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The Spread of Alcohol Consumption Behavior in a Large Social Network

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

Objective: To explore quantitatively whether alcohol consumption behavior spreads from person to person in a large social network of friends, coworkers, siblings, spouses, and neighbors, followed for 32 years.

Design: Longitudinal network cohort study.

Setting: The Framingham Heart Study.

Participants: 12 067 persons assessed at several time points between 1971 and 2003.

Measurements: Self-reported alcohol consumption (number of drinks per week on average over the past year and number of days drinking within the past week) and social network ties, measured at each time point.

Results: Clusters of drinkers and abstainers were present in the network at all time points, and the clusters extended to 3 degrees of separation. These clusters were not only due to selective formation of social ties among drinkers but also seem to reflect interpersonal influence. Changes in the alcohol consumption behavior of a person's social network had a statistically significant effect on that person's subsequent alcohol consumption behavior. The behaviors of immediate neighbors and coworkers were not significantly associated with a person's drinking behavior, but the behavior of relatives and friends was.

Limitations: A nonclinical measure of alcohol consumption was used. Also, it is unclear whether the effects on long-term health are positive or negative, because alcohol has been shown to be both harmful and protective. Finally, not all network ties were observed.

Conclusion: Network phenomena seem to influence alcohol consumption behavior. This has implications for clinical and public health interventions and further supports group-level interventions to reduce problematic drinking.

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Alcohol use is common in the United States. In 2002, 55% of adults reported having had at least 1 drink in the previous month, and the prevalence of past-month alcohol consumption was somewhat higher for men (62%) than for women (48%) (1). 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 for numerous health and social problems (2, 3), and approximately 75 000 deaths in 2001 were attributable to excessive alcohol use, which makes it the third-leading lifestyle-related cause of death (3).

Alcohol consumption behavior has many determinants. Previous studies (3, 4) suggest that biological factors have a significant effect on the progression from experimentation to regular use and that social and cultural factors play a critical role in experimentation with alcohol and the development of drinking patterns over time. 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 (4–8). Although this literature primarily focused on cross-sectional panels, some studies (6–8) have attempted to test whether social influences act over time. These studies, which focused on peer influence among college students, showed inconsistent results and tended to focus just on pairs of connected persons.

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

Using a longitudinal, dynamic network of 12 067 persons, we analyzed the role of social networks in alcohol use, focusing on 1) whether clusters of heavy drinkers and abstainers existed within the network; 2) whether a person's alcohol consumption behavior was associated with that of his or her social contacts; 3) the extent to which such associations depended on the nature and direction of the social ties (for example, friends of different kinds, siblings, spouses, coworkers, or neighbors); and 4) whether gender affected the spread of alcohol consumption across social ties.

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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, who mostly represent different generations linked to an original cohort, are included in the entire FHS. Participant data, collected every 2 to 4 years, includes physical examinations, laboratory tests, noninvasive cardiac and vascular testing, battery testing (such as the Mini-Mental State Examination), questionnaire results, and basic demographic information. For our analyses, we aligned the examination waves for the original cohort with those of the second-generation offspring cohort, which allowed us to treat all participants as having been examined in 7 waves. The offspring cohort, initiated in 1971, is the source of our study's principals, or focal individuals in the network (16). However, we included other FHS participants whom the principals listed as social contacts and refer to them here as "contacts." Therefore, even though 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, we created a separate data set that linked individuals through self-described social ties, collected in each of the 7 waves of the study. We could then detect relationships between participants (for example, spouse, sibling, friend, coworker, or neighbor) and observe changes in these ties across time. Either party to a link between 2 people might identify his or her link to the other. This is most relevant to the "friend" link, which could exist if A nominated B or B nominated A as a friend. We also used complete records of participants' and their contacts' address in each wave since 1971 in our analyses, although we have no information about relationships that participants did not report. For each wave, we could determine who is whose neighbor and the geographic distance between persons (10, 17). **Table 1** provides descriptive statistics for the 5124 principals in our sample.

