.12)	0.17 (0.06)	0.22 (0.09)	0.10 (0.05)
FP's years of education	−0.01 (0.02)	0.00 (0.01)	0.02 (0.04)	0.00 (0.02)	0.01 (0.02)	−0.01 (0.02)
FP current depression index	**0.07 (0.02)**	**0.08 (0.01)**	**0.07 (0.04)**	**0.06 (0.02)**	**0.05 (0.01)**	**0.06 (0.02)**
FP depression index in prior wave	0.00 (0.02)	−0.01 (0.01)	−0.01 (0.02)	−0.02 (0.01)	0.00 (0.00)	0.00 (0.01)
LP current depression index	−0.01 (0.01)	0.01 (0.01)	−0.02 (0.02)	0.00 (0.01)	0.01 (0.00)	0.01 (0.01)
LP depression index in prior wave	−0.02 (0.01)	−0.01 (0.01)	−0.01 (0.01)	0.00 (0.01)	0.00 (0.00)	0.00 (0.01)
Constant	0.82 (0.43)	0.71 (0.29)	−0.33 (0.68)	−0.01 (0.34)	1.02 (0.39)	0.82 (0.43)
Deviance	659	2,114	103	896	3,323	301
Null deviance	991	3,127	360	1,699	5,244	630
N	1,748	5,054	300	1,562	5,540	1,140

Note. LP = linked participant; FP = focal participant. Coefficients and standard errors in parentheses for linear regression of days per week FP feels lonely on covariates are shown. Observations for each model are restricted by type of relationship (e.g., the leftmost model includes only observations in which the FP named the LP as a "sibling" in the previous and current period, and the sibling is "nearby," i.e., lives no more than 1 mile away). Models were estimated using a general estimating equation with clustering on the FP and an independent working covariance structure (Liang & Zeger, 1986; Schildcrout & Heagerty, 2005). Models with an exchangeable correlation structure yielded poorer fit. Fit statistics show sum of squared deviance between predicted and observed values for the model and a null model with no covariates (Wei, 2002).

to have more impact on loneliness than did spouses. The gender differences we observed may contribute to this finding. Wheeler et al. (1983) reported that loneliness is related to how much time male and female participants interact with women each day, and we found that the spread of loneliness was stronger for women than for men. Research is needed to address whether the absence of an effect of spouses and family members on the loneliness is more typical of older than younger adults and women than men.

Fowler and Christakis (2008a) found that happiness also occurred in clusters and spread through networks. Several important differences have emerged in the induction of happiness and the induction of loneliness, however. First, Fowler and Christakis (2008) found happiness to be more likely than unhappiness to spread through social networks. The present research, in contrast, indicates that the spread of loneliness is more powerful than the spread of nonloneliness. Negative events typically have more powerful effects than positive events (i.e., differential reactivity; Cacioppo & Gardner, 1999), so Fowler and Christakis's (2008) findings about the spread of happiness through social networks is distinctive. Whereas laboratory studies are designed to gauge differential reactivity to a positive or negative event, the Fowler and Christakis (2008) study also reflects people's differential exposure to happy and unhappy events. Thus, happiness may spread through networks more than unhappiness because people have much more frequent exposures to friends expressing happiness than unhappiness.

Loneliness does not have a bipolar opposite like happiness, but, rather, is like hunger, thirst, and pain in that its absence is the normal condition, rather than an evocative state (Cacioppo & Patrick, 2008). Furthermore, as an aversive state, loneliness may motivate people to seek social connection (whatever the response of others to such overtures), which has the effect of increasing the likelihood that those proximal to a lonely individual will be exposed to loneliness. Together, these processes may make loneliness more contagious than nonloneliness.

