Social Network Assessments and Interventions for Health Behavior Change: A Critical Review

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Abstract

Social networks provide a powerful approach for health behavior change. This article documents how social network interventions have been successfully utilized for a range of health behaviors including HIV risk practices, smoking, exercise, dieting, family planning, bullying, and mental health. We review the literature that suggests relationship between health behaviors and social network attributes demonstrate a high degree of specificity. The article then examines hypothesized social influence mechanisms including social norms, modeling, and social rewards and the factors of social identity and social rewards that can be employed to sustain social network interventions. Areas of future research avenues are highlighted, including the need to examine and analytically adjust for contamination and social diffusion, social influence versus differential affiliation, and network change. Use and integration of mhealth and face-to-face networks for promoting health behavior change are also critical research areas.

Keywords

Social networks; behavior change; interventions; social influence; social support

Introduction

This article seeks to (1) examine evidence from social network and social influence approaches to behavior change to improve the impact, reach, and costs of health promotion interventions; (2) present issues in measuring social networks related to health behaviors; (3) and examine specific interpersonal relationships associated with health behaviors; (4) delineates mechanisms of both negative and positive social influences on individual-level and network-level behavior change, and (5) describes behavior change approaches used in developing network interventions. Finally, it examines methodological issues in network interventions and proposed future lines of research.

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Decades of research demonstrate that behavioral interventions can be change health behaviors. A major challenge is to enhance interventions' effectiveness, sustainability, and reach to those most in need. Social environments have been well documented to have major influences on the adoption of health behaviors. Classic studies in social psychology suggest that social environments can be modified or constructed to have a greater impact on behavior as compared to personality, attitudes, and other individual-level factors.[1, 2]

Behaviors or lack of support by significant others can present significant barriers to behavior change, and some notable randomized clinical trials of social support and network interventions have not lead to differences in behavior change.[3, 4] To develop more effective interventions, it is important to improve our understanding of how social processes may promote behavior change. In this article, we examine evidence from social network and social influence approaches to behavior change to improve the impact, reach, and costs of health promotion interventions. We also examine specific interpersonal relationships associated with health behaviors, mechanisms of both negative and positive social influences on individual-level and network-level behavior change, and psychological approaches used in developing network interventions.

Social network interventions have been successfully used in international health programs to promote modern family planning methods and bullying reduction among adolescents.[5, 6] Social network focused interventions have been utilized for weight reduction, diabetes, smoking cessation, exercise, and improving the well-being of people with schizophrenia.[7-11] In the field of HIV, social network interventions have been successfully used for the past two decades to reduce HIV risk behaviors among high-risk, hard-to-reach populations, including people who inject drugs, men who have sex with men, and other sexual minorities.[12-15] Usually they have been delivered face-to-face. More recently, they have incorporated social media and mhealth components.[16] Results from the growing body of randomized controlled trials of social network interventions have documented sustained behavior change for over 2 years.[17]

Network interventions often utilize existing social support, social exchange, and social influence processes such as modeling and verbal persuasion. They utilize the existing network structure to diffuse behavior change. Moreover, as network members often maintain relationships, networks interventions can help to sustain behavior change. For serious illness and health conditions, members of individuals' personal network are often emotionally, economically, and socially impacted. Hence, for secondary prevention it can be helpful to involve and consider these network members in the support, care, and behavior changes processes.

Some network interventions focus on egocentric, or personal networks, which are defined as focal individuals and their social ties. For altering HIV risk behaviors, interventionists may focus on risk networks, such as their drug sharing and sexual partners. The smallest network is a dyad, which can also be the intervention focus.[9] Other network interventions focus on sociometric networks, which are sets of individuals, such as classrooms or schools and the ties among individuals in these settings.[18] Interactions on social media can be analyzed with

sociometric software.[19] Often sociometric network analyses focus on network structures whereas personal network analyses tend to focus on network function.

Sociometric network interventions often identify key individuals for training based on network structures, such as those with the greatest numbers of ties or influence potential. For example, a friendship structure within a school or classroom can be diagramed as a sociometric network by mapping the friendships, in the form of lines, among students.[20] One method of fostering behavior changes through sociometric networks is using community opinion leaders (CPOLs). [21] In this approach influential individuals are identified and trained to be change agents. They can be identified through social network structure. For example, network attributes such as centrality can be derived for each network member, and those with the highest scores targeted for training. Opinion leaders may also be identified through nominations and ethnographic observations. As with other network interventions, key factors to consider are the stability and structure of the network, frequency of interaction, and the credibility of the opinion leader for the specific topic. An opinion leader who is credible about financial matters may lack credibility to promote safer sexual practices. Social network structural factors such as density (i.e., the proportion of individuals within a network who are linked to each other divided by the number of possible links) are also likely to moderate CPOLs effectiveness.