Measures

Alcohol consumption was self-reported in all studied waves, with participants reporting their average number of drinks per week over the past year as well as the number of days within the past week during which they consumed alcohol (beer, wine, and liquor). Self-reported data are generally considered a valid and reliable source when assessing alcohol consumption, although recall measures, such as those used in this study, can be subject to recall bias from participants (18).

We treated alcohol consumption as a continuous variable in some analyses (for example, number of drinks per day, calculated from participant responses) but conducted others with dichotomous cut-points, defining heavy drinkers as those who averaged more than 1 (for women) or 2 (for men) drinks per day; moderate drinkers as those whose alcohol consumption was less than the cutoff values for heavy drinkers; and abstainers as those who reported no alcohol consumption. We did not use self-reported number of days drinking in the past week as a measure in and of itself but rather as a means to calculate average number of drinks in a day. (These labels do not reflect clinical definitions of alcohol abuse or dependence.) **Table 2** shows averages for the study population across time, including age, alcohol consumption, and percentages of abstainers and drinkers. Although the differences in how we measured heavy drinking made it difficult to compare our results with those for other population samples, 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).

Context

A person's alcohol use might mirror that of his or her social contacts.

Contribution

Using the same group of Framingham Heart Study participants who helped to define the associations between social networks and other health behaviors, the researchers found that alcohol use was similar among individuals in a social cluster. Furthermore, changes in a person's alcohol intake over time followed changes in the alcohol intake of their social contacts.

Caution

Alcohol use was self-reported, and the researchers did not have access to social contacts who were not participating in the study.

Implication

Changing alcohol use may require intervening with social groups as well as with individuals.

—The Editors

Statistical Analysis

Our first goal was to evaluate whether a person's alcohol consumption behavior was associated with that of his or her social network ties at various degrees of separation. To test this hypothesis, we took an observed clustering of persons (and their alcohol consumption behavior) within the whole network and compared them with 1000 simulated networks with the same topology and overall prevalence of drinking as the observed network, but with the incidence of drinking (for example, at least 1 drink per day) randomly distributed across the nodes ("random drinking networks"). If clustering occurs in drinking behavior, then the probability that 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, which itera-

Table 1. **Summary Statistics for Principals**

Variables	Principals, %	Mean (SD)	Minimum	Lower Quartile	Upper Quartile	Maximum
All waves						
Continuous						
Drinks per day, *n*	–	0.88 (1.29)	0	0	1	17
Close friends, *n*	–	0.96 (0.88)	0	0	1	9
Family members, *n*	–	3.07 (3.59)	0	0	5	29
Contacts, *n*	–	2.70 (1.89)	1	1	4	19
Contacts who abstain, *n*	–	0.79 (1.02)	0	0	1	10
Contacts who drink heavily, *n*	–	0.56 (0.81)	0	0	1	7
Education, *y*	–	13.70 (2.29)	2	12	16	17
Age, *y*	–	50.87 (12.66)	21	42	60	90
Dichotomous, *n*						
Abstainers	29	–	–	–	–	–
Heavy drinkers	18	–	–	–	–	–
Women	52	–	–	–	–	–
Wave 1						
Continuous						
Drinks per day, *n*	–	1.06 (1.45)	0	0	1	14
Close friends, *n*	–	1.07 (0.84)	0	1	1	7
Family members, *n*	–	3.67 (3.96)	0	0	6	29
Contacts, *n*	–	3.11 (2.17)	1	1	4	17
Contacts who abstain, *n*	–	0.50 (0.80)	0	0	1	6
Contacts who drink heavily, *n*	–	0.76 (0.95)	0	0	1	6
Education, *y*	–	13.70 (2.29)	2	12	16	17
Age, *y*	–	38.06 (9.50)	21	30	45	70
Dichotomous, *n*						
Abstainers	15	–	–	–	–	–
Heavy drinkers	22	–	–	–	–	–
Women	52	–	–	–	–	–

tively repositions nodes to reduce the number of ties that cross each other, to draw the networks (22).

