Association Between Social Network Communities and Health Behavior: An Observational Sociocentric Network Study of Latrine Ownership in Rural India

Holly B. Shakya, PhD, Nicholas A. Christakis, MD, PhD, and James H. Fowler, PhD

Interconnected groups of individuals can shape the health-related behavior of the constituent individuals, in part by promulgating and enforcing group-specific social norms. An understanding of the process whereby such groups are assembled and such norms are enforced could be used to improve the health of both individuals and groups. Recently developed social network community detection techniques allow us to discern these groups and suggest ways of exploiting social processes to foster desirable behavior change in diverse settings,[1–3] and other work has begun to use network community detection to understand normative constraints in outcomes as diverse as smoking cessation[4] and adolescent delinquency.[5]

Descriptive norms are those regular behaviors that can be observed within a community and that can be adopted regardless of the expectations of others.[6] Injunctive norms, on the contrary, reflect community standards and are enforced through social sanctions; sanctions can be negative for transgressions or positive for conformity and can be as blatant as a public shaming or as subtle as unspoken disapproval.[7–10] Simply observing others' behaviors can unconsciously motivate action,[11] but injunctive norms are more complex, and may even be conflicting, because their primary function is to maintain social relationships.[12]

Medicine and public health have a rich tradition of efforts to change norms and hence move individuals and communities toward better health.[5,13,14] However, a key task of interventions seeking to do this is to identify the valid community or "reference group" for each individual in the population of interest. Normative change hinges on the fact that the individuals involved place a value on the expectations of those with whom they share social connections.[9,15,16] However, from which particular groups of people do individuals take

Objectives. We identified communities of interconnected people that might serve as normative reference groups for individual-level behavior related to latrine adoption.

Methods. We applied an algorithmic social network method to determine the network community from respondent-reported social ties of 16 403 individuals in 75 villages in rural Karnataka, India; data were collected from 2006 to 2008. We used multilevel modeling to test the association between latrine ownership and community-level and village-level latrine ownership. We also investigated the degree to which network cohesion affected individual latrine ownership.

Results. Three levels of social contacts (direct friends, social network community, and village) significantly predicted individual latrine ownership, but the strongest effect was found at the level of social network communities. In communities with high levels of network cohesion, the likelihood was decreased that any individual would own a latrine; this effect was significant only at lower levels of latrine ownership, suggesting a role for network cohesion in facilitating the nonownership norm.

Conclusions. Although many international health and development interventions target village units, these results raise the possibility that the optimal target for public health interventions may not be determined through geography but through social network interactions. (*Am J Public Health.* 2014;104:930–937. doi: 10.2105/AJPH.2013.301811)

their guidance? How is such a group defined? The theory of planned behavior, for instance, includes self-reported measures of reference groups subjectively defined as "people who are important to you."[17–19] Most research surveys (e.g., with outcomes as diverse as the use of contraception[20,21] or adolescent smoking[22]) have not collected data specific to social norms, requiring researchers instead to create measures of possible norms through the aggregation of existing measures and to infer reference groups from geographic boundaries, such as villages. However, does a valid reference group include (1) just those to whom one is directly connected (friends), (2) those to whom one is more broadly and indirectly connected (e.g., friends of friends), or (3) a still larger aggregation (e.g., the village or town in which one resides)? And are structural features of the network in which individuals are embedded relevant to the ability of reference groups to

enforce norms or stimulate the adoption of new behaviors?

Not only may the group one picks as a normative referent be relevant, but also the structure of the ties within that group may be crucial to any normative effect. Network cohesion is an important such structural characteristic. Cohesion can be quantified with transitivity, which is the probability that 2 of someone's social connections are connected to each other.[5,23-27] Transitivity can either constrain or compel adoption of complex behaviors (see Figure 1 for a theoretical illustration of this concept).[25,28,29] For example, people in more highly interconnected communities may be less likely to embrace behavior change because the strongly clustered nature of their social groups means that they may have little access to new information outside of their networks.[23,30] Furthermore, in highly interconnected communities, the effect of injunctive norms on
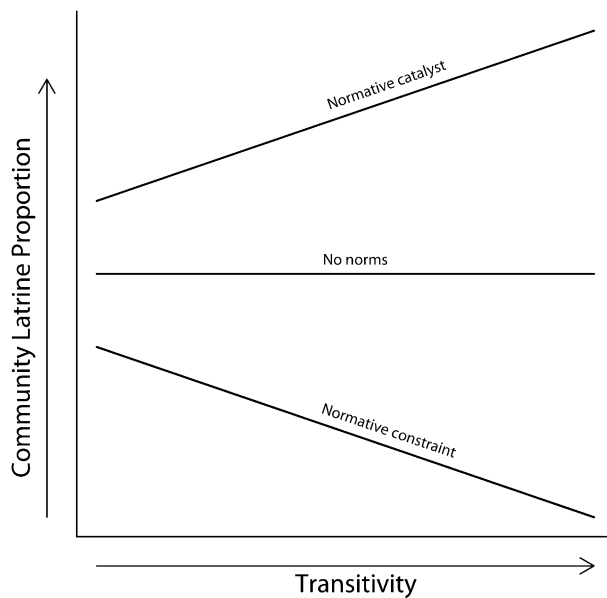
Note. When the overall latrine ownership proportion in a community is low, then the effect of transitivity is to act as a normative constraint on overall latrine ownership within the community. When latrine ownership is medium, then the effect of transitivity is null. At high levels of latrine ownership, transitivity then acts as a catalyst toward adoption, and community-level latrine ownership will increase.

FIGURE 1—Theoretical changes in community latrine proportion as a function of transitivity at 3 different levels of community latrine proportion.

individuals may be more powerful.[25,31–33] It can be very difficult for an individual to defy a social norm even when the expected outcome may be personally beneficial—because the individual can avoid sanctions only if the entire community is willing to change simultaneously.[34–36] This dynamic also works inversely, such that when a critical mass of a highly interconnected group has adopted a behavior, the probability also increases that any individual in that group will adopt it.[28,29,37,38]

We used algorithmic social network analytic methods to identify community groups and predict a socially influenced health behavior: latrine ownership in rural India. Poor sanitation, including the lack of clean, functioning toilets, is a major contributor to morbidity and mortality from infectious disease, particularly in India.[39–41] Open defecation has been practiced in many communities for centuries.[42] A large body of qualitative research points to the fact that, above and beyond demographic factors, social dynamics can influence the decision to build a latrine.[40,43] Although the government of India has devoted considerable resources, including subsidies, to

latrine-building campaigns over the last decade, results have been mixed, and considerable socioeconomic disparities persist.[44–46] The most successful latrine-building campaigns have been those initiated by Community-Led Total Sanitation; these successfully shift the norms of the community through village-wide agreements to stop open defecation, and these include shaming of those who transgress, and community commitment to invest in building latrines.[47,48]

We used so-called community detection methods to mathematically identify relevant social groups of interconnected people. These network communities are subsets of individuals with relatively strong within-group social connections and relatively weak between-group connections.[3,49,50] As such, they include not only direct social contacts (friends) but also friends of friends and friends of friends of friends.[51] Because latrine interventions in the developing world typically are implemented at the village level, we expected that both village-level latrine ownership practices and social network community–level practices would have important implications for individual behaviors.

