Social Networks and Health

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Abstract

People are interconnected, and so their health is interconnected. In recognition of this social fact, there has been growing conceptual and empirical attention over the past decade to the impact of social networks on health. This article reviews prominent findings from this literature. After drawing a distinction between social network studies and social support studies, we explore current research on dyadic and supradyadic network influences on health, highlighting findings from both egocentric and sociocentric analyses. We then discuss the policy implications of this body of work, as well as future research directions. We conclude that the existence of social networks means that people's health is interdependent and that health and health care can transcend the individual in ways that patients, doctors, policy makers, and researchers should care about.

INTRODUCTION

People are interconnected, and so their health is interconnected. Conceptual and empirical attention has therefore focused increasingly in the past decade on the impact of social networks on health. Network phenomena have become more prominent in research from fields as diverse as engineering, biology, and physics (Wellman & Berkowitz 1988, Watts & Strogatz 1998, Amaral et al. 2000, Albert & Barabasi 2002), and they also are relevant to health and medicine (Barabasi 2007) and, in particular, to the sociology of health and medicine.

We take as a predicate for our review the vast and important literature in sociology on social networks (Mitchell 1969, Laumann 1973, Fischer et al. 1977, Fischer 1982, Wasserman & Faust 1994) and the highly germane, albeit distinct, work on the social determinants of illness more generally (Berkman & Kawachi 2000, Kawachi & Berkman 2003). Our focus is more narrowly cast on the role of social networks in determining health. We begin by drawing a distinction between social network studies and social support studies, a distinction rarely maintained in the literature. We then explore current research on dyadic and supradyadic network influences on health. We conclude with a discussion of policy implications and future research directions.

The study of the effects of social networks on health emerged in the 1970s through the work of innovators such as Cassel, Cobb, and Berkman, who theorized or demonstrated empirically that social networks could affect mortality (Cassel 1976, Cobb 1976, Berkman & Syme 1979, Blazer 1982, House et al. 1982). Despite sociologists' prominence in the study of social networks in the same period (e.g., Laumann 1973, Fischer 1982, Marsden 1987, Coleman 1990, Wasserman & Faust 1994), most applications of social network approaches to studying health have, until recently, been conducted by public health researchers. In recent years, however, sociologists have become increasingly involved, and data sets, methods, and software useful for studying network influences on health are more available.

Social networks affect health through a variety of mechanisms, including (*a*) the provision of social support (both perceived and actual), (*b*) social influence (e.g., norms, social control), (*c*) social engagement, (*d*) person-to-person contacts (e.g., pathogen exposure, secondhand cigarette smoke), and (*e*) access to resources (e.g., money, jobs, information) (Berkman & Glass 2000). Some initial work has even begun to specify biological mechanisms by which social support flowing through a social network tie might affect morbidity and mortality.[1] The increasing involvement of sociologists in the study of network effects on health is thus a welcome development, as the sociological perspective affords a particularly strong vantage point for elucidating how information and influence is diffused, how networks work generally, and how social networks affect health specifically. (Sociologists also are particularly well positioned to consider and shed light on how race, gender, and class might interact with network processes to produce and maintain policy-relevant health inequalities, a separate topic not considered here.)

DIFFERENCES BETWEEN SOCIAL SUPPORT AND SOCIAL NETWORK ANALYSES

The study of social networks privileges the relationships between individuals; it presumes

[1] For example, higher levels of social support improve global immune functioning, as evinced by a fourfold relative risk reduction in susceptibility to experimental rhinovirus inoculation (Cohen et al. 1997). Similarly, several studies in oncology have shown that low levels of social support are associated with altered cytokine function (Esterling et al. 1996, Lutgendorf et al. 2002). Another potential pathway involves stress. Specifically, chronic stress appears to lead to chronic inflammation, particularly inability to suppress interleukin-6 (IL-6) (Miller et al. 2002), and recent data have shown that an increase in IL-6 levels from the 25th to 75th percentile is associated with a substantial increase in the odds of incident coronary disease (Pradhan et al. 2002), a finding confirmed in other populations (Ridker et al. 2000, Lindmark et al. 2001). Social interactions also may reduce the risk of dementia, and there is burgeoning interest in the field of social neuroscience, with a particular focus on the manner in which social networks integrate individuals into communities or provide mental stimulation via social complexity (Cacioppo et al. 2000).