Our second goal was to examine the possible determinants of any clustering in alcohol consumption behavior. We considered 3 explanations for nonrandom clustering of alcohol consumption behavior in the network: principals might choose to associate with like contacts (homophily) (23, 24); 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 contacts might exert social influence or peer effects on principals (induction). The availability of dynamic, longitudinal data on both network connections and drinking behavior allowed us to distinguish between interpersonal induction of drinking and homophily (25).

Our basic statistical approach involved specifying longitudinal logistic regression models in which a principal's drinking status at time $t + 1$ is a function of his or her various attributes, such as age, sex, and education; his or her drinking status at time t; and the drinking status of his or her contacts at times t and $t + 1$ (25). We used generalized estimating equation procedures to account for multiple observations of the same principal across both waves and principal–contact pairings (26). We assumed an independent working correlation structure for the clusters (27).

By using a time-lagged dependent variable (lagged to the previous examination) for alcohol consumption, we

Table 2. **Average Age and Alcohol Consumption Behavior, by Examination**

Examination	Midpoint Year of Examination	Age, *y**	Drinks per Day, *n*	Abstainers, %	Heavy Drinkers, %†
1	1972	46.8	1.04	18.7	22.2
2	1981	53.0	0.99	30.1	21.8
3	1986	55.2	0.88	34.2	18.5
4	1989	57.5	0.76	35.8	15.6
5	1993	60.0	0.70	35.9	14.4
6	1997	63.1	0.63	42.5	12.7
7	2000	64.7	0.70	37.8	14.9

* Average age of principals across each examination wave.
† Defined as averaging more than 2 drinks per day for men and 1 drink per day for women.

eliminated serial correlation in the errors (28) (evaluated with a Lagrange multiplier test) and substantially controlled for the principal's genetic endowment and any intrinsic, stable predilection to drink. In addition, the lagged independent variable for a contact's drinking status substantially controlled 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 that affect both of their alcohol consumption behaviors. We tested the possibility that omitted variables or unobserved events could explain the associations by examining how the type or direction of the social relationship between contacts affected the association between principal and contact drinking.

To calculate risk ratios and 95% CIs, we simulated the change in risk for principal drinking when contact contemporaneous drinking changes from 0 to 1 by using 1000 randomly drawn sets of estimates from the coefficient covariance matrix and assuming all other variables were held at their means (30). All of these tests are 2-tailed. For repeated tests that involved different types of social contacts, we applied a Bonferroni correction to the CIs.

We assessed the sensitivity of the results with multiple additional analyses (**Appendix**, available at www.annals.org). For example, we considered the possible effect 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. We found no significant correlation between number of drinks per day and number of ties to people outside the study ($\rho = 0.01$; $P = 0.15$), which suggests that the network data generation procedure did not bias the analyses.

Role of the Funding Source

The study was supported by the National Institutes of Health and the Robert Wood Johnson Foundation. The funding sources played no role in the design, conduct, or analysis of this study. Each researcher's institutional review board approved the study.

RESULTS

The **Appendix Figure**, available at www.annals.org, shows the largest connected subcomponent of the social network of friends, spouses, and siblings in the year 2000. Clusters of drinkers and abstainers can be seen in the network.