Measuring social networks

To delineate the social influence processes within social network it is critical to adequately measure network attributes. Investigators have examined the reliability of network inventories and have developed methods to improve reliability.[22-25] However, a key question is validity. Do networks inventories document key health-related individuals in the social environment and their attributes? Network inventory instruments usually first ask a set of questions to elicit names of specific network members and then a set of questions regarding their attributes. Name generating questions often ask for names of sources of social support, e.g., emotional, material/financial, informational. Examples of name generating items are "Who are the people that you talk to about personal topics?" and "*Who are the people you have had sex with?*" Name generators may distinguish perceived availability from enacted support (support actually received). Name generators may also delineate networks based on behavioral interactions, shared venue attendance (e.g., school or drinking establishment), role relationships (friends, coworkers, family) or affect (respect, like). In health domains, name generators may include specific health behaviors (e.g., smokes or drinks alcohol, or exercise) or encourages or discourages such behaviors. Once the list of names is generated, a set of attribute questions is asked about each network member. Attributional questions may include demographics, frequency of contact, duration of relationship, residential propinquity, role relation, health behaviors, perceived reciprocity of support, communication or support regarding health behaviors, as well as evaluative aspects of the relationship, e.g., satisfaction and trust. Name generators and relationships are not mutually exclusive questions. To understand alcohol use within the network, name generators and/ or attributional questions can be employed.

For a study on drug-related behavior, in delineating the drug network, it can be useful to use a name generator for listing which network members use drugs but then attributional questions about who uses with the respondent and the type, frequency, and mode of drug administration. From these questions, one can derive, for example, the number of daily heroin injectors in a network. Table 1 presents a small sample from the universe of categorizations of network members. To examine sources of HIV transmission risk, the number of drug injectors who are also sex contacts can be identified. The infinite number of groupings, it highlights the importance in theory and health issues to determine which name generators and attributional questions are include in a network inventory.

Network inventories should be adapted for the study population, context, and the health topic. Formative qualitative research, empirical findings, and hypothesized associations help to delimit the name generating and attribute questions for a given study. As psychometric properties such as Cronbach's alpha are not usually derived from network inventories other measures of reliability (test-retest) and validity (concurrent, discriminative, and predictive) are well suited for assessing network instruments.

Another key question in developing a network intervention, and hence should be assess, is the stability and frequency of interactions within the network. If a network has high turnover it is unlikely that any network member will have adequate opportunity to promote effectively the target behavior. Similarly, if there is infrequent contact with network members there will be few opportunities to model and reinforce the behavior. In the analyses of personal network data, one can model turnover in and turnover out, which is the number of new individuals who enter the network and those who leave, and to identify factors associated with network turnover.[26] To help address recall bias and the potential of forgetting important network members, at a subsequent assessment, after the network inventory is administered, the interviewer can show participants their prior network inventory and inquire about their relationship status with previously listed network members.

Personal networks can be linked together to form larger sociometric networks. Some study designs emphasize collecting of sociometric data with clear boundaries to ensure sampling of linked individuals, such as a classroom or by using a sampling strategy, which insures linkages between respondents. With sociometric analyses, a range of network structural characteristics can be calculated, such as centrality, or microstructural features such as cliques. The National Longitudinal Study of Adolescent Health (Add Health) is an example of a survey that was designed to ensure that a subset of the sample formed a sociometric network to allow for network analyses of social influence.[27, 28]

Network specificity

One major issue to improve network approaches to behavior change is identifying network members that have particular influence on a behavior of interest and thus would be most appropriate to train. In observational analyses of social networks, it is apparent that specific network members' attributes are associated with specific health behaviors. A study by Davey and colleagues[29] found that the size of drug use network *per say* was not associated with subsequent entry into drug abuse treatment; however, other network characteristics did

predict drug treatment entry. Having a greater number of network members who were currently in drug treatment predicted entry, the number of current cocaine users was negatively associated with treatment entry, and the number of heroin users in the network had no association with drug treatment entry. One interpretation of this finding is that since there are not effective pharmacological treatments for cocaine addiction, those network members who use cocaine would not find treatment effective and hence less likely to encourage others to seek drug treatment.

The relationship between network factors and health outcomes may also differ by gender. Knowlton and colleagues found that for HIV seropositive men, having a female partner and reciprocity of social support were positively associated with adherence to HIV medications.[30] Interpersonal conflict, or negative support, was associated with non-adherence. For women, however, the presence of emotional support from a sexual partner in the social network was negatively associated with medication adherence. [31] These findings suggest that there are specific network factors linked to positive and negative health outcomes and that these factors may differ by factors such as gender. Socioeconomic status may also moderate the link to the relationship between social network factors on health.

