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THE SPREAD OF ALCOHOL CONSUMPTION BEHAVIOR IN A LARGE SOCIAL NETWORK

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Abstract

Background—Alcohol consumption has important health related consequences and numerous biological and social determinants.

Objective—Quantitatively explore the possibility of person-to-person spread of alcohol consumption behavior within a large social network involving friends, co-workers, siblings, spouses, and neighbors followed for 32 years.

Design—Longitudinal network cohort study

Setting—The Framingham Heart Study.

Participants—12,067 people assessed at several time points between 1971 and 2003.

Measurements—At each time point, we measured: (1) self-reported alcohol consumption behavior, both in terms of number of drinks per week on average over the past year as well as number of days drinking within the past week, and (2) social network ties.

Results—Discernible clusters of drinkers and abstainers were present in the network at all time points, and the clusters extended to three degrees of separation (e.g., to a person's friends' friends' friends). These clusters were not solely due to selective formation of social ties among drinkers, but rather also appear to reflect inter-personal influence. Changes in the alcohol consumption behavior of an individual's social network had a statistically significant affect on an individual's subsequent alcohol consumption behavior. Immediate neighbors and coworkers did not exhibit statistically significant affects on drinking behavior.

Limitations—The measure of alcohol consumption is not a clinical one. Also, it is unclear whether these effects have positive or negative effects on long-term health, give that alcohol has been shown to have both harmful and protective health effects. Finally, not all network ties were observed.

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Conclusions—Network phenomena appear to influence alcohol consumption behavior. This has implications for clinical and public health interventions, and further supports group-level interventions to reduce problematic drinking.

Introduction

Alcohol use is common in the United States. In 2002, 55% of adults reported having at least one drink in the previous month, with the prevalence of past-month alcohol consumption somewhat higher for men (62%) than for women (48%) (1) Moreover, the lifetime prevalence of alcohol use disorders has been measured at 14.6% (1). Excessive alcohol use, either in the form of heavy drinking or binge drinking, increases the risk of numerous health and social problems (2,3), and, in 2001, approximately 75,000 deaths were attributable to excessive alcohol use, making it the third-leading lifestyle-related cause of death (3).

Alcohol consumption behavior has many determinants. Past work has suggested that biological factors appear to have a significant impact on the progression from experimentation to regular use while social and cultural factors appear to play a critical role in experimentation with alcohol and development of drinking patterns over time (3,4). Given the social nature of this behavior, it is not surprising that previous work has identified interactions with friends and family members as key factors (4,5,6,7,8). While this prior literature has primarily focused on cross-sectional panels, some studies have attempted to test whether social influences act over time (6,7,8). This work, primarily focused on peer influence among college students, has shown inconsistent results, and has tended to focus just on dyads of connected individuals.

The study of social influences on behavior has expanded in recent years to the study of numerous linked individuals over time.(9) Recent work in this area has shown that a variety of health-related phenomena, ranging from sexually transmitted diseases to obesity, smoking, and even suicide, may travel along and within social networks (10,11,12,13,14,15).

Using a longitudinal, dynamic network of 12,067 people, we analyze the role of social networks in alcohol use, focusing on the following questions: (1) Do clusters of heavy drinkers and abstainers exist within the network? (2) Is there an association between an individual's alcohol consumption behavior and the alcohol consumption behaviors of their social contacts? (3) How much do any associations depend on the nature and direction of the social ties (*e.g.*, friends of different kinds, siblings, spouses, co-workers, neighbors)? And (4) Does gender affect the spread of alcohol consumption across social ties?

Methods

Source Data

We used data from participants in the Framingham Heart Study (FHS). The FHS is a population-based, longitudinal, observational cohort study that was initiated in 1948 to prospectively investigate risk factors for cardiovascular disease. Four cohorts, mostly representing different generations linked to an original cohort, are included in the entire FHS study. Participant data, collected every two to four years, includes physical examinations, laboratory tests, noninvasive cardiac and vascular testing, battery testing (such as the Mini-Mental status exam), questionnaire results, and basic demographic information. For the purposes of the analyses reported here, exam waves for the Original cohort were aligned with those of the second-generation Offspring cohort, so that all subjects were treated as having been examined at just seven waves. The Offspring Cohort, initiated in 1971, is the source of this study's “principals,” or focal individuals in the network (16). However, other

FHS participants are included when listed as social contacts by the principals, which will be referred to as "contacts." Therefore, whereas principals come only from the Offspring Cohort, contacts are drawn from the entire set of both the original and offspring cohorts.

To ascertain social network ties, a separate dataset was created that linked individuals through self-described social ties collected at each of the seven waves of the study. Thus, it is possible to know which participants have a relationship (*e.g.*, spouse, sibling, friend, co-worker, neighbor) with other participants; and these ties could be observed to change across time. Each link between two people might be identified by *either party* identifying the other. This observation is most relevant to the "friend" link, as it is possible to make this link either when A nominates B as a friend, or when B nominates A. Complete records of participants' and their contacts' address in each wave since 1971 were also used in the analyses, though it is important to note that we do not have any information about relationships that participants did not report. At each wave, it was possible to determine (1) who is whose neighbor, and (2) the geographical distance between individuals (10, 17). **Table 1** provides descriptive statistics regarding the 5,124 principals in our sample.

Measures—Alcohol consumption was self-reported in all waves being studied, with participants answering questions for the the average number of drinks per week over the past year as well as the number of days within the past week consuming alcohol (beer, wine, and liquor) Self-reported data is generally considered a valid and reliable source when assessing of alcohol consumption, though recall measures like those used in this study can be subject to recall bias from participants. (18).