Our research aims were to (1) quantify groups of interconnected individuals with a social network algorithm; (2) assess whether latrine ownership at the level of direct contacts, community network groups, or villages was associated with individual latrine ownership; and (3) test the degree to which the level of connectivity at the community and village levels was associated with latrine ownership. Research that uses a community-detection approach to test the association between social network features and health behavior is rare; hence, this study offers the opportunity to investigate whether network-derived communities are a good unit of analysis for the measurement of injunctive social norms.

METHODS

We used sociocentric network data from 75 villages in rural Karnataka, India, that were collected as part of an analysis of microfinance diffusion.[52,53] Sociocentric studies focus on a small population and attempt to ascertain all of the social relationships within a set of interconnected individuals.[54] From 2006 to 2008,[52] a complete census of each village was taken by interviewing 1 person within each household about household characteristics such as latrine ownership; individual surveys also were used to collect demographic and network data from more than half of the eligible households (those with women between ages 18 and 57 years), which were randomly chosen using stratification by religion and geographic sublocation.[52,53] A total of 16 984 individuals were interviewed. We defined our population as being eligible women and their spouses; links to others outside this population, like any sociocentric network study, were unavoidably excluded. After we removed observations with missing data (and certain other exclusions; see "Network Measures"), our analysis included data on 16 403 individuals in 6786 households. Of these, 6490 were household heads, 5845 were spouses of household heads, and 4068 were other individuals in the household. (Data used for this study are publicly available at: http://thedata.harvard.edu/dvn/dv/jpal/faces/study/StudyPage.xhtml?globalId=hdl:1902.1/16559.)

Individual-Level Measures

We measured age, gender, religion (Hindu or Muslim), native language (Kannada, Tamil, Telugu, or Hindi), and caste (scheduled caste, scheduled tribe, other backward caste, or general). We measured education using 16 levels ranging from none to higher degree. Household quality variables included roof type (6 categories), number of rooms in the home, number of beds in the home, and household electricity (private, government, or none). We used these household quality measures as a proxy for income.[55] We also included the type of ration card held by each individual: below poverty level, above poverty level, or not holding a card.

Our outcome variable was a binary measure of household latrine ownership.

Network Measures

A name generator is the survey instrument used in social network data collection to elicit individuals' important connections.[56] Respondents (egos) were asked to name up to 8 social contacts (alters) for each of 12 name generators. All eligible women and their spouses could be named, thus allowing us to assemble the network. Each network tie indicated that one individual had named the other (or vice versa) in at least 1 name generator. Dyads in which the individual and her social contact were from the same household were excluded from the analysis. For each individual, we then created 1 continuous measure representing the proportion of her alters, including both inbound and outbound ties, that owned a latrine.

The social communities to which people belonged were mathematically generated from sociocentric social network data. To detect communities, we applied the "fast greedy" algorithm, which optimizes a quantity known as modularity.[57] Modularity is a measured property of a network obtained by calculating the proportion of ties (or "edges") that fall within groups minus that same proportion calculated for a random network.[58] The larger the value, the more likely it is that the observed network of ties within a group of individuals is not due to chance.[50]

To ascertain the relation between network connectivity and latrine ownership, we also calculated transitivity at both the community and the village levels. Transitivity measures the number of connected triads divided by the total number of possible triads (in other words, the probability that 2 of a person's friends are also friends with each other).

Network Community–Level and Village-Level Measures

Our key predictors were the proportion of a respondent's social network community that owns a latrine and the proportion of a respondent's village that owns a latrine. All group proportion measures were calculated excluding the participant's own value.[20,59] Communities that had 10 or fewer individuals were excluded from the analysis to ensure more reliable community-level means.[20]

Statistical Analyses

We first used logistic regression, including demographic and household covariates, to generate separate models regressing participant latrine ownership on the proportion of direct social contacts that owned a latrine, the proportion of same-community members that owned a latrine, and the proportion of same-village members that owned a latrine.

We specified multilevel models that included covariates at the participant, social contact (friend), community, and village levels. Specifically, we estimated hierarchical logistic regression models to adjust for the clustering of observations at the different levels, and we partitioned the variance of the dependent variables into social contact, community, and village components.[60]

RESULTS

Each of the 16 403 individual participants were in 1 of 396 communities nested within 75 villages. The mean community size was 48 (SD = 27) with a range of 11 to 185. The mean number of respondents per village was 244 (SD = 73) with a range of 90 to 398. Table 1 shows descriptive statistics for the study population. The overall mean rate of latrine ownership within the sample was 30%, although this varied according to community (range = 0%–85%) and village (range = 2%–58%).

Figure A (available as a supplement to the online version of this article at http://www. ajph.org) shows the distribution of latrine ownership proportions at the village versus community levels. Although these 2 measures

TABLE 1—Demographic and Individual Characteristics of Adult Respondents (n = 16 403) From Rural Karnataka, India: 2006–2008

Characteristic	Mean (SD) or Proportion
Age, y	39.30 (12.50)
Education, y	5.02 (4.65)
No. of rooms in house	2.60 (1.50)
No. of beds in house	1.04 (1.62)
Alter owns a latrine	0.31
Gender (female)	0.551
Caste	
Scheduled caste	0.252
Scheduled tribe	0.060
Other backward caste	0.566
General	0.122
Ration card category	
Above poverty	0.175
Below poverty	0.669
Does not own card	0.157
Roof type	
Thatch	0.020
Tile	0.314
Stone	0.305
Sheet	0.182
Reinforced cement concrete	0.138
Other	0.041
Household electricity	
Private	0.657
Government	0.285
No	0.058
Language	
Kannada	0.750
Tamil	0.040
Telugu	0.170
Urdu	0.040
Other	0.002
Latrine ownership	0.304

are correlated (Pearson $r = 0.62$), note that, within villages, network communities can vary widely in the proportion of their members who own latrines. Table A (available as a supplement to the online version of this article at http://www.ajph.org) shows the range of values for all measures aggregated at the community and village levels. In addition to the latrine measures, nearly all other measures show greater between-group variation at the community level than at the village level, suggesting the important observation that

communities may indeed be better units of analysis for discovering reference groups than are villages. Figure 2 shows the clustering of latrine ownership by community within 1 village in the network.