However, knowing associations from observational studies does not always provide information on the best relationships to target for interventions. For example, with medication adherence is it better to target friends, current sexual partners, or certain family members? It is likely that factors to consider in choosing network members may include the health condition, target behavior, social and economic status, gender and other social roles, as well as resources and support functions and frequency of interaction with social network members. In order to target network members for intervention, network inventories need to collect the most relevant information within the minimal amount of time.

Social support

In the fields of psychology and mental health, social support has been viewed as one of the major social influences on health behaviors. Social networks can be conceptualized as the specific sources of social support. The exchange of social support is the major basis of developing and maintaining social relationships. Although social support has been typically found to benefit health, interventions to enhance social support for promoting health outcomes have not always shown consistent positive effects on health outcomes. The specificity of social relationships that can be delineated by social network analyses can help to provide a more nuanced analysis of social support and may help to explain seemingly contradictory findings.

There has been a consensus in the literature of five major types of social support: emotional, financial or material, informational, instrumental, and socialization.[32] Emotional support, conceptualized as imparting a sense of belonging, esteem or being valued, has been emphasized in the literature. Networks can be conceptualized as sources and pathways of tangible and intangible support. For marginalized populations, who have limited individual-level resources, support network members are important sources of basic resources, such as food or housing, and information on where to obtain such resources. Emotional support has been frequently found to have a main effect on depressive symptoms, but in low resourced

communities, material support, as compared to emotional support, may be more strongly associated with psychological well-being.[33] Social support may also include informational support of communications about health issues, including perceived risk and coping assistance, as well as modeling of how to address effectively health issues.

Support provided by network members may not always fit the need. Support provision may also have unintended consequences. Instrumental support can reduce individuals' self-efficacy. Support may also perceived as over-involvement, mismatched, ambiguous, and incurring indebtedness Helping may lead to perceived indebtedness or resentment and may impede individuals' acceptance of support offered and its potential health effects.[34] Support need, such as caregiving, may also conflict with gender or familial roles, and conflict or negative support has been consistently found to be associated with negative outcomes. From social network analyses, it is possible to ascertain if individuals who provide material and emotional support are also the source of conflict as well as the level of reciprocity among network members. The same network members who provide material support and are sources of conflict may simultaneously impede and aid certain health outcomes.

The literature on informal caregiving has examined attributes of network relationships that may impede and foster the provision of social support. One notable factor is reciprocity.[35] Yet many social support interventions do not include strategies to facilitate reciprocity, rather they focus solely on providing support to individuals identified with certain health conditions. The support may lead to conflict and greater stress in the relationship due to recipient and supporter both trying to assert control over the same health behaviors. It is also possible that for some health behaviors perceived social support is important, whereas for other health-related behaviors, such as medical adherence, enacted support is more important.

Interventions may change enacted support without changing perceived support or change perceived support without changing enacted support. Moreover, support from weak ties may enhance well-being, but they may not sustain behavior change.[36] In designing network interventions that focus on maintaining and enhancing social support, it is necessary to: 1) determine the relative importance of perceived versus enacted support and strong versus weak ties; 2) ensure that the support provided does not undermine self-efficacy, autonomy, and control; provide avenues for reciprocity; and 3) develop support strategies that do not lead to interpersonal conflict or other unintended negative consequences. One of the advantages of many measures of social support is that they are relatively brief, but they do not usually indicate who provides what type of support and the potentially problematic aspect of the support provided.

Network intervention behavior change mechanisms

There are a range of mechanisms that can be employed in social network interventions to foster behaviors change. Network members can reward or punish others for engaging in the behavior. Based on social cognitive theory, network members can model behaviors, which may increase self-efficacy and response efficacy. Observational studies have found that social norms are clustered within social networks and that these norms influence health and

academic behaviors.[37, 38] Social networks intervention can be developed to promote social norms.[37, 39]

Network members can influence social norms by engaging in (descriptive norms) or endorsing a behavior (injunctive norms). Network members may also change communication norms so that it becomes more socially acceptable to talk about certain health related topics such as safer sex or cancer screening and prevention. Network members who are trained to discuss the importance of prostate and breast examinations may change the acceptability of communication norms. Talking about and modeling health behaviors can make social norms for engaging and endorsing these behaviors more salient, appear to be more prevalent and acceptable in the network, and hence influence behaviors. A peer educator who talks to friends about cancer screening may alter social norms to not only make the topic socially acceptable, but it may also increase the perception that cancer screening is normative as well as serve as a cue to act and heighten the perceived risk of cancer. Once a network incorporates a certain behavior it can become part of the group's social identity and hence the group will work to maintain the behavior to keep its identity. Networks members who promote certain health behaviors can also help to define a situation. For example, a network member may comment that eating a certain food is unhealthy where previously the behavior was not viewed from the perspective of health.