Alcohol consumption was treated as a continuous variable in some analyses (number of drinks per day, calculated from participant responses), while other analyses were conducted with dichotomous cut points: heavy drinkers were defined as averaging more than 1 (women) or 2 (men) drinks per day; moderate drinkers were those consuming alcohol below cut-offs for heavy drinkers; and abstainers were defined as reporting no alcohol consumption. The self-reported number of days drinking within the past week was not used as a measure in and of itself, but rather was used to calculate average number of drinks in a day. It is important to note that these labels do not reflect clinical definitions of alcohol abuse or dependence. Table 2 shows averages for the study population across time, including average age as well as population averages for alcohol consumption and percentages of abstainers and drinkers. While it is difficult to compare our results to other population samples in terms of heavy drinking due to the difference in how we measure it, the other averages for the mean-age groups in each year of the given waves are roughly similar to national averages of alcohol consumption behavior (1, 19, 20).

Statistical Analysis—The first goal of the analyses was to evaluate whether an individual's alcohol consumption behavior was associated with that of his or her social network ties at various degrees of separation. To test this hypothesis, the observed clustering of people (and their alcohol consumption behavior) within the whole network was compared to 1,000 simulated networks with the same network topology and the same overall prevalence of drinking as the observed network, but with the incidence of drinking (defined, say, as drinking at least one drink per day) randomly distributed across the nodes ("random drinking networks"). If clustering in drinking behavior is occurring, then the probability a contact is a drinker given that a principal is a drinker should be higher in the observed network than in the random drinking networks (21). We used the Kamada-Kawai algorithm to draw the networks; this algorithm iteratively repositions nodes in order to reduce the number of ties that cross each other. (22)

The second goal of the analyses was to examine the possible determinants of any clustering in alcohol consumption behavior. Three explanations for non-random clustering of alcohol consumption behavior within the network were considered: (1) principals might choose to associate with like contacts (also known as *homophily*) (23,24); (2) principals and contacts might share attributes or jointly experience unobserved contemporaneous events that cause their alcohol consumption behavior to covary (omitted variables or *confounding*); and/or (3) contacts might exert social influence or peer effects on principals (*induction*). Distinguishing the inter-personal induction of drinking from homophily was facilitated by the availability of dynamic, longitudinal data regarding *both* network connections and drinking behavior (25).

The basic statistical approach involved the specification of longitudinal logistic regression models wherein the principal's drinking status at time $t+1$ is a function of various attributes of principals such as age, gender, and education, their drinking status at time t, and the drinking status of their contacts at times t and $t+1$.(25) Generalized estimating equation procedures were used to account for multiple observations of the same principal across waves and across principal-contact pairings.(26) An independent working correlation structure for the clusters was assumed.(27)

The time-lagged dependent variable regarding alcohol consumption (lagged to the prior exam) eliminates serial correlation in the errors (28) (evaluated with a Lagrange multiplier test) and also substantially controls for principal's genetic endowment and any intrinsic, stable predilection to drink. Additionally, the lagged independent variable for a contact's drinking status substantially controls for homophily (25,29). The key variable of interest is a contact's alcohol consumption behavior at time $t+1$. A significant coefficient on this variable would suggest either that a contact's drinking affects a principal's drinking or that a principal and a contact experience contemporaneous events affecting both of their alcohol consumption behaviors. The possibility of omitted variables or unobserved events explaining the associations was tested by examining how the type or direction of the social relationship between principal and contact affected the association between principal and contact drinking.

Risk ratios and 95% confidence intervals were computed by simulating the change in risk of principal drinking when contact contemporaneous drinking changes from 0 to 1, using 1,000 randomly drawn sets of estimates from the coefficient covariance matrix and assuming all other variables were held at their means.(30) All these tests are two-tailed. For repeated tests involving different types of social contacts we applied a Bonferroni correction to the confidence intervals.

The sensitivity of the results was assessed with multiple additional analyses (see online supplement). For example, we considered the possible impact of incomplete or biased network data. If people who drink heavily are more likely to name people outside the study, underestimation of the effect of one person's alcohol consumption behavior on another might occur. Tests of the correlation between an individual's number of drinks per day and number of ties to people outside the study was not found to be significant (rho=0.01, p=0.15). This suggests that the network data generation procedure did not bias the analyses.

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Results

Figure 1 depicts the largest connected sub-component of the social network of friends, spouses, and siblings in the year 2000. Clusters of drinking and abstaining are visible in the network.

Figure 2 shows the correlation between principals and contacts with regards to their drinking behavior (numerical results for this and the other figures can be found in the online appendix). The results indicate that principals are 50% (95% C.I. 40% to 62%) more likely to drink heavily if a person they are directly connected to (at one degree of separation) drinks heavily. The size of the effect for people at two degrees of separation (e.g., the friend of a friend) is 36% (95% C.I. 25% to 48%) and for people at three degrees of separation (e.g., the friend of a friend of a friend) is 15% (95% C.I. 8% to 25%). At four degrees of separation, the effect disappears (4%, 95% C.I. –2% to 10%), in keeping with the "three degrees of influence" rule of social network contagion that has been exhibited for obesity, smoking, happiness, depression, loneliness, word-of-mouth advertising, and the spread of ideas among inventors (10-14,31). Analyses of the full network also show that subjects are 29% (95% C.I. 23% to 36%) more likely to abstain if a person they are directly connected to (at one degree of separation) abstains. The size of the effect for people at two degrees of separation (the friend of a friend) is 21% (95% C.I. 16% to 27%) and for people at three degrees of separation (the friend of a friend of a friend) is 5% (95% C.I. 1% to 10%). Again, at four degrees of separation the effect disappears (2%, 95% C.I. –1% to 6%).