that actors and actions are interdependent and that social ties facilitate the flow of information and influence (Wellman & Berkowitz 1988, Wasserman & Faust 1994). Indeed, theorists such as Coleman (1990) have argued that social relationships are a form of social capital, analogous to economic or human capital, that can be deployed for productive—and plausibly, health-related—ends.

Traditionally, most studies of social network effects on health actually focused on a related phenomenon, social support, a conflation that continues to a large extent today despite calls for change (Berkman & Glass 2000). Owing predominantly to data and methodological limitations, early studies operationalized social networks as an individual-level measure of the number of social contacts a person has (structural support, or its quantitative aspect) or how helpful they are, as subjectively reported by the person (functional support, or its qualitative aspect). Helpfulness in this context is generally construed as the perceived extent to which the support needs of a person (an ego) can be met by his/her social contacts (his/her alters). More specifically, helpfulness is the alters' perceived ability or willingness to provide instrumental support (i.e., financial support or aid with practical tasks), informational support, appraisal support (i.e., help in evaluating options and making decisions), or emotional support (Berkman et al. 2000). Unlike analyses of functional support, analyses of structural support typically distinguish between intimate ties and those involving more distant contacts, weighing the former more heavily when it comes to their effects on health. Nonetheless, networks with abundant weak ties have been found to have advantages in other realms, such as occupational mobility (as suggested in Granovetter's 1973 classic study), and it is possible that they are materially relevant to health, as well.

In contrast to social support studies (including those in the guise of social network studies), social network studies characterize the web of social relations around an individual, including, most importantly, who the contacts are and the nature of the ties that connect them. For example, one might look at particular characteristics of those who make up a person's support network or the type of links (e.g., close/distant, friend/relative) that connect them. Thus, whereas social support studies assess the quality or quantity of a person's social ties, social network studies treat the ties themselves as objects of study potentially relevant to outcomes of interest, and thus draw them explicitly. Rather than focusing, as social support studies do, on the (mere) existence of ties and conceptualizing network features as a trait reducible to the level of the individual (that is, person A has X level of social support, whereas person B has Y level of social support—a form of egocentric reduction of network information), social network studies actually map subjects' networks and probe the impact of particular network components and kinds of ties.[2] Rather than simply count the number of people in an individual's social network (e.g., person A has N friends and person B has M friends) or rate their relative helpfulness, social network studies examine their interrelationships by focusing explicitly on the specific network links. As such, social network studies involve the analysis of structures such as that depicted in **Figure 1**.

The study of social networks thus differs from—and in some sense is broader than—the study of social support. Moreover, the conceptual distinction between the two is important because networks have emergent properties not explained by the constituent parts and

[2]Among the more commonly analyzed network characteristics are (*a*) size (the number of ego's alters), (*b*) density (the extent to which alters know each other, i.e., are directly linked by a social tie), (*c*) connectivity (the extent to which alters are linked directly or indirectly via other contacts), (*d*) boundedness (the extent to which alters come from different categories of acquaintance, such as kin, neighbor, or coworker), (*e*) homogeneity (the extent to which alters resemble each other on various dimensions), (*f*) geodesic distance (the smallest number of connections separating an ego and an alter), (*g*) centralization (the extent to which network connectedness is dependent upon only a few contacts), and (*h*) cohesion (the robustness of a network's connectedness to the severance of ties). Tie characteristics commonly analyzed include level of intimacy, frequency of contact, multiplexity (or the diversity of resources flowing through a tie), duration, and reciprocity.

not present in the parts (Watts 2004). Understanding such properties requires seeing whole groups of individuals and their interconnections at once.