We found that 11% of the variance of individual latrine ownership can be accounted for at the village level and 29% at the community level. We tested the bivariate relations between individual latrine ownership and the size of the community and the size of the village with a random effects model to account for clustering at both the community and the village levels (not shown); neither association was significant, suggesting that the size of the network community was not driving the results.

Network Predictors of Latrine Ownership

In Table 2, we show models that test the relation between participant latrine ownership and latrine ownership of social contacts, members of the network community, and members of the village; these multilevel models include individual demographic controls and random effects at each level. Model 1 includes separate

measures of latrine ownership at the level of direct social contacts, community, and village. All 3 associations were strongly significant, but the association with network community latrine ownership was highest. The odds of individual latrine ownership increased by 1.19 times (95% confidence interval [CI] = 1.05, 1.34) for each 1 SD increase in village latrine ownership and by 1.12 times (95% CI = 1.07, 1.18) for each 1 SD increase in social contact ownership. However, they increased by 1.42 times (95% CI = 1.33, 1.54) for each 1 SD increase in community ownership, suggesting that the best reference group for an individual extends beyond the directly connected social contacts to friends of friends and the broader network community in which he or she is embedded. To frame these results in comparison with demographic effects, an individual in a community in which 70% of people own latrines has a 2.02 times (95% CI = 1.72, 2.39) greater odds of owning a latrine than does a person living in a community in which 30% of people own latrines. This is comparable to the difference in the odds of owning a latrine

between someone of general caste and someone of scheduled caste (odds ratio [OR] = 1.90; 95% CI = 1.56, 2.31), between someone with 12 years of education and someone with none (OR = 2.05; 95% CI = 1.62, 2.60), and between someone above the poverty level and someone below (OR = 2.04; 95% CI = 1.81, 2.32).

Social Cohesion

In Table 2, we evaluate 2 measures of network connectedness (transitivity at both village and community levels); both were individually significant in multivariate models including individual attributes and latrine proportion variables (not shown), but when we incorporated both measures, village-level transitivity was not significant at the .05 level. Figure B (available as a supplement to the online version of this article at http://www.ajph.org) shows that individual latrine ownership declined as community transitivity increased. In other words, individuals in more tightly connected communities were less likely to own latrines. The models with controls in Table 2 suggest that the odds of individual latrine ownership decreased by 1.13 (95% CI = 1.03, 1.23) for each 1 SD decrease in community-level transitivity.

Interaction Effect

Finally, we found that the association between community latrine ownership and individual latrine ownership varied according to community level transitivity (Table B and Figure C, available as supplements to the online version of this article at http://www.ajph.org). To explore this association further, we stratified the analyses, running separate models for communities with low and high latrine proportions (less than and greater than the median of 0.30). We found that for communities with low latrine proportions, each 1 SD decrease in community transitivity increased the odds of owning a latrine by 1.58 (95% CI = 1.42, 1.75), whereas for communities with high latrine proportions, the effect of transitivity was not significant.

DISCUSSION

To change the health behavior of individuals, we often must change the social norms within the web of ties in which individuals are
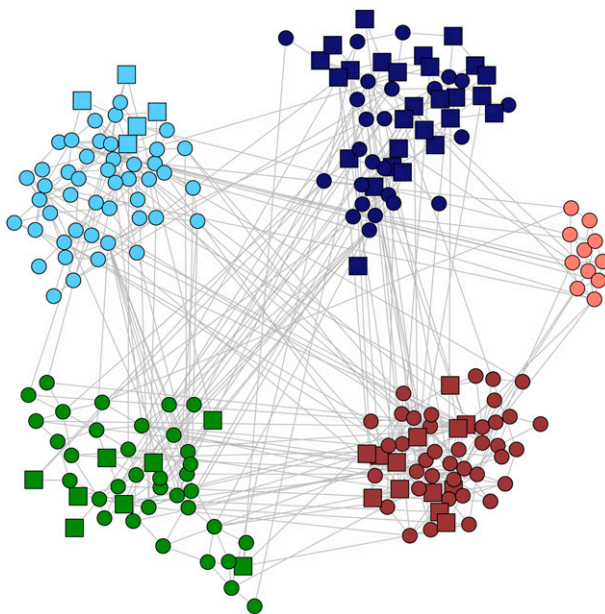
Note. Objectively identified network communities (using modularity maximization) are differentiated by color. Those who own latrines are depicted with squares, and those who do not own latrines are depicted with circles. Note both the clustering of individuals and the varying distribution of latrine ownership by community. For instance, in the pink community on the right side of the figure, no one has a latrine. The dark blue community toward the top, however, has a latrine ownership proportion of approximately 50%. If latrine ownership within the community was determined solely by geography, then we would expect the distribution of latrines to be uniform throughout the communities.

FIGURE 2—A network depiction of 1 village in Karnataka, India: 2006–2008.

TABLE 2—Results of Multilevel Logistic Regression Analysis Showing Association in Social Group Latrine Ownership With Individual Latrine Ownership at the Contact, Community, and Village Levels in Rural Karnataka, India: 2006–2008 (n = 16 403)