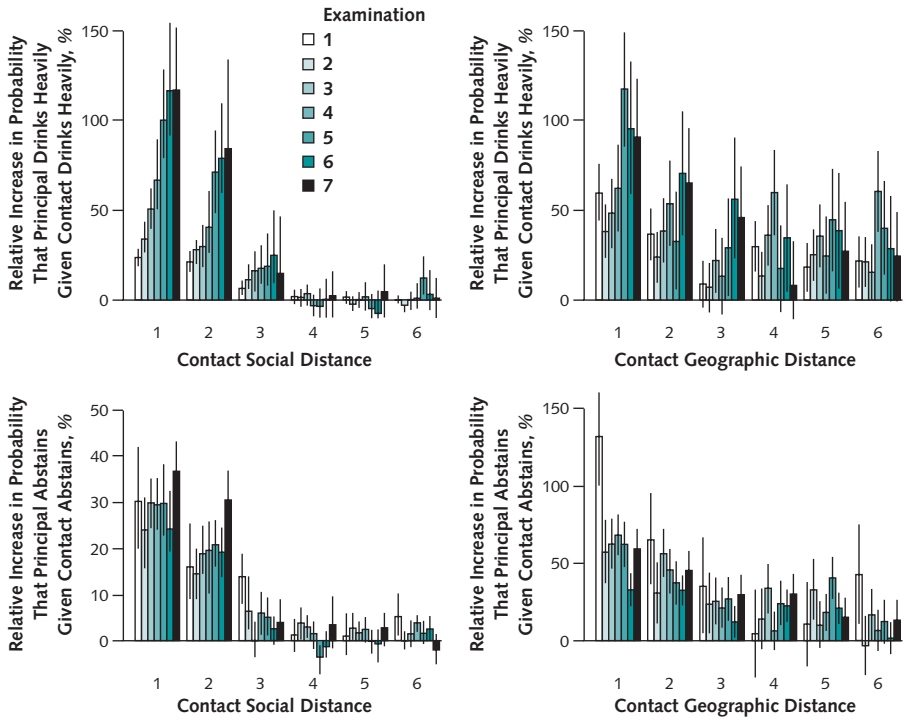
Figure 1 shows the correlation between principals and contacts with regard to their drinking behavior (the **Appendix**, available at www.annals.org, contains numerical results for this and the other figures). Our results indicate that principals are 50% (95% CI, 40% to 62%) more likely to drink heavily if a person they are directly connected to (1 degree of separation) drinks heavily. The size of the effect is 36% (CI, 25% to 48%) for people at 2 degrees of separation (such as the friend of a friend) and 15% (CI, 8% to 25%) for people at 3 degrees of separation (such as the friend of a friend of a friend). The effect disappears at 4 degrees of separation (4% [CI, −2% to 10%]), which is consistent with the "3 degrees of influence" rule of social network contagion that has been shown 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 persons are 29% (CI, 23% to 36%) more likely to abstain if someone they are directly connected to (1 degree of separation) abstains. The size of this effect is 21% (CI, 16% to 27%) at 2 degrees of separation and 5% (CI, 1% to 10%) at 3 degrees of separation, and it disappears at 4 degrees of separation (2% [CI, −1% to 6%]).

Of note, the decline in effect size with social distance in **Figure 2** contrasts with a lack of decline in effect size as people become more geographically distant from one another. We confirmed this by testing an interaction between distance and the effect size. Our results suggest that 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 of social contacts affects a person's alcohol consumption behavior. **Figure 3** shows the smoothed bivariate relationship between the fraction of a principal's friends and family who drank heavily or abstained at one examination and the average number of drinks per day that principal reported at the next examination. Being surrounded by heavy drinkers increased the reported alcohol consumption by about 70% (CI, 35% to 142%) compared with those who were not connected to any heavy drinkers. Conversely, being surrounded by abstainers decreased reported alcohol consumption by half.

When we controlled for age, sex, education, and examination and regressed each principal's future alcohol consumption behavior on the basis of number of contacts who were heavy drinkers, moderate drinkers, or abstainers, we found that each additional heavy drinker increased the likelihood that a principal drank heavily by 18% (CI, 11% to 25%; $P < 0.001$) and decreased the likelihood that a principal abstained by 7% (CI, 2% to 12%; $P = 0.009$) but had no effect on moderate alcohol consumption behavior (CI, −8% to 1%; $P = 0.113$). Conversely, each additional abstainer significantly reduced the likelihood that a principal drank heavily by 10% (CI, 4% to 15%; $P = 0.001$), increased the likelihood that a principal abstained by 22% (CI, 17% to 28%), and decreased the likelihood that a principal drank moderately by 11% (CI, 8% to 14%). Finally, each additional moderate drinker had no significant effect on whether a principal drank heavily (CI, −2% to 7%; $P = 0.214$) but significantly decreased the probability that he or she abstained by 5% (CI, 2% to 9%) and increased the likelihood that he or she drank moderately by 6% (CI, 2% to 9%).