It is notable that in **Figure 2** the decline in the effect size with social distance contrasts to a lack of decline in the effect size as people become more geographically distant from one another. This result was confirmed by testing an interaction between distance and the effect size. These results suggest a friend or family member who lives hundreds of miles away is associated with as big an effect as one who lives next door.

The actual alcohol consumption behavior in individuals' social contacts affects individuals' alcohol consumption behavior. **Figure 3** shows the smoothed bivariate relationship between the fraction of a principal's friends and family who drink heavily and abstain at one exam, and the average number of drinks per day at the following exam. Being surrounded by heavy drinkers increases by about 70% (95% CI: 35% to 142%) the amount of alcohol a person drinks at the next exam compared to those who are not connected to any heavy drinkers. Conversely, being surrounded by abstainers cuts in half the amount of alcohol a person drinks at the next exam.

When the principal's future alcohol consumption behavior, controlling for age, gender, education, and exam was regressed on the number of heavy drinking, moderate drinking, and abstaining contacts, each additional heavy drinking contact was found to significantly increase the likelihood that a principal drinks heavily by 18% (95% CI: 11% to 25%, $p<0.001$) and decreases the likelihood principal abstains by 7% (95% CI: 2% to 12%, $p=0.009$), but has no effect on moderate alcohol consumption behavior (CI: –8% to 1%, $p=0.113$). Conversely, each additional abstaining contact significantly *reduces* the likelihood of heavy drinking by 10% (95% CI: 4% to 15%, $p=0.001$), increases the likelihood of abstaining by 22% (95% CI: 17% to 28%), and also decreases the likelihood of moderate drinking by 11% (95% CI: 8% to 14%). Finally, each additional contact that drinks moderately has no significant effect on heavy drinking (95% CI: –2% to 7%, $p=0.214$) but it significantly decreases the probability of abstaining by 5% (95% CI: 2% to 9%) and increases the likelihood of moderate drinking by 6% (95% CI: 2% to 9%).

We next evaluated the extent of dyadic, inter-personal association in alcohol consumption behavior. As discussed in the methods section, these models account for homophily by including a time-lagged measure of a contact's alcohol consumption behavior. We evaluated the possible role of unobserved contemporaneous events by separately analyzing models on subsets of the data involving various principal/contact pairings. **Figure 4** summarizes the associations from the models (numerical results can be found in the online appendix). With respect to friends, we found significant gender differences in the spread of heavy alcohol consumption behavior. If a principal's female friend started drinking heavily, then the principal's chances of drinking heavily increased by 154% (95% CI: 30% to 354%). In contrast, a male friend's heavy alcohol consumption behavior appears to have no significant effect on the principal. The type of friendship also appeared to be important: a female who thinks of the principal as a friend but not vice versa (a contact-perceived friend) does not appear to have a significant effect, but the overlapping confidence intervals indicate that the difference in the effect size is not significant. Gender also played a role among spouses. Heavy drinking by a wife increased the likelihood that the husband drank heavily by 196% (95% CI:91% to 329%), whereas heavy drinking by a husband increased the likelihood that a wife drank heavily by 126% (95% CI:67% to 202%). Among siblings the effect was significantly smaller and did not differ whether the contact was a sister (37%, 95% CI:0% to 85%) or a brother (34%, 95% CI:8% to 66%). Immediate neighbors and coworkers did not exhibit any significant effects on a principal's drinking behavior.

These analyses were repeated for abstention behavior and showed broadly similar results. The effect of female friends abstaining (42%, 95% CI: 9% to 84%) was about the same size as the effect of male friends abstaining (44%, 95% CI: -3% to 106%), though the latter was barely insignificant. Abstaining wives, on the other hand, did appear to exhibit somewhat more influence (74%, 95% CI: 40% to 115%) than husbands (56%, 32% to 82%), but the effect of a sister (28%, 95% CI: 13% to 45%) was actually somewhat weaker than the effect of a brother (39%, 95% CI: 19% to 60%). Once again, immediate neighbors and coworkers had no effect on a principal's drinking behavior with respect to abstention.

Discussion

Alcohol consumption behavior among individuals and others in their social networks is highly correlated. Interpersonal effects with respect to alcohol behavior vary in size according to the type of relationship. One possible way in which induction of these effects may occur is through social norms (10,12,32-35); unfortunately, the study data does not include any measures of attitudes towards alcohol consumption, and claims about the underlying mechanisms for the network effects must remain speculative.

These general findings correspond with previous literature on obesity, smoking, happiness, and depression (10,11,12,13,14), though there are specific patterns of spread that appear to be particular to alcohol use. One unique pattern found in this study relates to the bimodal nature of the social network effects. While network effects were found for smoking cessation (11) (a positive health outcome) and for gaining weight (10) (a negative health outcome), in the case of alcohol consumption, there appears to be a bi-directionality of the effect with respect to both heavy drinking and abstaining. This finding suggests that social network effects may have both positive and negative health consequences for alcohol consumption behavior, depending on the circumstances.

Another important finding relates to the role of gender in the spread of alcohol consumption behavior. Our findings suggest that female contacts are significantly more likely to influence the spread of heavy alcohol consumption behavior than male contacts. While differences may have been expected in principals of different genders (i.e. men and women perceiving

peer influences and social norms about alcohol differently (36,37)), the effect of *contact* gender was unexpected. One possible explanation for these effects is that significant increases in drinking behavior among women are much less common and more often associated with dramatic shifts in roles and contexts in life, such as job changes and work stress, thus reflecting an impact of confounding factors (38). A related possibility is that changes in perceived norms towards drinking among women are more powerfully transmitted along social networks, possibly due to women usually being perceived as sharing norms for less alcohol consumption (37, 38). That is, a woman changing her behavior is a stronger stimulus.