Fixed Part	Model 1, OR (95% CI)	Model 2, OR (95% CI)	Model 3 (With Village-Level Fixed Effects[a]), OR (95% CI)
Proportion of contacts with latrine	1.48 (1.24, 1.76)	1.48 (1.24, 1.76)	1.45 (1.21, 1.73)
Community latrine proportion	5.87 (3.89, 8.86)	4.53 (2.94, 6.97)	5.00 (3.45, 7.26)
Village latrine proportion	4.18 (1.47, 11.80)	3.53 (1.15, 10.77)	
Community transitivity		0.15 (0.05, 0.49)	0.18 (0.07, 0.50)
Village transitivity		0.30 (0.01, 6.60)	
Caste			
Scheduled caste (Ref)	1.00	1.00	1.00
Scheduled tribe	0.83 (0.63, 1.09)	0.84 (0.64, 1.11)	0.87 (0.67, 1.12)
Other backward caste	1.54 (1.31, 1.80)	1.57 (1.34, 1.83)	1.54 (1.34, 1.76)
General	1.90 (1.56, 2.31)	1.95 (1.61, 2.38)	1.97 (1.62, 2.40)
Household electricity			
Private (Ref)	1.00	1.00	1.00
Government	0.37 (0.33, 0.42)	0.37 (0.33, 0.42)	0.38 (0.34, 0.43)
No	0.25 (0.18, 0.34)	0.25 (0.18, 0.34)	0.25 (0.18, 0.34)
No. of rooms in house	1.21 (1.16, 1.26)	1.21 (1.16, 1.26)	1.21 (1.16, 1.26)
No. of beds in house	1.43 (1.38, 1.49)	1.43 (1.38, 1.49)	1.43 (1.38, 1.49)
Roof type			
Thatch (Ref)	1.00	1.00	1.00
Tile	0.79 (0.47, 1.31)	0.79 (0.48, 1.32)	0.77 (0.46, 1.28)
Stone	1.77 (1.06, 2.94)	1.75 (1.05, 2.91)	1.80 (1.08, 3.00)
Sheet	1.67 (1.00, 2.77)	1.67 (1.00, 2.77)	1.67 (1.00, 2.77)
Reinforced cement concrete	4.26 (2.51, 7.24)	4.26 (2.51, 7.24)	4.35 (2.56, 7.38)
Other	0.82 (0.46, 1.45)	0.81 (0.46, 1.43)	0.84 (0.47, 1.47)
Years of education	1.06 (1.04, 1.08)	1.06 (1.06, 1.06)	1.06 (1.06, 1.06)
Ration card			
Above poverty (Ref)	1.00	1.00	1.00
Below poverty	0.49 (0.43, 0.55)	0.49 (0.43, 0.55)	0.49 (0.43, 0.55)
No card	0.68 (0.59, 0.78)	0.68 (0.59, 0.78)	0.68 (0.59, 0.78)
Language			
Kannada (Ref)	1.00	1.00	1.00
Tamil	0.90 (0.68, 1.18)	0.90 (0.68, 1.18)	0.87 (0.66, 1.14)
Telugu	1.17 (1.00, 1.37)	1.16 (0.99, 1.36)	1.17 (1.00, 1.37)
Urdu	1.80 (1.40, 2.33)	1.88 (1.46, 2.42)	1.86 (1.44, 2.40)
Other	1.70 (0.69, 4.19)	1.72 (0.70, 4.23)	1.77 (0.72, 4.36)
Village-level variance	0.19	0.21	
Community-level variance	0.12	0.13	0.05
Log likelihood	–6799	–6792	–6682

Note. CI = confidence interval; OR = odds ratio.
[a]Not shown.

participants to directly name important others (as done for theory of planned behavior) is a step in the right direction, but it does not capture the multidimensional layers of social connections possible in sociocentric network analysis. Similarly, researchers who use demographic and health survey data have approximated reference groups from sampling clusters, but this method is based solely on geography, with no measures of direct social ties.

These results suggest that organic social network communities are more strongly associated with normatively driven behavior (in this case, latrine ownership) than are direct social contacts (e.g., friends) and contacts bounded geographically within a village. Although current efforts to change norms are typically directed at the village level,[63] these results imply that norm-based interventions may be more effective if they target network communities within villages.

The results also showed that network connectivity is inversely associated with individual latrine ownership at the community level. Individuals in less transitive communities are more likely to own latrines than are those within more transitive communities. These results are consistent with previous research suggesting that the degree of connectivity within a network can affect the adoption of novel behaviors.[31,33,64–67] If a behavior is normatively determined, then those in highly connected reciprocal networks may adopt more slowly, because the change must occur at the community level rather than at the individual level.[23] Centola et al.[28,68] reported that because the transmission of norm-changing behavior often requires multiple reinforced exposures, it can be inhibited initially by highly transitive networks but ultimately requires the reinforcement of such networks to successfully occur. Research on condom use, for instance, has found that individuals in more tightly connected networks are less likely to have sexual partners willing to use condoms.[31,32] Potentially, once a critical mass of partners in tightly knit social groups adopted condom use, it would be reinforced rather than inhibited.

We conjecture that the network-determined communities we identified in our study actually make up the salient reference groups to which individuals turn for information on normative

embedded, targeting small but well-defined groups of people at the same time. The ability to identify the socially relevant groups within which the norms are held, therefore, is crucial to the science of behavior change and hence to the goal of sustainable health promotion efforts

in diverse settings. Identifying reference groups, however, is a complex task. Earlier work involving theory of planned behavior found that group-level norms are predictive of behavior only when the reference group has been correctly identified.[61,62] Asking

expectations. Descriptive norms can potentially diffuse between people within the same geographic vicinity, such as between strangers at the local market.[64] Injunctive norms, however, can take place only within communities that are socially relevant to an individual and with whom that individual strives to maintain positive relationships.[12] The relationships we observed in this sample could certainly be the result of both dynamics. However, the fact that socially connected network communities are the most significantly correlated with latrine ownership suggests that an injunctive normative dynamic may be the most significant for latrine adoption. The fact that transitivity at the community level is correlated with a decreased probability of latrine adoption is further evidence of possible normative influence.

Furthermore, the interaction model suggests that the effect of community transitivity is strong in communities with few latrines but is negligible in communities where the proportion of latrines is greater than 30%. If normative influences are working against latrine adoption, we would expect a strong relation between the level of transitivity in the network and the probability of an individual owning a latrine, but we also would expect this effect to lessen as latrine ownership became more accepted within the community. If latrine ownership became the normative standard within communities (e.g., at rates > 70%), we might expect to see a positive correlation between transitivity and community latrine ownership, as the new norm of ownership would be more reinforced. As more and more people within tightly connected communities adopt latrines, individual exposure to latrines would increase, the exposure would occur from multiple close connections, and ultimately the new norm would be established. We cannot evaluate this possible association with these data because we have very few communities at those very high rates of adoption.

Finally, to explain these dynamics, we also must consider the possibility of homophily,[69,70] or the fact that individuals may choose their social relationships based on similarities that would also lead each individual to build a latrine. That our community groups showed a higher degree of within-group demographic homogeneity than villages did is

clear evidence of homophily, as well as important evidence that these groups are indeed potential sources of reference for normative beliefs. In our analyses, however, these demographic and other plausible, measured factors were controlled for at the ego level. Thus, although homophily may certainly drive group formation, our evidence suggested that normative forces beyond homophily may be driving latrine-building decisions.

Limitations

This study had several limitations. First, because the data were from a single time point, we were not able to track time-dependent effects that might have shed light on causal explanations for the associations we observed. Although our results were consistent with our causal hypothesis, longitudinal studies with randomly assigned treatment groups would substantially strengthen this analysis. We are undertaking such studies. Second, the data were sociocentric, but only 50% of the population was surveyed. Although exclusions were random, having missing network ties could have biased our results. Third, latrine ownership does not guarantee latrine use. Further analysis could shed light on the degree to which latrine use is socially predicted and whether network-based interventions eventually lead to a decrease in morbidity and mortality from sanitation-related infectious disease.