Communication skills training

One of the major approaches to promoting behavior change within social networks is by network members talking about and encouraging certain health behaviors. Trainings in communication skills are necessary to initiate and maintain conversations about health behaviors. There is also the necessity of training individuals in communication skills to reward verbally others who engage in the behavior, present information or model behaviors that are credible, and discuss health behaviors in a manner that does not elicit reactance or impugn self-efficacy.

Telling network members that smoking is bad for their health may not be the best approach for a peer educator to initiate a conversation. Such a statement may be perceived as judgmental and not lead to additional conversations about smoking. One of the goals of such conversations is to heighten social norms. A discussion of the need to reduce second hand smoke exposure to children may heighten norms regarding children's well-being.

The effectiveness of communications to change health behaviors has been linked to dose.[40] The simple statement about a behavior being unhealthy may not lead to increased conversations about the behavior. Good health communications materials are not only memorable, but they are also sufficiently interesting to become a topic of future conversations—and gossip. For encouraging others to quit smoking, communication skills that emphasize what the speakers have found to work for them as well as the difficulties they encountered may meet with less resistance than preaching about the ills of smoking.

Social roles, self-concept, and motivations

For network interventions to be successful, individuals must be motivating to continue to encourage behavior change among their network members. This necessitates that the

methods employed to change network member's behaviors are rewarding. Promoting the health behaviors of network members can be self-rewarding as they may enhance self-concept, provide meaningful social roles, as well as garner positive feedback from network members. The role of health or peer educator may give social status, an individual identity, and a social identity of belonging to a valued group. Promoting behavior change among network members may also enhance important social relationships. Investigators who develop social diffusion interventions must create social roles that are culturally consistent and plausible. These roles need to be constructed so that they garner rewards and positive feedback from social network members. Some of the constructed roles include expert, friend, health educator, outreach worker, and sponsor.

In impoverished communities with low employment and marriage rates, the role of peer health educator may help to fill the lack of prosocial roles. Social roles also provide guidance and legitimacy for engaging in new behaviors. For example, the role of health educator may also legitimize talking to network members about topics such as screening for prostate and breast cancer or condom use and HIV testing. Outside of these roles, such conversations may not be socially acceptable.

Promoting a health behavior can make the role of health educator a key aspect of identity or self-concept. For peer educators, engaging in healthy behaviors may help to bolster their identity and unhealthy behaviors may be seen as a threat to the identity. Although some network members may reinforce health promotion roles, others may challenge these roles and question the motivations behind them. A high school student who tries to dissuade peers from alcohol consumption may be ridiculed. Consequently, in designing social roles it is important to provide support, test them in realistic situations, develop rebuttal skill sets, and methods to reframe negative feedback. Self-statements such as "they weren't ready to hear what I'm saying" or "I'm trying to make the community a better place and if I can help one person it is worth it" can buffer negative feedback.

In training drug users to be peer educators for HIV prevention, we have utilized role plays to address potential negative feedback, which questions their role as peer health educators. For example, we may role-play a scenario challenging their role with the statement "Who do you think you are, a junkie, telling me what to do?" Potential responses may include "I have messed up in the past, but now I'm trying to do things to make our neighborhood better." Alternatively, "We can all do things to help others." Social support provided in small group training sessions from other peer educators and the modeling of successful problem-solving may be helpful to maintain the identity of and motivation for peer education.

One of the impacts of these social roles is that they can lead to substantial behavior change in those individuals who inhabit the roles. It is well established from research on cognitive dissonance, self-perception theory, and active learning that individuals in the roles of promoting behavior change are more likely to change their behaviors as compared to those who do not engage in such roles.[41-43] In the role of peer educator, an emphasis on the importance of modeling as well as engaging in the health behavior in order to be a credible and respected peer educator may also facilitate health behavior change. In our research on peer education for HIV prevention, we have found that the peer educators change their risk

behaviors more than their risk network members, but the risk network members in the experimental condition change more than do the network members in the control condition.[12]

Social influence versus differential affiliation

In utilizing social network approaches to promote health behaviors it is important not to overestimate their impact. Although there is strong theoretical and empirical support for social influences for behavior change, there is also strong evidence of reverse causation; that is, differential affiliation with individuals with similar attributes interacting, liking each other, and maintaining their relationships. There has been lively debate on whether the findings of similar behaviors among network members are due to social influence, differential affiliation, or both.[44]

However, the research on observational studies on social influence and differential affiliation do not necessitate that the study results are ample guidance for social network interventions that purposefully try to change behaviors through social influence processes. It is certainly plausible that individuals who consume hazardous amounts of alcohol affiliate with other heavy drinkers.[45] Nevertheless, it is also plausible that other current or former heavy drinkers may be able to influence each other's drinking patters.