While there are a number of significant associations in the results, it is important to revisit the question of whether they represent the spread of alcohol consumption behavior (induction) as opposed to reflecting selection effects (homophily) or shared environmental effects (confounding) (39, 40, 41). While it is impossible to completely rule out these alternative explanations, a number of our findings strongly suggest that induction plays an important role. For example, the directionality of friendship ties is significant in predicting the spread of alcohol consumption behavior; these effects provide some evidence for the inter-personal induction of alcohol consumption behavior and suggest that covariance in drinking between friends is not the result of unobserved contemporaneous exposures to both principal and contact. If it were, there should be an equally strong influence, regardless of the directionality of friendship. Moreover, the results show that neither immediate neighbors nor geographic distance modify alcohol consumption behavior. If shared exposure (such as proximity to liquor stores or local economic hardship) were key, the effects would decay with distance. Moreover, since the models control for a principal's prior drinking status, it is possible to account for sources of confounding that are stable over time (such as childhood exposures or genetic endowment). Finally, it is possible to control for a contact's prior drinking status, thus accounting for a possible tendency of drinkers to form ties among themselves. To help further control for homphily and environmental exposures, the authors are currently pursuing follow-up studies using econometric and experimental methods.

Limitations

This work has a few notable limitations. First, our outcome measure is not a clinical tool, so we cannot make any specific conclusions about the spread of alcohol related disorders *per se* in our sample. Second, it is not possible to estimate the relative negative health impact of increasing alcohol use, since alcohol use has been reported to have both positive and negative health effects. For example, moderate alcohol use is consistently associated with a lower risk (relative to abstention) for myocardial infarction in prospective cohort studies (43). This beneficial effect of moderate alcohol intake has been found to hold even for men with relatively healthy lifestyles (44,45). In addition to these cardiovascular effects, some evidence also suggests that mild to moderate alcohol intake may be related to better cognitive functioning in older adults (46). Therefore, network effects that both increase and decrease alcohol consumption could have health benefits. Third, this sample is ethnically (but not socioeconomically) homogenous. Finally, all network ties are observed in the dataset. This leaves open the potential that our estimates may be biased.

Conclusion

Our results support the basic idea that, since people are connected, their health is also connected. Network phenomena might be exploited to spread positive health behaviors, a suggestion supported by numerous prior studies in the domain of drinking. For example, drinking cessation programs that provide peer support – that is, that modify the social network of the target – are more successful (47,48,49). Interestingly, the oldest peer social support network in the country, Alcoholics Anonymous, is specifically designed to help

foster social network connections to encourage abstinence among its members and to foster ties between principals and principal-identified contacts known as “sponsors.” Alcoholics Anonymous reflects the creation of a kind of deliberate social network. Not only bad, but also good, behaviors may spread across a range of social ties at some distance from their origin. More generally, our findings reinforce the idea that drinking is a public health and clinical problem that involves groups of inter-connected people who evince shared behaviors, and targeting these behaviors would rightly involve addressing groups of people and not just individuals.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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References

1. Substance Abuse and Mental Health Services Administration. Results from the 2002 National Survey on Drug Use and Health: National Findings. :2003.Office of Applied StudiesRockville, MD NHSDA 1999 Series H-22, DHHS Publication No. SMA 03–3836.
2. Naimi T, Brewer B, Mokdad A, Serdula M, Denny C, Marks J. Binge drinking among U.S. adults. JAMA. 2003; 289:70–5. [PubMed: 12503979]
3. Kelley, JF.; Renner, JA. Alcohol-Related Disorders.. In: Stern, T.; Rosenbaum, J.; Biederman, J.; Fava, M.; Rauch, S., editors. The MGH Textbook of Comprehensive Clinical Psychiatry. Mosby-Elsevier; Philadelphia: 2008.
4. Prescott CA, Kendler KS. Genetic and Environmental Contributions to alcohol abuse and dependence in a population-based sample of male twins. Am J Psychiatry. 1999; 156:34–40. [PubMed: 9892295]
5. Reifman A, Barnes G, Dintcheff B, Farrell M, Uhteg L. Parental and peer influences on the onset of heavier drinking among adolescents. Journal of Studies on Alcohol. 1998; 59:311–318. [PubMed: 9598712]
6. Duncan GJ, Boisloy J, Kremer M, Levy DM, Eccles J. Peer Effects in Drug use and Sex among College Students. Journal of Abnormal Child Psychology. 2005; 33(3):375–385. [PubMed: 15957564]
7. Galea S, Nandi A, Vlahov D. The Social Epidemiology of Substance Abuse. Epidemiologic Reviews. 2004; 26:36–52. [PubMed: 15234946]
8. Pagan JL, Rose RJ, Viken RJ, Pulkinnen L, Kaprio J, Dick DM. Genetic and Environmental Influences on Stages of Alcohol Use Across Adolescence and into Young Adulthood. Behavioral Genetics. 2006; 36:483–497. 4.
9. Newman MEJ. The structure and function of complex networks. SIAM Review. 2003; 45:167–256.
10. Christakis NA, Fowler JH. The Spread of Obesity in a Large Social network over 32 years”. The New England Journal of Medicine. 2007; 357:370–379. [PubMed: 17652652]
11. Christakis NA, Fowler JH. The Collective Dynamics of Smoking in a Large Social Network”. The New England Journal of Medicine. 2008; 358:2249–2258. [PubMed: 18499567]
12. Fowler JH, Christakis NA. Dynamic spread of happiness in a large social network: longitudinal analysis over 20 years in the Framingham Heart Study. British Medical Journal. 2008; 337:a2338. [PubMed: 19056788]