Conclusions

Understanding the role of network communities in facilitating health behavior change is a new and emerging field of research. This is one of the few studies to show that employing a network community intervention might facilitate adoption, particularly for behaviors that are complex and socially determined. Analysis of large data sets is becoming easier, and health behavior researchers will have increasing opportunities to identify network communities within large populations of people.

Perhaps the optimal target for public health interventions is not determined through geography but through social network communities; similarly, the more optimal target for clinical interventions may not be the individual but, again, the community. Even though many

international health and development interventions target village units, if the village unit is not the primary source of normative expectations for individuals, then village-level interventions aimed at changing norms may be inefficient or even ineffective. Future work should explore interventions that focus on identifying and engaging socially meaningful community groups to determine whether this helps maximize the likelihood of widespread and enduring behavior change. ∎

About the Authors

Holly B. Shakya is with School of Medicine, University of California, San Diego. Nicholas A. Christakis is with Yale Department of Sociology, New Haven, CT. James H. Fowler is with Political Science Department, University of California, San Diego, La Jolla.

Correspondence should be sent to Holly B. Shakya, PhD, 9500 Gilman Dr, Mail Code 0041, University of California, La Jolla, CA 92093 (e-mail: hshakya@ucsd.edu). Reprints can be ordered at http://www.ajph.org by clicking the "Reprints" link.

This article was accepted November 21, 2013.

References

1. Valente TW. Network interventions. *Science.* 2012;337(6090):49–53.

2. Christakis NA, Fowler JH. The spread of obesity in a large social network over 32 years. *N Engl J Med.* 2007;357(4):370–379.

3. Porter MA, Onnela JP, Mucha PJ. Communities in networks. *Notices Am Math Soc.* 2009;56(9):1082–1097.

4. Cobb NK, Graham AL, Abrams DB. Social network structure of a large online community for smoking cessation. *Am J Public Health.* 2010;100(7):1282–1289.

5. Kreager DA, Rulison K, Moody J. Delinquency and the structure of adolescent peer groups. *Criminology.* 2011;49(1):95–127.

6. Cialdini RB, Reno RR, Kallgren CA. A focus theory of normative conduct: recycling the concept of norms to reduce littering in public places. *J Pers Soc Psychol.* 1990; 58(6):1015–1026.

7. Cialdini RB, Kallgren CA, Reno RR. A focus theory of normative conduct: a theoretical refinement and reevaluation of the role of norms in human behavior. In: Zanna MP, ed. *Advances in Experimental Social Psychology.* San Diego, CA: Academic Press Inc; 1991: 201–234.

8. Coleman JS. The emergence of norms. In: Wippler R, Opp K-D, Hecther M, eds. *Social Institutions: Their Emergence, Maintenance, and Effects.* New York, NY: Aldine de Gruyter; 1990:35–39.

9. Bicchieri C. The Grammar of Society: The Nature and Dynamics of Social Norms. New York, NY: Cambridge University Press; 2006:1–54.

10. Bendor J, Swistak P. The evolution of norms. *Am J Sociol.* 2001;106(6):1493–1545.

11. Cialdini RB. Descriptive social norms as underappreciated sources of social control. *Psychometrika.* 2007; 72(2):263–268.

12. Jacobson RP, Mortensen CR, Cialdini RB. Bodies obliged and unbound: differentiated response tendencies for injunctive and descriptive social norms. *J Pers Soc Psychol.* 2011;100(3):433–448.

13. Cleveland MJ, Feinberg ME, Osgood DW, Moody J. Do peers' parents matter? A new link between positive parenting and adolescent substance use. *J Stud Alcohol Drugs.* 2012;73(3):423–433.

14. Cruz JE, Emery RE, Turkheimer E. Peer network drinking predicts increased alcohol use from adolescence to early adulthood after controlling for genetic and shared environmental selection. *Dev Psychol.* 2012; 48(5):1390–1402.

15. Bicchieri C. *The Grammar of Society: The Nature and Dynamics of Social Norms.* New York, NY: Cambridge University Press; 2006.

16. Ajzen I, Fishbein M. Attitudinal and normative variables as predictors of specific behavior. *J Pers Soc Psychol.* 1973;27(1):41–57.

17. Ajzen I. Constructing a TpB questionnaire: conceptual and methodological considerations. 2002. Available at: http://people.umass.edu/aizen/pdf/tpb.measurement. pdf. Accessed August 2013.

18. Ajzen I. The theory of planned behavior. *Organ Behav Hum Decis Process.* 1991;50(2):179–211.

19. Ajzen I, Cote NG. Attitudes and the prediction of behavior. In: Crano W, Prislin R, eds. *Attitudes and Attitude Change.* New York, NY: Psychology Press; 2008:289–311.

20. Storey J, Kaggwa E. The influence of changes in fertility related norms on contraceptive use in Egypt, 1995–2005. *Popul Rev.* 2009;48(1):1–19.

21. Kaggwa EB, Diop N, Storey JD. The role of individual and community normative factors: a multilevel analysis of contraceptive use among women in union in Mali. *Int Fam Plan Perspect.* 2008;34(2): 79–88.

22. Wiium N, Torsheim T, Wold B. Normative processes and adolescents' smoking behaviour in Norway:

23. Granovetter M. The strength of weak ties: a network theory revisited. *Sociol Theory.* 1983;1(1): 201–233.

24. Valente T. *Social Networks and Health: Models, Methods, and Applications.* New York, NY: Oxford University Press; 2010.

25. Trotter RT, Baldwin JA, Bowen A. Network structure and proxy network measures of HIV, drug and incarceration risks for active drug users. *Connections.* 1995;18(1):89–104.

26. van der Leij MJ, Goyal S. Strong ties in a small world. *Rev Netw Econ.* 2011;10(2):article 1.

27. Shi X, Adamic LA, Strauss MJ. Networks of strong ties. *Physica A Stat Mech Appl.* 2007;378(1):33–47.

28. Centola D, Macy M. Complex contagions and the weakness of long ties. *Am J Sociol.* 2007;113(3): 702–734.

29. Centola D. The spread of behavior in an online social network experiment. *Science.* 2010;329(5996): 1194–1197.

30. Granovetter MS. The strength of weak ties. *Am J Sociol.* 1973;78(6):1360–1380.

31. Latkin CA, Forman V, Knowlton A, Sherman S. Norms, social networks, and HIV-related risk behaviors among urban disadvantaged drug users. *Soc Sci Med.* 2003;56(3):465–476.

32. Liu H, Feng T, Liu H, et al. Egocentric networks of Chinese men who have sex with men: network components, condom use norms, and safer sex. *AIDS Patient Care STDs.* 2009;23(10):885–893.