Social media networks and mobile technology to promote health (mhealth)

Although network interventions have often been in small group formats, social media has been successfully used for online self-help groups to promote smoking cessation and other health behaviors.[46] One of the distinct values of online groups is the ease of accessibility for many individuals. For researchers, online groups provide readily available data to examine how network structure and role function may facilitate integration within the online community and support behavior change. Electronic communications can bolster norms, model behavior, provide social support and cues for behavior change, and serve as an avenue for feedback to address barrier to behavior change. Yet overuse of social media has been found to be associated with social isolation and poor psychological well-being. As with face-to-face social interactions, it is important to match the specificity of support and mechanism of social influence with the targeted behavior. In studying and utilizing social media, it is useful to differentiate primary and close relationships from weaker ties. Online support networks are often comprised of the latter, who may be similar in terms of health conditions, but such networks may have high turnover. These networks can provide empathetic understanding, validation, and role models but are less likely to provide instrumental social support.

Social diffusion in network interventions

One of the primary tenants of network interventions is that information, attitudes, and behavior change through social diffusion. Network structure and composition may influence the speed and effectives of social diffusion. To study diffusion it is useful to assess networks longitudinally. Online social networks provide an optimal medium to study social diffusion. It may be also useful to test different approaches to enhance diffusion, such as training

several network members who reinforce each other's messages as well as recruit the network members of network members as peer educators.

In developing social network interventions, certain methodological issues may lead to over or underestimating the impact of diffusion. It has been argued that the Framingham study social network analyses may overestimate the social influence that network members may have on each other. However, in randomized clinical trials of social network interventions the impact of interventions may be underestimated.[44, 47] Social diffusion can also be viewed as contamination or interference if diffusion occurs from an experimental network into a control group network.[48] The ideal public health campaign would lead to complete social diffusion and behavior change among network members, yet such an intervention can also lead to complete contamination between the experimental and control networks and hence the inability to detect differences between the networks. This phenomenon suggests that it can be important to understand the structure and stability of social networks before and during social diffusion interventions. Tracking the interactions between control and experimental participants may be necessary to document diffusion. However, this documentation may be difficult as diffusion may spread out from the experimental participants to individuals who are not in the intervention and then spread back to those in the control condition.

Future research

In the past, delineating sociometric networks has been labor intensive, yet methods that use electronic communications and social media such as downloading and linking cell phone and Facebook contacts allow for the greater ease of using sociometric data. There is a dearth of literature of how sociometric networks change overtime and how this change may influence health behaviors. The dearth of research on network change also hold for the literature on personal networks. Moreover, little is known about how networks change after individuals change their health behaviors. Most interventions encourage individuals to work with their existing networks. Few network interventions counsel participants to break social ties or to find new ties. Future research should examine how ties change after behaviors change and the relative merit of changing ties versus improving existing relationships. Moreover, although there are some observational and longitudinal sociometric studies that document the link between social network factors and behavior change, these findings may not tell us how to best design network interventions for maximum diffusion, sustainability, and behavior change. Consequently, we need both more network interventions as well as mediation analyses to obtain a greater understanding of the dynamics of network interventions,

Several investigators have questioned the validity of the analyses of the Framingham study and subsequent conclusions regarding the power of social networks to foster behavior change.[44, 47] In studying social network influences on health behaviors it is critical to ensure that analytic approaches take into consideration the dependencies in the data structure. Failure to do so can lead to underestimations of confidence intervals and over-estimations of statistical significance.

There are also key methodological issues that need additional research. Social diffusion may produce contamination in randomized clinical trials leading to underestimating intervention effects. Understanding how to account for this source of error may provide us with a more accurate assessment of behavioral interventions. Information on network structure and stability may be useful to model and control contamination due to social diffusion.[49]

Social network interventions have demonstrated their ability to effectively change health behaviors, yet even the same types of network interventions with similar populations have led to different results. These differences in reported outcomes may be due in part to the match among key outcomes variables, mechanism of behavior change, and the role and function of specific network members. Network structural factors are likely to moderate the impact of diffusion interventions. As we become inundated with social media and electronic communications the influence of both types, formats, and sources of informational and emotional support are likely to change. Face-to-face versus social media and other mhealth interventions should not simply be compared on their power to change behavior, cost, reach, and sustainability. A key question is how do we best combine these modalities based on the population, health conditions, and social context? We also must not develop interventions that are quickly obsolete due to quickly changing social media. Finally, we should also not forget the critical role of networks in providing material resources. An electronic reminder for a medical care appointment may not be helpful without transportation, and without adequate food and housing, such an appointment may become a very low priority.