Figure 1. **Relationship of social and geographic distance to heavy drinking and abstaining in connected persons.**



We derived effects 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 or abstainers were randomly distributed. "Contact social distance" refers to the closest social distance (or degree of separation) between the contact and principal (for example, a direct friend = 1 and a friend's friend = 2). For geographic distance, we ranked all physical distances between the homes of directly connected principals and contacts (pairs at 1 degree of separation) and created 6 equally sized groups (1 = closest, 6 = farthest). The average distances for these groups are 0 miles (group 1), 0.26 mile (group 2), 1.5 miles (group 3), 3.4 miles (group 4), 9.3 miles (group 5), and 471 miles (group 6).

We next evaluated the extent of paired, interpersonal association in alcohol consumption behavior. As discussed, our 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 that involved various principal–contact pairings. **Figure 3** summarizes the associations from the models (the **Appendix**, available at www.annals.org, contains numerical results). With respect to friends, we found significant sex 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% (CI, 30% to 354%). In contrast, a male friend's heavy alcohol consumption behavior seemed to have no significant effect on the principal. The type of friendship also seemed to be important: A woman did not seem to have a significant effect if she thought of the principal as a friend, but not vice versa (a contact-perceived friend), but the overlapping CIs indicate that the difference in the effect size is not significant. Sex also played a role among spouses. Heavy drinking by a wife increased the likelihood that the husband drank heavily by 196% (CI, 91% to 329%), whereas heavy drinking by a husband increased the likelihood that a wife drank heavily by 126% (CI, 67% to 202%). Among siblings, the effect was significantly smaller and did not differ whether the contact was a sister (37% [CI, 0% to 85%]) or a brother (34% [CI, 8% to 66%]). Immediate neighbors and coworkers had no significant effects on a principal's drinking behavior.

We repeated our analyses for abstention behavior and found broadly similar results. The effect of female friends abstaining was about the same size as that of male friends abstaining (42% [CI, 9% to 84%] vs. 44% [CI, −3% to 106%]), although the latter was barely insignificant. Wives who abstained seemed to have more influence than husbands (74% [CI, 40% to 115%] vs. 56% [CI, 32% to 82%]), but the effect of a sister was weaker than that of a brother (28% [CI, 13% to 45%] vs. 39% [CI, 19% to 60%]). Once again, immediate neighbors and coworkers had no effect on a principal's drinking behavior with respect to abstention.