Owing to a paucity of data and to methodological challenges, studies of how social networks affect health are more difficult and less common than are studies of social support. Nonetheless, many of the now classic early social support studies, including the Alameda County Study, Tecumseh Community Health Study, Evans County Study, and the Established Populations for the Epidemiologic Study of the Elderly—as well as social support studies conducted today—are important for demonstrating that socially isolated individuals are less able than others to buffer the impact of health stressors and consequently are at greater risk for negative health outcomes such as illness or death (House et al. 1982, Berkman & Breslow 1983, Schoenbach et al. 1986, Seeman et al. 1993). These conclusions have been replicated hundreds of times in diverse populations (Cohen & Syme 1985, House et al. 1988).

RESEARCH ON THE EFFECTS OF SOCIAL NETWORKS ON HEALTH

Social network analyses include studies of both (*a*) egocentric (or local) networks, in which an individual is located at the hub of a wheel, with the rim delineating his/her social contacts and the spokes the ties that connect them; and (*b*) sociocentric (or sociometric, complete, or global) networks, in which all or nearly all members of a community or group and their linkages to each other are represented (these are also sometimes called saturation samples). The critical difference between the two is that egocentric models include only direct links to the focal individuals (the egos) that make up a study population, whereas sociocentric networks include both direct and indirect ties and map the entire sample. Consequently, whereas egocentric networks can be mapped by gathering information about social contacts from egos alone, sociocentric networks require that contacts (the alters) themselves be observed or queried; that is, they require that both sets of actors—those who influence and those being influenced—are directly observed. Because they thus make greater demands of data, studies of sociocentric networks are rarer. Nonetheless, they often yield more novel insights and are better suited to demonstrating the emergent quality of networks.

Dyadic Effects

The simplest form of a network is, of course, a social dyad (e.g., two spouses, two siblings, two friends, two coworkers, two neighbors).[3] Because they require less complicated data sets to study than do analyses of supradyadic effects, dyadic effects are the most widely researched network effects on health, and a large number and variety of studies provide evidence for their existence. We begin with a review of prominent findings from this literature before turning our attention to the more cutting-edge research taking place on supradyadic effects.[4]

Spouses are the most studied pair with respect to how the health of members of a dyad is interrelated. Extensive cross-sectional evidence has shown that married persons have substantially lower mortality than the unmarried (Farr 1858, Gove 1973, Litwak et al. 1989, Hu & Goldman 1990). Initial efforts to differentiate between a true protective effect of marriage and an effect caused by selection on the basis of health into marriage were hampered by data inadequacies (Goldman 1993, 1994). However, recent work suggests that, although selection does play a part, a causal relationship also contributes to the overall mortality advantage enjoyed by the married (Berkman & Breslow 1983, Welin et al. 1985, Schoenbach et al. 1986, Zick & Smith 1991, Berkman et al. 1992,

[3]For a nice illustration of interpersonal effects in coworkers, albeit outside the health domain, see Carman's (2004) investigation of the spread of charitable giving among office mates.

[4]It is worth noting that the networks we focus on are networks of laypeople. Other networks relevant to health exist, such as networks of doctors or institutions (see, e.g., Coleman et al. 1957, 1966; Keating et al. 2007).

Seeman et al. 1993, Lillard & Waite 1995, Lillard & Panis 1996, Korenman et al. 1997).

The obverse of the health benefits of marriage is the health cost of widowhood. Indeed, numerous studies have documented a short-term rise in mortality following the loss of a spouse, termed the widow/er effect, which is usually more pronounced in men (Young et al. 1963, Cox & Ford 1964, Parkes et al. 1969, Hesling & Szklo 1981, Jones 1987, Kaprio et al. 1987, Lillard & Waite 1995, Schaefer et al. 1995, Martikainen & Valkonen 1996, Elwert & Christakis 2006). This interpersonal health effect conforms to broader findings on the role of social support in mortality (Berkman & Syme 1979, House et al. 1988, Berkman et al. 1992, Thoits 1995), and the mechanisms behind it are similarly multifactorial.