33. Barrington C, Latkin C, Sweat MD, Moreno L, Ellen J, Kerrigan D. Talking the talk, walking the walk: social network norms, communication patterns, and condom use among the male partners of female sex workers in La Romana, Dominican Republic. *Soc Sci Med.* 2009;68 (11):2037–2044.

34. LeJeune J, Mackie G. *Social Dynamics of Abandonment of Harmful Practices: A New Look at the Theory.* Florence, Italy: UNICEF Innocenti Research Centre; 2008.

35. Bicchieri C, Muldoon R. Social norms. In: Zalta EN, ed. *Stanford Encyclopedia of Philosophy.* Spring 2011 ed. Stanford, CA: The Metaphysics Research Lab; 2011.

36. Mackie G, Moneti F, Denny E, Shakya H. What Are Social Norms? How Are They Measured? San Diego, CA: UNICEF/UCSD Center on Global Justice Project Cooperation Agreement Working Paper; 2012.

37. Burke MA, Young HP. Social norms. In: Benhabib J, Bisin A, Jackson M, eds. *Handbook of Social Economics.* Amsterdam, The Netherlands: North Holland; 2009: 311–338.

38. Sunstein CR. Social norms and social roles. *Columbia Law Rev.* 1996;96(4):903–968.

39. Prüss A, Kay D, Fewtrell L, Bartram J. Estimating the burden of disease from water, sanitation, and hygiene at a global level. *Environ Health Perspect.* 2002;110(5): 537–542.

40. Pattanayak SK, Yang JC, Dickinson KL, et al. Shame or subsidy revisited: social mobilization for sanitation in Orissa, India. *Bull World Health Organ.* 2009;87(8): 580–587.

41. United Nations. *The Millennium Development Goals Report.* New York, NY: United Nations; 2011.

42. Dickinson K, Pattanayak S. Open sky latrines: do social effects influence technology adoption in the case of a (very) impure public good? Duke University; 2012. Working Paper.

43. Jenkins MW, Curtis V. Achieving the 'good life': why some people want latrines in rural Benin. *Soc Sci Med.* 2005;61(11):2446–2459.

44. Bonu S, Kim H. *Sanitation in India: Progress, Differentials, Correlates, and Challenges.* Mandaluyong City, Philippines: Asian Development Bank; 2009.

45. UNICEF. *Meeting the MGD Drinking Water and Sanitation Target: The Urban and Rural Challenge of the Decade.* Geneva, Switzerland: World Health Organization; 2006.

46. Chambers R. Going to scale with community-led total sanitation: reflections on experience, issues and ways forward. January 1, 2009; 2009:1–50. IDS Practice Paper 1.

47. Dyalchand A, Khale M, Vasudevan S, Kale N. What communication and institutional arrangements influence sanitation related social norms in rural India? Available at: http://www.communityledtotalsanitation.org/sites/ communityledtotalsanitation.org/files/CLTS_Soc. Accessed August 2, 2013.

48. Jenkins MW, Cairncross S. Modelling latrine diffusion in Benin: towards a community typology of demand for improved sanitation in developing countries. *J Water Health.* 2010;8(1):166–183.

49. Moody J. Peer influence groups: identifying dense clusters in large networks. *Soc Networks.* 2001;23 (4):261–283.

50. Newman MEJ. Modularity and community structure in networks. *Proc Natl Acad Sci U S A.* 2006;103 (23):8577–8582.

51. Christakis NA, Fowler JH. Social contagion theory: examining dynamic social networks and human behavior. *Stat Med.* 2013;32(4):556–577.

52. Jackson MO, Rodriguez-Barraquer T, Tan X. Social patterns and social quilts: network patterns of favor exchange. *Am Econ Rev.* 2012;102(5):1857– 1897.

53. Banerjee A, Chandrasekhar AG, Duflo E, Jackson MO. The diffusion of microfinance. *Science.* 2013;341 (6144).

54. Marin A, Wellman B. Social network analysis: an introduction. In: Scott J, Carrington P, eds. *The SAGE Handbook of Social Network Analysis.* Thousand Oaks, CA: Sage; 2011:11.

55. Morris SS, Carletto C, Hoddinott J, Christiaensen LJM. Validity of rapid estimates of household wealth and income for health surveys in rural Africa. *J Epidemiol Community Health.* 2000;54(5):381–387.

56. Marin A. Are respondents more likely to list alters with certain characteristics? Implications for name generator data. *Soc Netw.* 2004;26(4):289–307.

57. Csardi G. Package igraph. Available at: http://cran. r-project.org/web/packages/igraph/igraph.pdf. Accessed August 2, 2013.

58. Clauset A, Newman MEJ, Moore C. Finding community structure in very large networks. *Phys Rev E Stat Nonlin Soft Matter Phys.* 2004;70(6 pt 2): 066111.

59. Storey J, Schoemaker J. Communication, normative influence and the sustainability of health behavior over time: a multilevel analysis of contraceptive use in Indonesia, 1997-2003. Paper presented at: Annual Meeting of the International Communication Association; June 19–23, 2006; Dresden, Germany.

60. Guo G, Zhao H. Multilevel modeling for binary data. *Annu Rev Sociol.* 2000;26:441–462.

61. Terry DJ, Hogg MA, White KM. The theory of planned behaviour: self-identity, social identity and group norms. *Br J Soc Psychol.* 1999;38(3):225–244.

62. Terry DJ, Hogg MA. Group norms and the attitude-behavior relationship: a role for group identification. *Pers Soc Psychol Bull.* 1996;22(8):776–793.

63. Pattanayak S, Dickinson KL, Yang JC, Patil SR, Praharaj P, Mallick RK. Nature's call: can a social mobilization campaign lead households to use toilets and reduce diarrhea? Results from a randomized trial in Orissa. Research Triangle Park, NC: RTI; 2007. Working Paper.

64. Kohler HP, Behrman JR, Watkins SC. The density of social networks and fertility decisions: evidence from South Nyanza District, Kenya. *Demography.* 2001;38(1):43–58.

65. Uzzi B, Spiro J. Collaboration and creativity: the small world problem. *Am J Sociol.* 2005;111(2):447–504.

66. Uzzi B, Amaral LA, Reed-Tsochas F. Small-world networks and management science research: a review. *Eur Manage Rev.* 2007;4(2):77–91.

67. Newman ME. The structure of scientific collaboration networks. *Proc Natl Acad Sci U S A.* 2001;98(2):404–409.

68. Centola D, Eguiluz VM, Macy MW. Cascade dynamics of complex propagation. *Physica A Stat Mech Appl.* 2007;374(1):449–456.

69. McPherson M, Smith-Lovin L, Cook JM. Birds of a feather: homophily in social networks. *Annu Rev Sociol.* 2001;27:415–444.