13. Christakis, NA.; Fowler, JH. Connected: The Suprising Power of Our Social Networks and How They Shape Our Lives. Little Brown; New York: 2009.
14. Rosenquist, JN.; Christakis, NA.; Fowler, JH. The Spread of Depressive Symptoms in a large social network over 32 years.. Working Paper
15. Bearman PS, Moody J. Suicide and Friendships among American Adolescents. Am J Pub Health. 2004; 94(1):89–95. [PubMed: 14713704]
16. Kannel WB, Feinleib M, McNamara PM, et al. An investigation of coronary heart disease in families: The Framingham offspring study. Am J Epidemiol. 1979; 110:281–290. [PubMed: 474565]
17. Fitzpatrick, GL.; Modlin, ML. Direct-Line Distances: International Edition. The Scarecrow Press; Metuchen, N.J.: 1986.
18. Del Boca FK, Darkes J. The validity of self-reports of alcohol consumption: state of the science and challenges for research. Addiction. 2003; S2:1–12. [PubMed: 14984237]
19. Substance Abuse and Mental Health Services Administration. 1998 National Survey on Drug Use and Health: Main Findings. Office of Applied Studies, NSDUH; Rockville, MD: 1999. 1999
20. Substance Abuse and Mental Health Services Administration. 2002 National Survey on Drug Use and Health: Main Findings. Office of Applied Studies, NSDUH; Rockville, MD: 2003.
21. Szabo, G.; Barabasi, AL. [September 9th, 2009] Network Effects in Service Usage. arXiv.org (Publisher) PDF Available at http://lanl.arxiv.org/abs/physics/0611177
22. Kamada T, Kawai S. An algorithm for drawing general undirected graphs. Information Processing Letters. 1989; 31:7–15.
23. McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: homophily in social networks. Annual Review of Sociology. 2001; 27:415–444.
24. Sackett DL, Anderson GD, Milner R, Feinleib M, Kannel WB. Concordance for coronary risk factors among spouses. Circulation. 1975; 52:589–595. [PubMed: 1080450]
25. Carrington, PJ.; Scott, J.; Wasserman, S. Models and Methods in Social Network Analysis. Cambridge University Press; New York: 2005.
26. Liang KY, Zeger SL. Longitudinal data analysis using generalized linear models. Biometrika. 1986; 73:13–22.
27. Schildcrout JS. Regression analysis of longitudinal binary data with time-dependent environmental covariates: bias and efficiency. Biostatistics. 2005; 6:633–652. [PubMed: 15917376]
28. Hosking JRM. Lagrange-Multiplier Tests of Time-Series Models Lagrange-Multiplier Tests of Time-Series Models. Journal of the Royal Statistical Society B. 1980; 42(2):170–181.
29. Fowler JH, Christakis NA. Estimating peer effects on health in social networks. Journal of Health Economics. 2008; 27(5):1400–1405. [PubMed: 18692263]
30. Tanner, Martin A. Tools for Statistical Inference: Methods for the Exploration of Posterior Distributions and Likelihood Functions. Spring-Verlag; New York: 1996.
31. Cacioppo J, Fowler JH, Christakis NA. Alone in the Crowd: The Structure and Spread of Loneliness in a Large Social Network. Journal of Personality and Social Psychology. 2008; 96(12) TBD (December 2009).
32. Berkowitz, AD. The Social Norms Approach: Theory, Research and Annotated Bibliography.. In: Newton, MA., editor. The Higher Education Center for Alcohol and Other Drug Prevention. U.S. Department of Education;
33. Borsari B, Carey KB. Peer influences on college drinking: A review of the research. Journal of Substance Abuse. 2001; 13:391–424. 2001. [PubMed: 11775073]
34. Borsari B, Carey KB. Descriptive and injunctive norms in college drinking: A meta-analytic integration. Journal of Studies on Alcohol. 2003; 64:331–341. [PubMed: 12817821]
35. Perkins HW. Social norms and the prevention of alcohol misuse in collegiate contexts. Journal of Studies on Alcohol. 2002; (Suppl. 14):164–172.
36. Prentice, DA.; Miller, DT. Pluralistic Ignorance and the Perpetuation of Social Norms by Unwitting actors.. In: Zanna, MP., editor. Advances in Social Psychology: Volume 28. Academic Press; 1996.