A second difference between the spread of happiness and loneliness concerns the effect of gender. Fowler and Christakis (2008) found no gender differences in the spread of happiness, whereas we found that loneliness spreads much more easily among women than among men. Women may be more likely to express and share their emotions and may be more attentive to the emotions of others (Hatfield et al., 1994), but the spread of happiness, as well as loneliness, would be fostered similarly among women were this a sufficient cause. There is also a stigma associated with loneliness, particularly among men; women are more likely to engage in intimate disclosures than are men; and relational connectedness is more important for women than for men (Brewer & Gardner, 1996; Hawkley et al., 2005; Shaver & Brennan, 1991). These processes may explain the greater spread of loneliness among women relative to men. The present results, however, clearly show that gender, like proximity and type of relationship, influences the spread of loneliness.

A limitation of all social network analyses is that the studies are necessarily bound their sample. The compact nature of the Framingham population in the period from 1971 to 2007 and the geographical proximity of the influence mitigate this constraint, but we nevertheless considered whether the results might have changed with a larger sample frame that includes all named individuals who were themselves not participants in the Framingham Heart Study. For instance, we calculated the statistical relationship between the tendency to name people outside the study and loneliness. A Pearson correlation between the number of contacts named outside the study and loneliness is not significant and actually flips signs from one exam to another (Exam 6, 0.016, $p = .39$; Exam 7, -0.011, $p = .53$). This result suggests that the sampling frame is not biasing the average level of loneliness in the target individuals we are studying.

A second possible limitation is that we included all participants in the analysis. It is possible that the death or loss of certain critical social network members during the study systematically affect how lonely FPs felt across time. To address this possibility, we restricted analysis to those individuals (both FPs and LPs) who remained alive at the end of the study. If death is the only or most important source of network loss that causes the association between FP and LP loneliness, then removing observations of people who died during the study should reduce the association to insignificance. Results of these analyses show that the restriction has no effect on the association between FP and LP loneliness. Loneliness in nearby friends, nearby mutual friends, spouses, and immediate neighbors all remain significantly associated with FP loneliness. The death of critical network members, therefore, does not appear to account for our results.

Prior research has shown that disability is a predictor of loneliness (Hawkley et al., 2008). A related issue, therefore, is whether the disability status of FPs factor into our findings. To address this issue, we created a disability index by summing five questions from the Katz Index of Activities of Daily Living (Spector, Katz, Murphy, & Fulton, 1987) about the subjects' ability to independently dress themselves, bathe themselves, eat and drink, get into and out of a chair, and use the toilet. The Pearson correlation between the indices in our data is 0.06 (*ns*). If disabilities affect the correlation in loneliness between social contacts, then the coefficient on LP loneliness may be reduced to insignificance when we add disability variables to the models in Tables 6 and 7. Specifically, we added a contemporaneous and lagged variable for both FP's and LP's disability index. The results of these ancillary analyses indicated that loneliness in nearby friends, nearby mutual friends, immediate neighbors, and nearby neighbors all remain significantly associated with FP loneliness. Thus, disability does not appear to account for our findings.

In conclusion, the observation that loneliness can be passed from person to person is reminiscent of sociologist Emile Durkheim's (1951) famous observation about suicide. He noticed that suicide rates stayed the same across time and across groups, even though the individual members of those groups came and went. In other words, whether people took their own lives depended on the kind of society they inhabited. Although suicide, like loneliness, has often been regarded as entirely individualistic, Durkheim's work indicates that suicide is driven in part by larger social forces. Although loneliness has a heritable component, the present study shows it also to be influenced by broader social network processes. Indeed, we detected an extraordinary pattern at the edge of the social network. On the periphery, people have fewer friends, which makes them lonely, but it also drives them to cut the few ties that they have left. But before they do, they tend to transmit the same feeling of loneliness to their remaining friends, starting the cycle anew. These reinforcing effects mean that our social fabric can fray at the edges, like a yarn that comes loose at the end of a crocheted sweater. An important implication of this finding is that interventions to reduce loneliness in our society may benefit by aggressively targeting the people in the periphery to help repair their social networks. By helping them, we might create a protective barrier against loneliness that can keep the whole network from unraveling.

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