The interdependence between two people can also have negative health consequences short of death. For example, the hospitalization of one spouse has been shown to increase the risk of death of the other (Christakis & Allison 2006), and providing better terminal care to one spouse may lead to a decreased risk of death in the other (Christakis & Iwashyna 2003). Studies have linked declining physical health in spousal caregivers to poor health in the care recipient, due perhaps to the caregiving demand. Indeed, caring for a sick spouse can produce high stress and, consequently, reduced immunity, and caregiving has been linked to an increased risk of infection, doctor visits, serious illness, and death (Baron et al. 1990, Kiecolt-Glaser et al. 1991, Shaw et al. 1997, Schulz & Beach 1999). Poor mental health in a spouse also affects the physical health of the caregiving partner (Zarit et al. 1986, Pruchno & Resch 1989a, Shaw et al. 1997, Scholte op Reimer et al. 1998). In fact, mental impairment may induce more burden in the caregiving spouse than does physical impairment (Christakis & Allison 2006). The mental health of the caregiver also can decline, and depression is a consistent adverse correlate of caregiving (Pruchno & Potashnik 1989, Kiecolt-Glaser et al. 1991, Mittelman et al. 1995, Russo et al. 1995). This so-called caregiving effect is gender-dependent and varies according to other factors, as well (Clipp & George 1993, Russo & Vitaliano 1995, Dunkin & Anderson-Hanley 1998, Williamson et al. 1998). For example, although wives are more likely than husbands to be caregivers (for numerous reasons, ranging from longer female life expectancy to differential social expectations), studies typically find that caregiving wives report greater strain or perceived burden than do caregiving husbands or control populations (Barusch & Spaid 1989, Pruchno & Resch 1989b, Blood et al. 1994, Russo & Vitaliano 1995, Dunkin & Anderson-Hanley 1998), with greater attendant psychological fatigue and depression (Fitting et al. 1986, Barusch & Spaid 1989, Pruchno & Resch 1989b, Moritz et al. 1989, Pruchno & Potashnik 1989, Pruchno et al. 1990, Kiecolt-Glaser et al. 1991, Siegel et al. 1991, Russo et al. 1995, Mittelman et al. 1995, Collins & Jones 1997).

Thus, at least in the case of spouses, there is compelling evidence that the health of one member of a dyad can affect the health of the other. Although spousal relationships demonstrate how the health of humans who are linked through a social tie may be interdependent, an important question is whether health effects obtain in social relations beyond spouses, e.g., among siblings, parents, friends, coworkers, or neighbors. Operating through a diverse set of mechanisms, for example, might not a heart attack or stroke in one individual trigger clinically and socially meaningful changes in the health or health behavior of his/her siblings, friends, or other members of his/her social network?

Although interpersonal health effects are likely weaker in nonspousal relationships than in spousal ones, they are nonetheless of substantial importance, both conceptually and practically.[5] First, nonspousal social relations are

[5]The magnitude and possibly even the direction of network effects should vary according to the social distance between the actors. In general, one should find weaker effects with increasing social distance, so that, for example, a health event or behavior change in a focal individual would have progressively weaker effects in terms of motivating behavior change as one moves down the continuum from family member to neighbor.

much more numerous than are spousal ones. Second, research suggests that even weak ties can produce social benefits (Granovetter 1973), and this may also extend to the health domain. And third, the potential existence of nonspousal interpersonal health effects raises important policy questions, such as whether network effects lie at the root of neighborhood effects on health (see Entwisle et al. 2007 for a thoughtful consideration of the interplay between network and neighborhood effects[6]) or contribute to health disparities by race or income.

There is evidence of various nonspousal interpersonal health effects. For example, parental physical or mental health impairment can adversely affect the physical and mental health of children. Specifically, maternal depression is associated with more behavioral problems, depression, and substance abuse, as well as more emergency room visits, hospitalizations, allergies, asthma, colds, and other ailments in offspring (Billings & Moos 1983, Weissman et al. 1987, Zuckerman & Beardslee 1987, Lee & Gotlib 1989, Schwartz et al. 1990, McLennan & Kotelchuck 2000, Weissman et al. 2006). Although less often studied, paternal depression also appears to affect child health (Forehand et al. 1986, Jacob & Johnson 1997), as do parental physical health problems, which have been linked to both depression and poor physical health in offspring (Mikail & von Baeyer 1990, Drotar 1994, Walker et al. 1994, Armistead et al. 1995, Korneluk & Lee 1998).