DISCUSSION

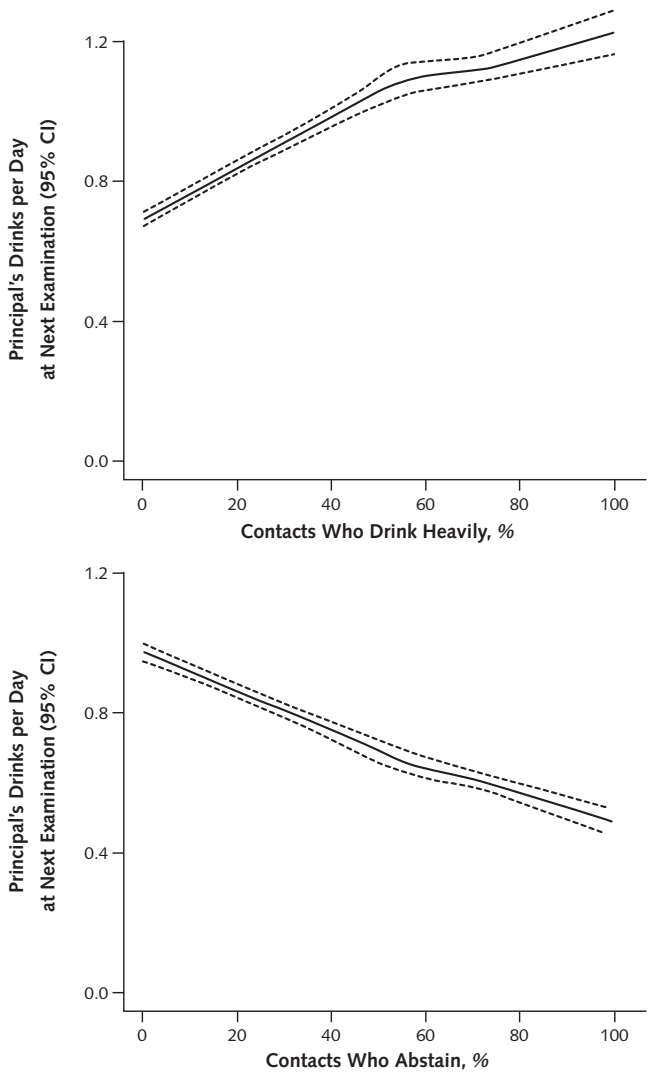
Alcohol consumption behavior among persons and those in their social networks is highly correlated. Interpersonal effects with respect to alcohol behavior vary in size according to the type of relationship. Induction of these

effects may occur through social norms (10, 12, 32–35); unfortunately, the study data include no measures of attitudes toward alcohol consumption, and claims about the underlying mechanisms for the network effects remain speculative.

Our general findings correspond with previous literature on obesity, smoking, happiness, and depression (10–14), although certain patterns of spread seem to be specific to alcohol use. One unique pattern we found relates to the bimodal nature of the social network effects. Whereas network effects were found for smoking cessation (11) (a positive health outcome) and for gaining weight (10) (a negative health outcome), the effect seems to be bidirectional in alcohol consumption with respect to both heavy drinking and abstaining. This suggests that social network effects may have both positive and negative health consequences for alcohol consumption behavior, depending on the circumstances.

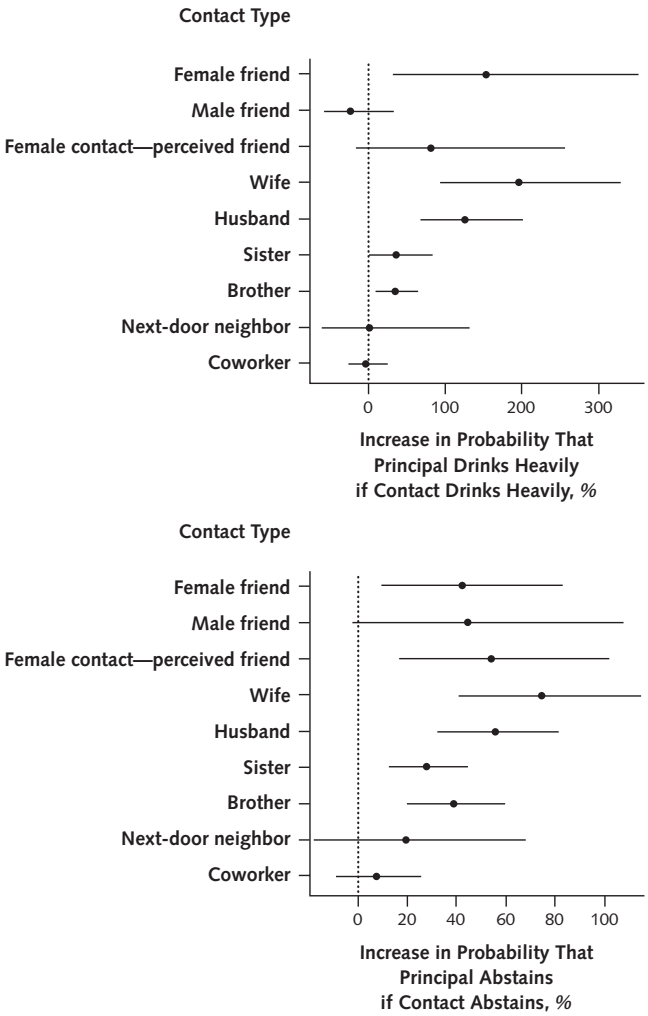
Another important finding relates to the role of sex in the spread of alcohol consumption behavior. Our findings suggest that female contacts are significantly more likely