37. Wilsnack SC, Klassen AD, Schur BE, Wilsnack RW. Predicting Onset and Chronicity of Women's Problem Drinking: A 5-year Longitudinal Analysis. Amer Jour Pub Health. 1991; 81(3):305–318. [PubMed: 1994739]
38. Eagly, AH.; Wood, W.; Diekman, AB. Social Role Theory of Sex Differences and Similarities: A Current Appraisal.. In: Eckes, T.; Trautner, HM., editors. The Development Social Psychology of Gender. Lawrence Erlbaum Associates; Philadelphia: 2000.
39. Bullers S, Cooper ML, Russell M. Social network drinking and adult alcohol involvement: A longitudinal exploration of the direction of influence. Addictive Behaviors. 2001; 26:181–199. [PubMed: 11316376]
40. Peterson PL, Hawkins JD, Abbott RD, Catalano RF. Disentangling the Effects of Parental Drinking, Family Management, and Parental Alcohol Norms on Current Drinking by Black and White Adolescents. Journal of Research on Adolescence. 1994; 4(2):203–227.
41. McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: homophily in social networks. Annual Review of Sociology. 2001; 27:415–444.
42. Granovetter MS. The strength of weak ties. American Journal of Sociology. 1973; 78:1360–80.
43. Maclure M. Demonstration of deductive meta-analysis: ethanol intake and risk of myocardial infarction. Epidemiol Rev. 1993; 15:328–351. [PubMed: 8174661]
44. Mukamal KJ, Chiuve SE, Rimm EB. Alcohol consumption and risk for coronary heart disease in men with healthy lifestyles. Arch Intern Med. 2006; 166:2145–50. [PubMed: 17060546]
45. Espeland MA, Coker LH, Wallace R, Rapp SR, Resnick SM, Limacher M, Powell LH, Messina CR, Women's Health Initiative Study of Cognitive Aging. Association between alcohol intake and domain-specific cognitive function in older women. Neuroepidemiology. 2006; 27:1–12. [PubMed: 16717476]
46. Reid MC, Van Ness PH, Hawkins KA, Towle V, Concato J, Guo Z. Light to moderate alcohol consumption is associated with better cognitive function among older male veterans receiving primary care. J Geriatr Psychiatry Neurol. 2006; 19:98–105. [PubMed: 16690995]
47. Wing RR, Jeffery RW. Benefits of recruiting participants with friends and increasing social support for weight loss and maintenance. Journal of Consulting & Clinical Psychology. 1999; 67:132–8. [PubMed: 10028217]
48. Malchodi CS, Oncken C, Dornelas EA, Caramanica L, Gregonis E, Curry SL. The effects of peer counseling on drinking cessation and reduction. Obstetrics & Gynecology. 2003; 101:504–10. [PubMed: 12636954]
49. McKnight AJ, McPherson K. Evaluation of peer intervention training for high school alcohol safety education. Accident Analysis & Prevention. 1986; 18:339–47. [PubMed: 3741584]

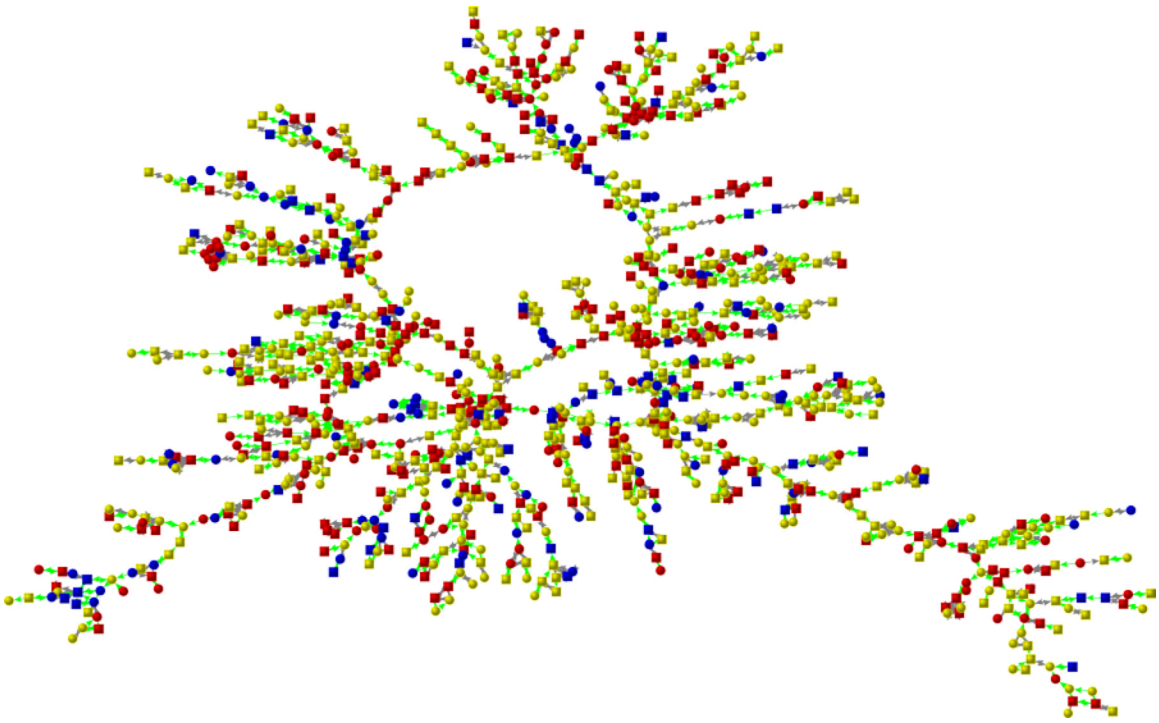

Figure 1. Drinking in the Framingham Social Network in 2000

This graph shows a sample the largest component of friends, spouses, and siblings at exam 7 (centered on the year 2000). There are 1,073 individuals shown. Each node represents a subject and its shape denotes gender (circles are male, squares are female). Lines between nodes indicate relationship (grey for siblings, green for friends and spouses). Node color denotes alcohol consumption behavior: red nodes indicate abstention, blue nodes indicate heavy drinking (more than one drink per day for women and more than two drinks per day for men), and yellow nodes indicate moderate intake between these two extremes. The graph suggests clustering in abstention and heavy alcohol consumption behavior, both of which are confirmed by statistical models discussed in the main text and presented in the supplement.