Just as parental disability affects child health, disability in children also affects the well-being of other family members. For instance, several studies have documented a higher prevalence of psychopathology among mothers of disabled children (Thyen et al. 1998), especially when the child has significant functional limitations (Waddington & Busch-Rossnagel 1992, Silver et al. 1999). Siblings of children with disabling medical conditions also are at increased risk of experiencing above-average levels of psychopathology (Breslau et al. 1987). Of course, such parent-child studies raise important questions about genetic codeterminacy and endogeneity owing to shared exposures, and ongoing research is experimenting with a variety of research designs to obtain better estimates of causal effects.

The interpersonal health effects among friends that have been studied are primarily behavioral peer effects. For example, the smoking behavior of an adolescent's friends influences the odds of smoking initiation, continuation, and cessation (Burt & Peterson 1998, Chen et al. 2001, Kaplan et al. 2001), and similar effects have been documented for alcohol use (Urberg et al. 1997, Andrews et al. 2002). Not surprisingly, then, smoking and alcohol cessation programs that provide peer support—that is, that modify the social network of the target—are more successful than those that do not (McKnight & McPherson 1986, Prince 1995, Albrecht et al. 1998, Malchodi et al. 2003). Indeed, this general line of thinking motivates the so-called "social norms feedback campaigns" being implemented on many college campuses (Wechsler et al. 1995, Thombs & Hamilton 2002).

Other social relationships also influence the consumption of tobacco and alcohol. For example, the use of these and other substances tends to aggregate in families (Bierut et al. 1998), and there is extensive evidence of sibling similarity in substance use in particular, consistent with the theory that, in addition to sharing genetic risks, siblings directly influence each others' smoking and drinking behaviors (Bierut et al. 1998, Boyle et al. 2001, Avenevoli & Merikangas 2003, Rajan et al. 2003). A recent study that used twin and nontwin sibling data from the National Longitudinal Study of Adolescent Health (Add Health) provides additional support for direct sibling influence (Rende et al. 2005). It found that frequent contact with, affection for, and also sharing mutual friends with a sibling who smokes significantly influence the likelihood that an adolescent will smoke, suggestive of influence

[6]There also is a large literature on the effects of neighborhoods, and hence of neighbors, on health, but that is reviewed elsewhere (Kawachi & Berkman 2003).

beyond that explained by heredity and shared environment.

Like tobacco and alcohol consumption, some behaviors related to weight gain and weight loss appear to be socially transmissible. Studies have linked unhealthy weight-control behaviors among adolescent girls to the dieting behaviors of their peers (Eisenberg et al. 2005), and children's food preferences have been shown to be manipulable using peer modeling (Lowe et al. 2004). Among adults, delivering a successful weight-loss intervention to one person has been shown to trigger substantial weight loss in that person's friends, and evidence suggests that weight-loss interventions that target social networks are more effective than are those that target isolated individuals (Black et al. 1990, Kelsey et al. 1997, Wing & Jeffery 1999, Gorin et al. 2005, Verheijden et al. 2005).

Still other health outcomes also are subject to social influence. For instance, the occurrence of breast cancer in one woman has been shown to motivate others to whom she is connected to undergo mammography (Murabito et al. 2001), and multiple randomized controlled trials (with variable results) have assessed the health benefits for women with metastatic breast cancer of participating in "supportive/expressive group therapy"—that is, artificially created social networks (Spiegel et al. 1989, Goodwin et al. 2001, Spiegel 2001). Even impersonal social connections can be conduits for health-related social influence: Cancer in a celebrity, for example, may motivate people not known to the index case to undergo cancer screening or choose particular treatments (Nattinger et al. 1998, Cram et al. 2003).