REFERENCES

1. Sherif, M.; Harvey, OJ.; White, BJ.; Hood, WR.; Sherif, CW. intergroup Conflict and Cooperation: The Robbers Cave Experiment. Vol. 10. University Book Exchange; Norman, OK: 1961.

2. Darley, JM.; Latane, B. The Unresponsive Bystander: Why Doesn't He Help?. Appleton-Century-Crofts; New York, NY: 1970.

3. Berkman LF, Blumenthal J, Burg M, et al. Effects of treating depression and low perceived social support on clinical events after myocardial infarction: The enhancing recovery in coronary heart disease patients (ENRICHD) randomized trial. JAMA. 2003; 289(23):3106–3116. [PubMed: 12813116]

4. NIMH Collaborative HIV/STD Prevention Trial Group. Results of the NIMH collaborative HIV/ sexually transmitted disease prevention trial of a community popular opinion leader intervention. J Acquir Immune Defic Syndr. 2010; 54(2):204–214. doi: 10.1097/QAI.0b013e3181d61def. [PubMed: 20354444]

5. Kincaid DL. Social networks, ideation, and contraceptive behavior in bangladesh: A longitudinal analysis. Soc Sci Med. 2000; 50(2):215–231. [PubMed: 10619691]

6. Wolfer R, Scheithauer H. Social influence and bullying behavior: Intervention-based network dynamics of the fairplayer.manual bullying prevention program. Aggress Behav. 2014; 40(4):309–319. doi: 10.1002/ab.21524 [doi]. [PubMed: 24415349]

7. Shaya FT, Chirikov VV, Howard D, et al. Effect of social networks intervention in type 2 diabetes: A partial randomised study. J Epidemiol Community Health. 2014; 68(4):326–332. doi: 101136/ jech-2013-203274 [doi]. [PubMed: 24297971]

8. Saul JE, Schillo BA, Evered S, et al. Impact of a statewide internet-based tobacco cessation intervention. J Med Internet Res. 2007; 9(3):e28. doi: 10.2196/jmir.9.4.e28. [PubMed: 17942390]

9. Sorkin DH, Mavandadi S, Rook KS, et al. Dyadic collaboration in shared health behavior change: The effects of a randomized trial to test a lifestyle intervention for high-risk latinas. Health Psychol. 2014; 33(6):566–575. doi: 10.1037/hea0000063 [doi]. [PubMed: 24884910]

10. Terzian E, Tognoni G, Bracco R, et al. Social network intervention in patients with schizophrenia and marked social withdrawal: A randomized controlled study. Can J Psychiatry. 2013; 58(11): 622–631. [PubMed: 24246433]

11. Valente TW. Network interventions. Science. 2012; 337(6090):49–53. doi: 10.1126/science. 1217330 [doi]. [PubMed: 22767921]

12. Latkin C, Donnell D, Liu TY, Davey-Rothwell M, Celentano D, Metzger D. The dynamic relationship between social norms and behaviors: The results of an HIV prevention network intervention for injection drug users. Addiction. 2013; 108(5):934–943. doi: 10.1111/add.12095 [doi]. [PubMed: 23362861]

13. Tobin KE, Kuramoto SJ, Davey-Rothwell MA, Latkin CA. The STEP into action study: A peer-based, personal risk network-focused HIV prevention intervention with injection drug users in baltimore, maryland. Addiction. 2011; 106(2):366–75. doi: 10.1111/j.1360-0443.2010.03146.x. [PubMed: 21054614]

14. Hoffman IF, Latkin CA, Kukhareva PV, et al. A peer-educator network HIV prevention intervention among injection drug users: Results of a randomized controlled trial in st. petersburg, russia. AIDS Behav. 2013; 17(7):2510–2520. doi: 10.1007/s10461-013-0563-4 [doi]. [PubMed: 23881187]

15. Davey-Rothwell MA, Tobin K, Yang C, Sun CJ, Latkin CA. Results of a randomized controlled trial of a peer mentor HIV/STI prevention intervention for women over an 18 month follow-up. AIDS Behav. 2011; 15(8):1654–1663. doi: 10.1007/s10461-011-9943-9. [PubMed: 21468659]