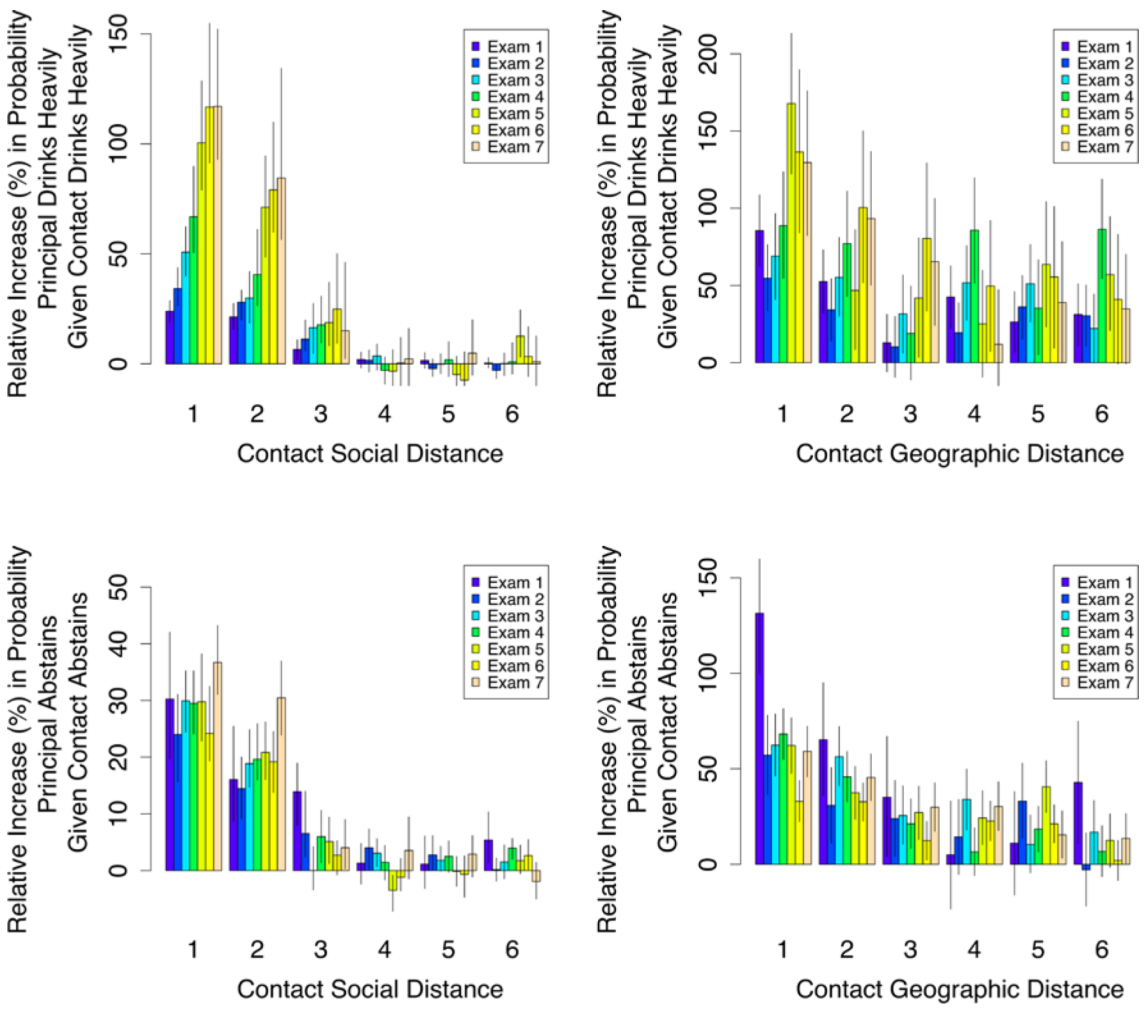

Figure 2. Relationship of Social and Geographic Distance to Heavy Drinking and Abstaining in Connected Persons

Top panels show the effect of social and geographic distance from heavy-drinking contacts on the probability that a principal is a heavy drinker in the Framingham Heart Study Social Network. Heavy drinking is defined in this case as having more than one drink per day for women and more than two drinks per day for men. The effects were derived by comparing the conditional probability of drinking in the observed network with an identical network (with topology preserved) in which the same number of heavy drinkers is randomly distributed. In the panel on the left, contact social distance refers to closest social distance (or degree of separation) between the contact and principal (e.g. direct friend = distance 1, friend's friend = distance 2, etc.). In the panel on the right, we ranked all physical distances between homes of directly connected principals and contacts (*i.e.*, just those pairs at one degree of separation) and created six equally sized groups (1 = closest, 6 = farthest). The average distances for these six groups are: 1 = 0 miles; 2 = 0.26 miles; 3 = 1.5 miles; 4 = 3.4 miles; 5 = 9.3 miles; and 6 = 471 miles. There is no trend across physical distance. The bottom panels show the same kinds of analyses for the effect of abstaining contacts on the probability that principal abstains.