Finally, it is important to note that, despite most analyses emphasizing the salubrious potential of social ties, social influence also can constrain healthy behavior or encourage unhealthy behavior. For example, associations with smokers or drinkers can hinder individuals' attempts to quit smoking or drinking alcohol. In a similar fashion, qualitative investigations of the influence of social contacts on weight-control behaviors have highlighted the perceived barriers that nonsupportive family members may constitute to individuals' attempts to engage in health behaviors such as healthy eating (Sallis et al. 1987, Fleury 1993, Kelsey et al. 1997).

Supradyadic Effects

The newest research in the field of social network influences on health is taking place in the realm of supradyadic effects. In contrast to dyadic analyses, which require data only on pairs of individuals, analyses of supradyadic effects require more complete maps of individuals' social networks. Consequently, they are less common than are social network analyses of dyadic effects. Nonetheless, research documenting interindividual influence involving multiple persons or groups suggests that supradyadic network effects are significant and worthy of analysis, a supposition that receives support from the few supradyadic network studies that have been conducted.

One example is a recent study by Christakis & Fowler (2007) that employed a global network design and documented how obesity can spread through social networks in a manner reminiscent of an infectious disease or a fad—a kind of person-to-person contagion of a biobehavioral trait. The authors examined Framingham Heart Study (FHS) cohorts supplemented by dynamic, longitudinal information on who was friend, relative, or neighbor to whom during roughly 30 years of follow-up. Because they were working with global and not local network data, they were able to ascertain that obesity clusters in the network extended to three degrees of separation, meaning that if an ego's alter's alter's alter was obese (defined as a BMI greater than or equal to 30), it increased the likelihood that the ego him/herself was obese. The finding that obesity was clustered within the FHS network is visually illustrated by **Figure 1**, which depicts for the year 2000 the largest connected component (that is, a network subgraph in which all nodes are reachable from all other nodes) in the network.

Christakis & Fowler (2007) also found that a person's likelihood of becoming obese was partially determined by whether or not his/her social contacts became obese during the same period. Specifically, if a person's friend became obese, it increased the likelihood that he/she would become obese by 57% (95%CI: 6–123%), with larger effects found for same-sex friends. If a person's sibling became obese, he/she was 40% (95%CI: 21–69%) more likely to become obese, with larger effects again seen for same-sex relationships. If a person's spouse became obese, he/she was 37% (95%CI: 7–73%) more likely to become obese.

Interestingly, no association was found for neighbors, and the distance friends or siblings lived from each other had no impact on the strength of the friend or sibling effect, suggesting that the observed effects were not due to a shared environment. Moreover, the authors focused on changes in BMI, regardless of one's former weight status, instead of the likelihood of being obese at a given point in time, thereby obviating the possibility that the results they observed were caused by homophilous partner preferences (i.e., already obese persons seeking out the companionship of other obese persons).

In addition, the directionality of friendship ties affected the magnitude of the friend effect. A friendship could exist because person A identified person B as his friend, because person B identified person A as his friend, or both. If the person an ego nominated as his friend (the alter) became obese, it increased the likelihood that the ego became obese by 57%. However, if the nomination went in the opposite direction, there was no statistically significant effect on the ego's change in BMI of the alter gaining weight. The largest effects were observed for reciprocal nominations, which were associated with a 171% (95%CI: 59–326%) increased likelihood of the ego becoming obese. That the directionality of the friendship tie may affect the existence and magnitude of the friend effect suggests that the observed interpersonal effects might have a causal basis, rather than the ego and alter having simultaneously experienced the same weight-gain-inducing shock.

Given the necessary complexity of the data used, such sociocentric studies of behavioral diffusion point to the need for improved statistical procedures to support more robust causal inference (Manski 1995). In addition, they raise the question of whether the behaviors analyzed spread by so-called simple or complex contagion (Centola et al. 2007, Centola & Macy 2007). That is, whereas germs or a piece of information might spread from person to person without requiring any kind of network reinforcement (an example of a simple contagion), the spread of behaviors might require egos to have multiple alters who evince a behavior before the egos themselves adopt it (an example of a complex contagion).