16. Young SD, Holloway I, Jaganath D, Rice E, Westmoreland D, Coates T. Project HOPE: Online social network changes in an HIV prevention randomized controlled trial for african american and latino men who have sex with men. Am J Public Health. 2014; 104(9):1707–1712. doi: 10.2105/ AJPH.2014.301992 [doi]. [PubMed: 25033137]

17. Latkin CA, Donnell D, Metzger D, et al. The efficacy of a network intervention to reduce HIV risk behaviors among drug users and risk partners in chiang mai, thailand and philadelphia, USA. Soc Sci Med. 2009; 68(4):740–748. doi: 10.1016/j.socscimed.2008.11.019. [PubMed: 19070413]

18. Cappella E, Kim HY, Neal JW, Jackson DR. Classroom peer relationships and behavioral engagement in elementary school: The role of social network equity. Am J Community Psychol. 2013; 52(3-4):367–379. doi: 10.1007/s10464-013-9603-5 [doi]. [PubMed: 24081319]

19. Borgatti S, Everett M, Freeman L. UCINet 6 network analysis software . 2002:6.

20. Ramirez-Ortiz G, Caballero-Hoyos R, Ramirez-Lopez G, Valente TW. The effects of social networks on tobacco use among high-school adolescents in mexico. Salud Publica Mex. 2012; 54(4):433–441. doi: S0036-36342012000400014 [pii]. [PubMed: 22832836]

21. Kelly JA. Popular opinion leaders and HIV prevention peer education: Resolving discrepant findings, and implications for the development of effective community programmes. AIDS Care. 2004; 16(2):139–150. [PubMed: 14676020]

22. Brewer DD. Forgetting in the recall-based elicitation of personal and social networks. Soc Networks. 2000; 22(1):29–43.

23. Rice E, Holloway IW, Barman-Adhikari A, Fuentes D, Brown CH, Palinkas LA. A mixed methods approach to network data collection. Field methods. 2014; 26(3):252–268. doi: 10.1177/1525822X13518168 [doi]. [PubMed: 25285047]

24. Merluzzi J, Burt RS. How many names are enough? identifying network effects with the least set of listed contacts. Soc Networks. 2013; 35(3):331–337.

25. Almquist ZW. Random errors in egocentric networks. Soc Networks. 2012; 34(4):493–505. doi: 10.1016/j.socnet.2012.03.002 [doi]. [PubMed: 23878412]

26. Costenbader EC, Astone NM, Latkin CA. The dynamics of injection drug users' personal networks and HIV risk behaviors. Addiction. 2006; 101(7):1003–1013. doi: 10.1111/j. 1360-0443.2006.01431.x. [PubMed: 16771892]

27. Haas SA, Schaefer DR. With a little help from my friends? asymmetrical social influence on adolescent smoking initiation and cessation. J Health Soc Behav. 2014; 55(2):126–143. doi: 0022146514532817 [pii]. [PubMed: 24818954]

28. de la Haye K, Green HD Jr, Pollard MS, Kennedy DP, Tucker JS. Befriending risky peers: Factors driving adolescents' selection of friends with similar marijuana use. J Youth Adolesc. 2014 doi: 10.1007/s10964-014-0210-z [doi].

29. Davey MA, Latkin CA, Hua W, Tobin KE, Strathdee S. Individual and social network factors that predict entry to drug treatment. Am J Addict. 2007; 16(1):38–45. doi: 10.1080/10601330601080057. [PubMed: 17364420]

30. Knowlton AR, Yang C, Bohnert A, Wissow L, Chander G, Arnsten JA. Informal care and reciprocity of support are associated with HAART adherence among men in baltimore, MD, USA. AIDS Behav. 2011; 15(7):1429–36. doi: 10.1007/s10461-010-9749-1. [PubMed: 20632081]

31. Knowlton AR, Yang C, Bohnert A, Wissow L, Chander G, Arnsten JA. Main partner factors associated with worse adherence to HAART among women in baltimore, maryland: A preliminary study. AIDS Care. 2011; 23(9):1102–1110. doi: 10.1080/09540121.2011.554516; 10.1080/09540121.2011.554516. [PubMed: 21476149]

32. Thoits PA. Mechanisms linking social ties and support to physical and mental health. J Health Soc Behav. 2011; 52(2):145–161. doi: 10.1177/0022146510395592 [doi]. [PubMed: 21673143]

33. Tsai AC, Bangsberg DR, Frongillo EA, et al. Food insecurity, depression and the modifying role of social support among people living with HIV/AIDS in rural uganda. Soc Sci Med. 2012; 74(12): 2012–2019. doi: 10.1016/j.socscimed.2012.02.033 [doi]. [PubMed: 22513248]