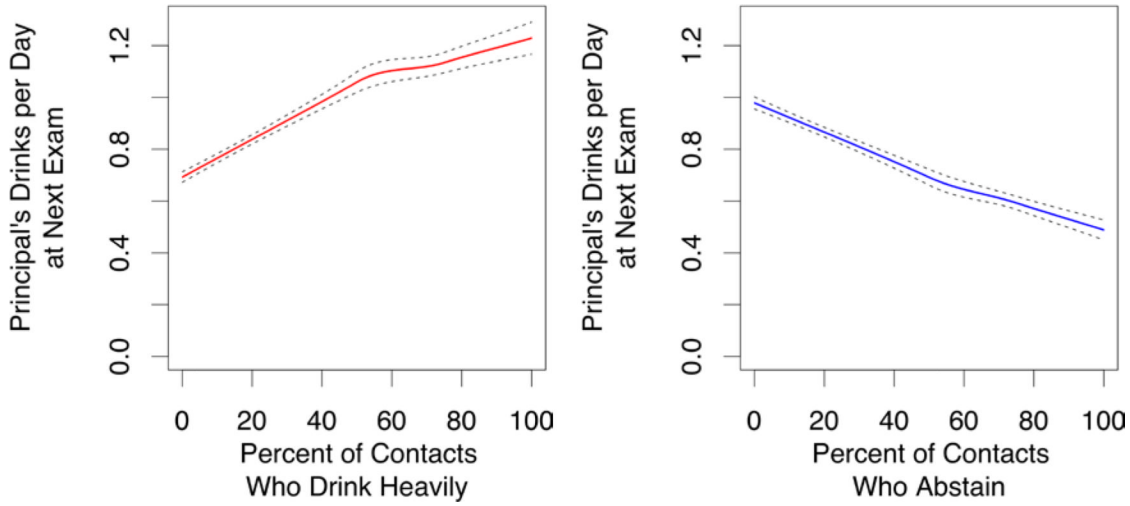

Figure 3. Effect of Heavy Drinking and Abstaining Contacts on Principals in the Framingham Social Network

This plot shows that future alcohol consumption behavior is positively associated with the fraction of friends and family who are heavy drinkers (red line) and negatively associated with the fraction of friends and family in the previous exam that are abstainers (blue line). Both lines based on bivariate LOESS regression, and dotted lines indicate 95% confidence intervals.

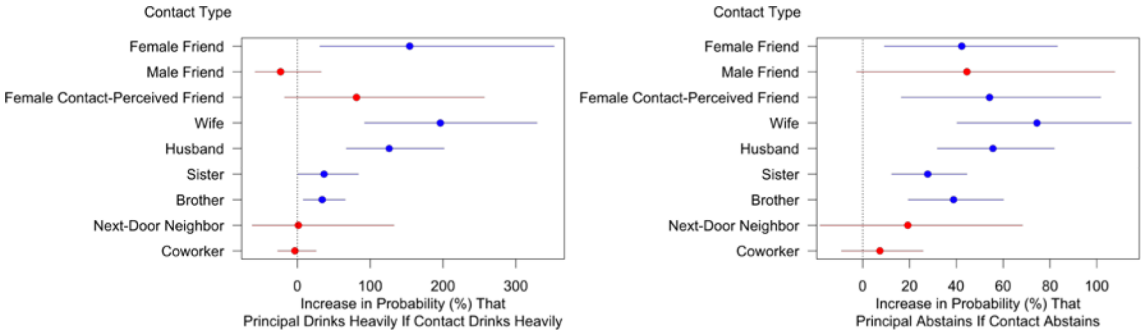

Figure 4. Contact Type and Drinking in the Framingham Social Network

This graph shows the change in principal alcohol consumption behavior given contact alcohol consumption behavior. The left panel focuses on heavy drinking (more than one drink per day for women and more than two drinks per day for men) and the right panel focuses on abstention. Estimates based on generalized estimating equation logit models of drinking on several different sub-samples of the Framingham Heart Study Social Network. The dependent variable in each model is principal drinking status and independent variables include lagged principal drinking status, contact drinking status, lagged contact drinking status, principal age, gender, and education, and fixed effects for each wave. Full models and equations are available in the appendix. Mean effect sizes and Bonferroni-corrected 95% confidence intervals were calculated by simulating first difference in contact contemporaneous drinking (changing from 0 to 1) using 1,000 randomly drawn sets of estimates from coefficient covariance matrix and assuming all other variables are held at their means.

Table 1

Summary Statistics for Principals

	Mean	S.D.	Min.	Lower Quartile	Upper Quartile	Max.
Continuous Variables, All Waves						
Drinks per Day	0.88	1.29	0	0	1	17
Number of Close Friends	0.96	0.88	0	0	1	9
Number of Family Members	3.07	3.59	0	0	5	29
Number of Contacts	2.70	1.89	1	1	4	19
Number of Contacts Who Abstain	0.79	1.02	0	0	1	10
Number of Contacts Who Drink Heavily	0.56	0.81	0	0	1	7
Years of Education	13.70	2.29	2	12	16	17
Age	50.87	12.66	21	42	60	90
Dichotomous Variables, All Waves						
Abstains	29%					
Drinks Heavily	18%					
Female	52%					
Continuous Variables, Wave 1						
Drinks per Day	1.06	1.45	0	0	1	14
Number of Close Friends	1.07	0.84	0	1	1	7
Number of Family Members	3.67	3.96	0	0	6	29
Number of Contacts	3.11	2.17	1	1	4	17
Number of Contacts Who Abstain	0.50	0.80	0	0	1	6
Number of Contacts Who Drink Heavily	0.76	0.95	0	0	1	6
Years of Education	13.70	2.29	2	12	16	17
Age	38.06	9.50	21	30	45	70
Dichotomous Variables, Wave 1						
Abstains	15%					
Drinks Heavily	22%					
Female	52%					

This table shows summary statistics for the 5,124 members of the FHS offspring cohort who served as principals in the analyses. Averages are across all seven waves of the study in the top half of the table and for wave 1 in the bottom half.

Table 2

Average Age and Alcohol Consumption Behavior, by Exam

	Mid-point Year of Exam	Age	Drinks per Day	Percent Abstainers	Percent Heavy Drinkers
Exam 1	1972	46.8	1.04	18.7	22.2
Exam 2	1981	53.0	0.99	30.1	21.8
Exam 3	1986	55.2	0.88	34.2	18.5
Exam 4	1989	57.5	0.76	35.8	15.6
Exam 5	1993	60.0	0.70	35.9	14.4
Exam 6	1997	63.1	0.63	42.5	12.7
Exam 7	2000	64.7	0.70	37.8	14.9

Average age for principals across each exam wave. Heavy drinkers defined as averaging more than 2 drinks per day for men and 1 drink per day for women