Beyond obesity, numerous other health behaviors might also spread within social networks, such as smoking, eating, exercise, alcohol consumption, or drug use. Further health-related behaviors that might spread within social networks include the propensity to get health screenings, visit doctors, comply with doctors' recommendations, or even visit particular hospitals or providers.

Cutting-edge research also has focused on the role of network structure in determining the spread of sexually transmitted diseases (STDs). Although many of these studies are more epidemiological than sociological, given their focus on how sexual networks facilitate the spread of an infectious disease, they are excellent for demonstrating the emergent quality of network influence, that is, how network effects are not reducible to the individual level. Moreover, because the sexual networks that transmit STDs share with social networks the element of partner choice (as opposed to random-mixing contact structures through which, say, a cold or flu diffuses), important lessons regarding more traditional social network processes can be derived from their study.

For example, Bearman et al. (2004), as part of an ongoing series of highly original and creative investigations of social network effects, used a subsample of Add Health data to model the complete sexual network of a mid-sized, predominantly white Midwestern high school using information on reported romantic partnerships over an 18-month period. They found that a surprisingly sizeable 52% of all romantically involved students were embedded in one very large "spanning tree," that is, "a long chain of interconnections that stretches across a population, like rural phone wires running from a long trunk line to individual houses" (Bearman et al. 2004, p. 51). This spanning tree was especially notable for its lack of redundant ties, meaning that most students were connected to the superstructure by one pathway only. The authors accounted for the emergence of this network structure by providing evidence of homophilic partner preferences in combination with an apparent proscription against cycles of length 4, that is, a rule that holds, "Don't date your old partner's current partner's old partner" (p. 46). They also found that the majority of the remaining romantically involved students were members of disjoint dyads or triads, with very few components of intermediate size (a structural feature that is indeed typical of sociocentric studies).

Most models of STD transmission assume the existence of high activity cores that disseminate disease to lower activity groups or individuals and sustain epidemics by functioning as reservoirs of infection. As Bearman et al. (2004) point out, however, their findings are significant both for their inconsistency with this traditional notion of core groups as the drivers of STD diffusion and for their implications for STD control, which stem from the largest component's fragility: If a link from the trunk of the spanning tree is removed, the transmission of infection beyond that linkage is effectively halted as the super-component breaks into two disjoint components. As such, the network they documented was highly vulnerable to the removal of single ties or nodes, which, they argue, is best achieved by broad-based, broadcast STD control programs—that is, those that target the entire population rather than specific activity groups.

In studying similar dynamics with respect to the HIV/AIDS epidemic in sub-Saharan Africa, Helleringer & Kohler (2007) collected information on up to five recent sexual partners of the 18- to 35-year-old residents of seven villages located on an island in Lake Malawi. They found that, contrary to expectations, residents reported relatively few partners. Despite this finding, upon mapping the resulting sexual network, they discovered that a striking 49% of network members were connected in one large interconnected component, a finding reminiscent of Bearman and colleagues' (2004) spanning tree. However, unlike in the Bearman et al. study, this large component documented by Helleringer & Kohler was remarkably robust to the removal of individual ties or nodes as a result of numerous redundant paths (i.e., instances in which respondents directly or indirectly shared more than one sexual partner).

Like Bearman et al. (2004), Helleringer & Kohler (2007) failed to find evidence of high activity hubs, that is, persons or groups capable of sustaining the HIV/AIDS epidemic by having many sexual partners. As they note, their findings thus call into question the assumption behind much HIV work in sub-Saharan Africa that the current epidemic is driven either by a high activity core made up of sex workers and their patrons or by other high activity individuals transmitting disease to a low activity periphery made up of individuals with one or few partners.

In addition to the insights they provide into mechanisms underlying the spread of STDs and, consequently, methods for possible containment, the Bearman et al. (2004) and Helleringer & Kohler (2007) studies are important for demonstrating the value of collecting global network data as opposed to egocentric network data. Without global network data, the contact macrostructure through which infectious disease—or alternatively, influence, information, or other socially transmissible constructs—must flow cannot be mapped and studied. They also illustrate the potential incompleteness of the picture obtained from local network data by showing that without information on individuals' partners' partners, one cannot determine whether a person is at high risk of contracting an STD by virtue of having well-connected, promiscuous partners or at negligible risk because the partners are relatively chaste.