34. Miyamoto Y, Sono T. Lessons from peer support among individuals with mental health difficulties: A review of the literature. Clin Pract Epidemiol Ment Health. 2012; 8:22–29. [PubMed: 22563347]

35. Mitchell MM, Robinson AC, Wolff JL, Knowlton AR. Perceived mental health status of drug users with HIV: Concordance between caregivers and care recipient reports and associations with caregiving burden and reciprocity. AIDS Behav. 2014; 18(6):1103–1113. doi: 101007/s10461-013-0681-z [doi]. [PubMed: 24385229]

36. Rogers A, Brooks H, Vassilev I, Kennedy A, Blickem C, Reeves D. Why less may be more: A mixed methods study of the work and relatedness of 'weak ties' in supporting long-term condition self-management. Implement Sci. 2014; 9 19-5908-9-19. doi: 10.1186/1748-5908-9-19 [doi].

37. Latkin CA, Donnell D, Celentano DD, et al. Relationships between social norms, social network characteristics, and HIV risk behaviors in thailand and the united states. Health Psychol. 2009; 28(3):323–329. doi: 10.1037/a0014707. [PubMed: 19450038]

38. Frank KA, Muller C, Schiller KS, et al. The social dynamics of mathematics coursetaking in high school. AJS. 2008; 113(6):1645–1696. doi: 10.1086/587153 [doi]. [PubMed: 21031147]

39. Leahey TM, Gokee LaRose J, Fava JL, Wing RR. Social influences are associated with BMI and weight loss intentions in young adults. Obesity (Silver Spring). 2011; 19(6):1157–1162. doi: 10.1038/oby.2010.301 [doi]. [PubMed: 21164501]

40. Kincaid DL, Babalola S, Figueroa ME. HIV communication programs, condom use at sexual debut, and HIV infections averted in south africa, 2005. J Acquir Immune Defic Syndr. 2014; 66(Suppl 3):S278–84. doi: 10.1097/QAI.0000000000000242 [doi]. [PubMed: 25007197]

41. Bem DJ. Self-perception: An alternative interpretation of cognitive dissonance phenomena. Psychol Rev. 1967; 74(3):183–200. [PubMed: 5342882]

42. Festinger L. Cognitive dissonance. Sci Am. 1962; 207:93–102. [PubMed: 13892642]

43. Pfeffer J, Salamcik GR. Determinants of supervisory behavior: A role set analysis. Human Relations. 1975; 28(2):139–154.

44. Shalizi CR, Thomas AC. Homophily and contagion are generically confounded in observational social network studies. Sociol Methods Res. 2011; 40(2):211–239. doi: 10.1177/0049124111404820 [doi]. [PubMed: 22523436]

45. Mundt MP, Mercken L, Zakletskaia L. Peer selection and influence effects on adolescent alcohol use: A stochastic actor-based model. BMC Pediatr. 2012; 12:115–2431-12-115. doi: 10.1186/1471-2431-12-115 [doi]. [PubMed: 22867027]

46. 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. doi: 10.2105/AJPH. 2009.165449. [PubMed: 20466971]

47. Lyons R. The spread of evidence-poor medicine via flawed social-network analysis. Statistics, Politics, and Policy. 2011; 2(1):1–26.

48. Liu L, Hudgens MG. Large sample randomization inference of causal effects in the presence of interference. J Am Stat Assoc. 2014; 109(505):288–301. doi: 10.1080/01621459.2013.844698 [doi]. [PubMed: 24659836]

49. Hunter RF, McAneney H, Davis M, Tully MA, Valente TW, Kee F. "Hidden" social networks in behavior change interventions. Am J Public Health. 2015; 105(3):513–516. doi: 10.2105/AJPH. 2014.302399 [doi]. [PubMed: 25602895]

Table 1

Examples of personal network categories based on network inventory.

Number of drug users in network
Number of network members w/ whom participant shares drugs daily
Number of network members who are active speedball injectors
Number of network members who are active heroin snorters
Number of network members who are active crack smokers
Number of network members actively do all 3 drugs
Numbers of network members who are active injectors
Number who are drug users and in sex network
Numbers of network members who are drug users and kin
Have a drug-using sex partner in network
Number of women in network
Number of kin in network
Number of female kin in network
Number of non-kin in network
Percent of females in the network
Average closeness in network
Number of network members who have conflicts with participant
Number of network members who are injecting sex partners
Number of network members who are injecting non-sex partners
Numbers of network members in drug treatment program
Number of network members who provide health advice
Number of network members who provide emotional support