Figure 2. **Effect of heavy drinking and abstaining contacts on principals in the Framingham Heart Study social network.**



Solid lines are based on bivariate LOESS regression, and dotted lines indicate 95% CIs. **Top.** Effect of contacts who drink heavily. **Bottom.** Effect of contacts who abstain.

Figure 3. **Contact type and drinking in the Framingham Heart Study social network.**



Changes in principal alcohol consumption given contact alcohol consumption are shown. Estimates are based on generalized estimating equation logit models of drinking in several subsamples of the Framingham Heart Study social network. The dependent variable in each model is principal drinking status. Independent variables include lagged principal drinking status; contact drinking status; lagged contact drinking status; principal age, sex, and education; and fixed effects for each wave. The **Appendix** (available at www.annals.org) contains full models and equations. To calculate mean effect sizes and Bonferroni-corrected 95% CIs, we simulated first difference in contact contemporaneous drinking (changing from 0 to 1) by using 1000 randomly drawn sets of estimates from the coefficient covariance matrix and assuming all other variables to be held at their means. **Top.** Effects of heavy drinking. **Bottom.** Effects of abstention.

than male contacts to influence the spread of heavy alcohol consumption behavior. Although differences may have been expected in principals of different sex (men and women perceiving peer influences and social norms about alcohol differently [36, 37]), the effect of contact sex was unexpected. One possible explanation 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, which would reflect the effect of confounding factors (38). A related possibility is that changes in perceived norms toward drinking among women are more powerfully transmitted along social networks, possibly because women are usually perceived as sharing norms for less alcohol consumption (37, 38) and a woman who changes her behavior would therefore be a stronger stimulus.

Although our results have several significant associations, it is important to revisit whether they represent the spread of alcohol consumption behavior (induction) or reflect selection effects (homophily) or shared environmental effects (confounding) (23, 39, 40). Although we cannot completely rule out these alternative explanations, several of our findings strongly suggest that induction plays an important role (41). First, the directionality of friendship ties is significant in predicting the spread of alcohol consumption behavior. This provides some evidence for the interpersonal induction of alcohol consumption behavior and suggests that covariance in drinking between friends is not the result of mutual unobserved contemporaneous exposures. If it were, the influence should be equally strong regardless of the directionality of friendship. Second, our results show that neither immediate neighbors nor geographic distance modifies alcohol consumption behavior. If shared exposure (such as proximity to liquor stores or local economic hardship) were key, the effects would decay with distance. Third, because our models control for a principal's previous drinking status, we can account for sources of confounding that are stable over time (such as childhood exposures or genetic endowment). Finally, we can control for a contact's previous drinking status, thus accounting for a possible tendency of drinkers to form ties among themselves. To further control for homophily and environmental exposures, we are currently pursuing follow-up studies that use econometric and experimental methods.

Our study has 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, we cannot estimate the relative negative health effect of increasing alcohol use, because 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 for myocardial infarction (relative to abstention) in prospective cohort studies (42). This beneficial effect of moderate alcohol intake has been found to hold even for men with relatively healthy lifestyles (43, 44). In addition to cardiovascular effects, some evidence suggests that mild to moderate alcohol intake may be related to better cognitive functioning in older adults (45). Therefore, network effects that increase or decrease alcohol consumption could both have health benefits. Third, our sample is ethnically (but not socioeconomically) homogenous. Finally, all network ties were observed in the data set, which means our estimates may be biased.