70. Aral S, Muchnik L, Sundararajan A. Distinguishing influence-based contagion from homophily-driven diffusion in dynamic networks. *Proc Natl Acad Sci U S A.* 2009;106(51):21544–21549.

	Estimate	Individual SD(Range)	Village SD(Range)
Table A: Community and village level attributes aggregated from individual measures of respondents from rural Karnataka India N=16403			
Proportion with household latrine	0.30	0.20 (0.00-.85)	0.12 (0.02-0.58)
Proportion high caste	0.69	0.33 (0.00-1.00)	0.15 (0.04-1.00)
Proportion above poverty line	0.17	0.14 (0.00-0.69)	0.09 (0.00-0.39)
Proportion Hindu	0.96	0.14 (0.00-1.00)	0.08 (0.59-1.00)
Proportion with RCC roofing	0.14	0.13 (0.00-0.62)	0.09 (0.00-0.45)
Proportion with household electricity	0.66	0.21 (0.00-1.00)	0.14 (0.9-0.89)
Proportion Kannada language	0.75	0.30 (0.00-1.00)	0.24 (0.53-1.00)
Mean education in years	5.02	1.55 (1.35-10.85)	0.97(2.20-6.69)
Mean number of beds in house	1.05	0.74 (0.00-5.8)	0.59 (0.27-3.25)
Mean number of rooms in house	2.61	0.60 (1.07-5.56)	0.38 (1.56-3.46)
All group measures were calculated excluding the participant's own value.			

Table B: Logistic regression of latrine ownership on social group latrine ownership proportions at the contact, community, and village levels, interaction model plus stratified by community latrine ownership proportion (all models run with village level fixed effects: not shown)

	Model 1: Interaction community level transitivity*community level latrine proportion			Model 2: Low community latrine proportion (<=0.30)			Model 3 High community latrine proportion (>0.30)		
	OR	95% CI		OR	95% CI		OR	95% CI	
Community transitivity*community latrine prop	136	(2.05	8995)						
Community latrine proportion	2.66	(1.34	5.29)						
Community level transitivity	0.04	(0.01	0.21)	0.00	(0.00	0.03	0.44	(0.05	3.77)
Proportion of contacts with a latrine	1.45	(1.21	1.73)	0.86	(0.59	1.25)	1.31	(1.08	1.59)
Caste									
Scheduled caste	Ref								
Scheduled tribe	0.87	(0.67	1.12)	0.79	(0.48	1.28)	1.13	(0.78	1.64)
OBC	1.52	(1.33	1.75)	1.97	(1.50	2.60)	1.79	(1.41	2.26)
General	1.93	(1.59	2.35)	2.80	(1.93	4.06)	2.32	(1.73	3.11)
HH electricity									
Private	Ref								
Govt.	0.38	(0.34	0.43)	0.35	(0.28	0.44)	0.35	(0.30	0.41)
No	0.25	(0.18	0.34)	0.34	(0.21	0.55)	0.19	(0.12	0.30)
# of rooms in house	1.21	(1.16	1.26)	1.28	(1.21	1.36)	1.17	(1.13	1.22)
# of beds in house	1.43	(1.38	1.49)	1.45	(1.37	1.54)	1.45	(1.37	1.54)
Roof-type									
Thatch	Ref								
Tile	0.77	(0.46	1.28)	0.46	(0.22	0.99)	1.65	(0.75	3.61)
Stone	1.80	(1.08	3.00)	1.08	(0.49	2.37)	3.78	(1.69	8.45)
Sheet	1.67	(1.00	2.77)	1.23	(0.57	2.65)	3.32	(1.49	7.42)
RCC	4.31	(2.54	7.31)	3.63	(1.66	7.96)	8.00	(3.58	17.88)
Other	0.84	(0.47	1.47)	0.41	(0.16	1.02)	1.92	(0.82	4.45)
Years of education	1.06	(1.06	1.06)	1.05	(1.03	1.07)	1.07	(1.05	1.09)
Ration card									
Above poverty line	Ref								
Below poverty line	0.49	(0.44	0.55)	0.53	(0.43	0.65)	0.45	(0.38	0.53)
No ration card	0.68	(0.59	0.78)	0.52	(0.39	0.68)	0.76	(0.64	0.91)
Language									
Kannada	Ref								
Tamil	0.88	(0.67	1.16)	0.48	(0.30	0.77)	1.21	(0.80	1.83)
Telugu	1.17	(1.00	1.37)	1.15	(0.87	1.51)	1.17	(0.96	1.43)
Urdu	1.82	(1.41	2.35)	2.03	(1.11	3.73)	1.82	(1.31	2.54)
Other	1.80	(0.73	4.44)	0.45	(0.04	4.72)	2.34	(0.75	7.29)

Note: OR= odds ratio; CI= confidence interval

Name generators used in study:

1.) Talk to: Name the 4 non-relatives whom you speak to the most.
2.) Visit-go: In your free time, whose house do you visit?
3.) Visit-come: Who visits your house in his or her free time?
4.) Borrow-kerorice: If you needed to borrow kerosene or rice, to whom would you go?
5.) Lend-kerorice: Who would come to you if he/she needed to borrow kerosene or rice?
6.) Borrow-money: If you suddenly needed to borrow Rs. 50 for a day, whom would you ask?
7.) Lend-money: Who do you trust enough that if he/she needed to borrow Rs. 50 for a day you would lend it the him/her?
8.) Advice-come: Who comes to you for advice?
9.) Advice-go: If you had to make a difficult personal decision, whom would you ask foR advice?
10.) Medical-help: If you had a medical emergency and were alone at home whom would you ask for help in getting to a hospital?
11.) Relatives: Name any close relatives, aside those in this household, who also live in this village?
12.) Temple-company: Do you visit temple/mosque/church? Do you go with anyone else? What are the names of these people?
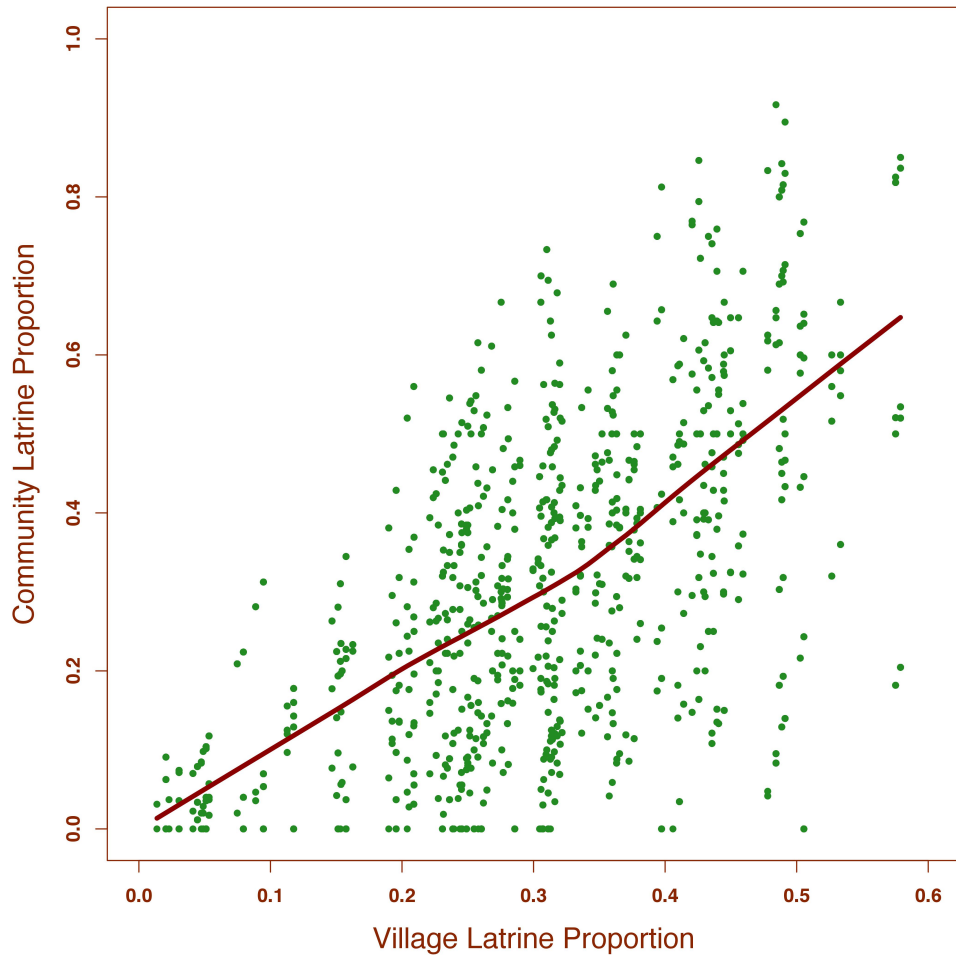
Figure A: The village latrine proportion by community latrine proportion. Although overall there is a positive relationship between the proportion of people in a community with latrines and the proportion of people in that community's village with latrines, it is apparent that there is considerable variation as well.
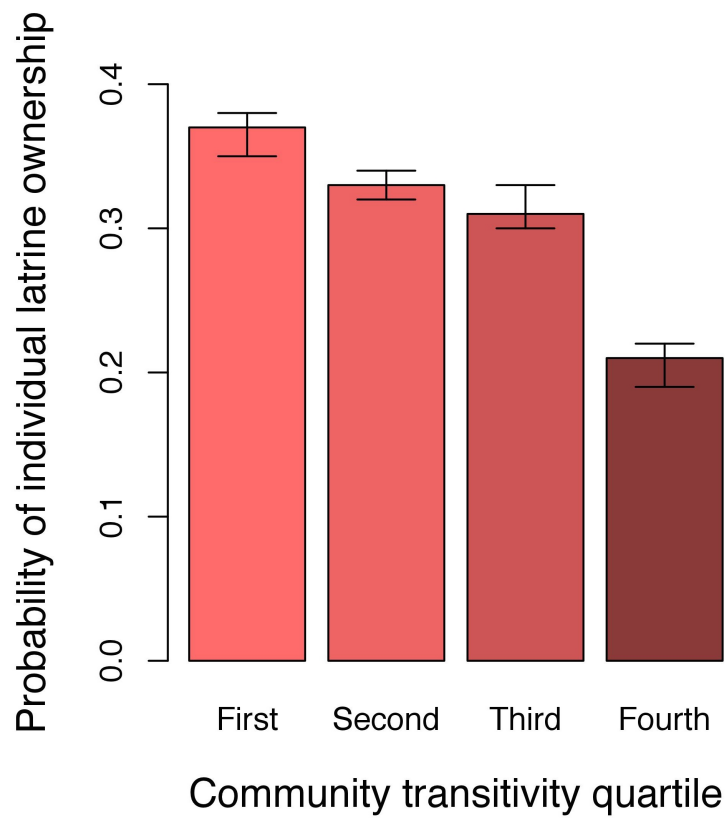
Figure B: Individual latrine ownership declined as community transitivity increased. In other words, individuals in more tightly connected communities were less likely to own latrines.
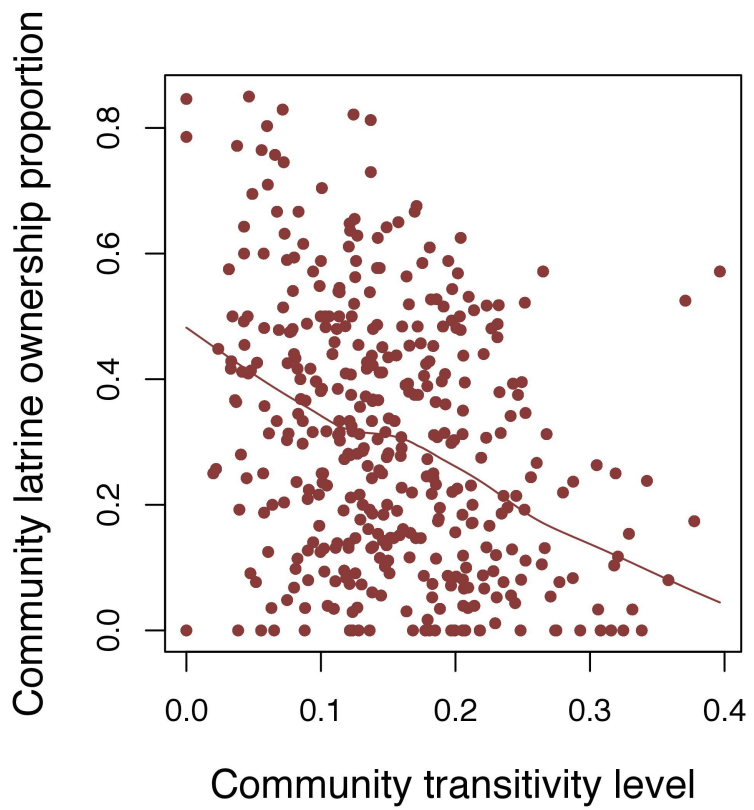
Figure C: As community transitivity increases, the proportion of the community with a latrine decreases. This suggests that a normative process drives latrine adoption, and that individuals within more tightly connected communities may be constrained by normative influences from adopting latrines.