Our results support the basic idea that because persons are connected, their health is also connected. Network phenomena might be exploited to spread positive health behaviors, a suggestion supported by numerous studies in the domain of drinking. For example, drinking cessation programs that provide peer support—that modify the social network of the target—are more successful (46–48). Of note, 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 establish ties between principals and principal-identified contacts known as "sponsors." Alcoholics Anonymous reflects the creation of a kind of deliberate social network. Both good and bad behaviors may spread across a range of social ties at some distance from their origin. Our findings also reinforce the idea that drinking is a public health and clinical problem that involves groups of interconnected people who evince shared behaviors, and targeting these behaviors would rightly involve addressing groups and not just individuals.

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Reproducible Research Statement: *Study protocol and data set:* Not available. *Statistical code:* Available from Dr. Fowler (e-mail, jhfowler@ucsd.edu).

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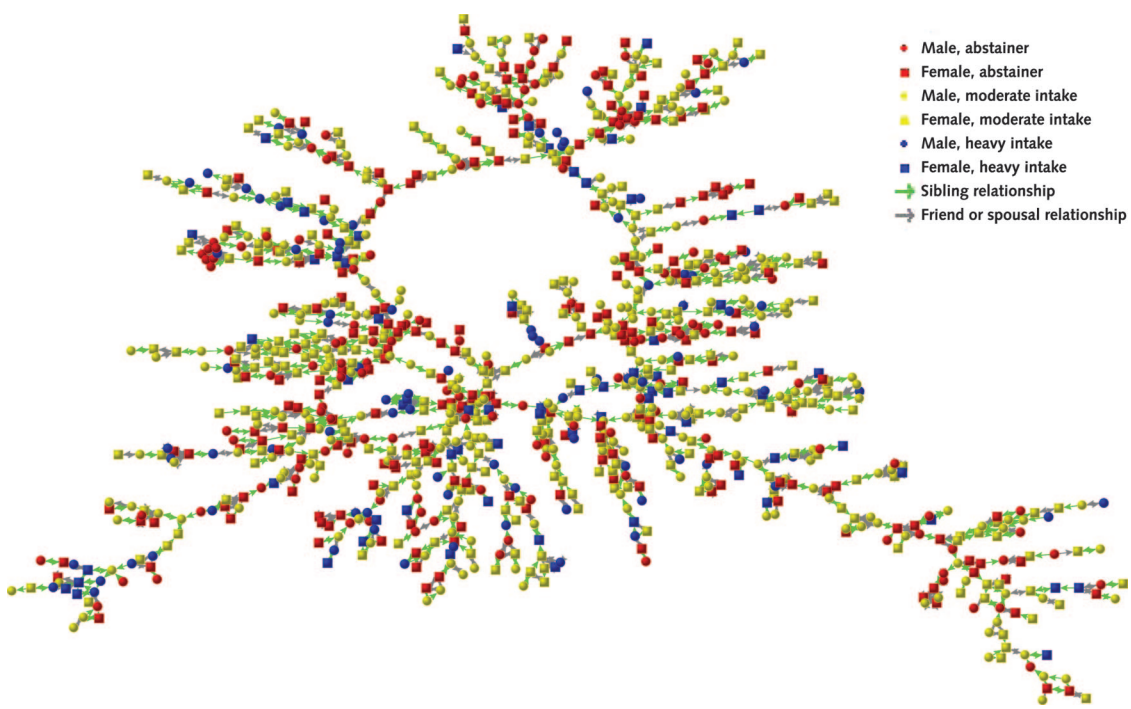
Appendix Figure. **Drinking in the Framingham Heart Study social network in 2000.**



A sample of the largest component of friends, spouses, and siblings at examination 7 (centered on the year 2000); 1073 individuals are shown. Each node represents 1 person. The graph suggests clustering in abstention and heavy alcohol consumption behavior, both of which are confirmed by statistical models.