Other innovative empirical studies of the role of networks in spreading disease that similarly demonstrate the nonlinear quality of network transmission dynamics have been conducted among injecting drug users and other high HIV risk populations in the United States (e.g., Curtis et al. 1995, Latkin et al. 1995, Friedman et al. 1997, Rothenberg et al. 1998, Valente & Vlahov 2001, Potterat et al. 2002). A shortcoming of these studies, however, is that, owing to challenges arising from the populations studied, they employ nonprobability (typically chain-referral) samples. As such, how much one can extrapolate from their findings to draw conclusions about the global network properties that shape disease spread is unclear. That said, methods to cope with this issue are emerging (Heckathorn 1997, 2002; Salganik & Heckathorn 2004).

Although all these studies stand out for having actually observed alters themselves, rather than relying on ego reporting for information on alters, other studies have attempted to deduce global network qualities from local network designs, that is, by collecting information about network partners from egos. For example, in an important and well-known study, Laumann & Youm (1999) used a local network design to examine the black-white STD differential in the United States. Drawing on the epidemiological concepts of core groups and core-periphery contact, they proposed that higher STD rates among blacks than whites are largely attributable to differences in the two groups' sexual networking patterns. Using data on past sexual partnerships collected as part of the National Health and Social Life Survey, including the estimated number of respondents' partners' partners, the authors found that, even controlling for individual-level risk factors such as number of partners, blacks have more bacterial STDs than do whites. Using a network analytic approach utilizing log-linear analysis and a simulation, they attributed this finding to two factors: an intraracial effect and an interracial effect. The intraracial effect is that blacks have more sexual contacts between the core and the periphery than do whites (i.e., more within-group dissortative mating among blacks than whites). To illustrate, a peripheral (which they defined as having had only one sexual partner in the past year) black person is five times more likely to choose a partner in the core (defined as persons with four or more partners in the past year) than is a peripheral white person. The result is that STDs are more likely to be contained within the white core, whereas they are more likely to spill out into the black periphery.

The interracial effect is that infections stay within the black community because blacks are highly segregated from whites and Hispanics in the race/ethnicity of their sexual partners (i.e., more between-group assortative mating among blacks than whites). Owing to this factor alone, blacks are 30% more likely than whites to contract an STD. As such, Laumann & Youm (1999) found that a significant proportion of the black-white STD differential in the United States is due to differences in within-group and between-group sexual networking patterns, which promote intraracial transmission among blacks and limit transmission of infection to other racial/ethnic groups. As Laumann & Youm point out, these network effects could not be identified using analytic methods that incorporate only individual-level risk factors.

Another study that used a local network design is Liljeros et al. (2001). The authors analyzed Swedish survey data on the number of sexual partners reported in the past year and over a lifetime and found that the cumulative distributions decayed as a scale-free power law, meaning that, when plotted, they followed a straight line in a double-logarithmic plot. They interpreted this finding as evidence that safe-sex campaigns will be most effective if, rather than targeting all members of a community equally (as recommended by Bearman et al. 2004), messages are instead directed at high activity members—the hubs of the network. Although this approach of extrapolating from egocentric, local networks to draw conclusions about sociocentric, global network properties has sparked debate about the appropriateness of the methods (Jones & Handcock 2003, Liljeros et al. 2003), this study and the controversy it has stirred are nonetheless useful for illustrating the difference between sociocentric versus egocentric approaches.

Finally, social networks have been found to play a role in spreading other health constructs. Social network approaches (specifically, analyses of contact networks) have been used to illuminate how infectious diseases other than STDs, including tuberculosis (Klovdahl et al. 2001), severe acute respiratory syndrome (SARS, Meyers et al. 2005), and pneumonia (Meyers et al. 2003), can diffuse through a population. In addition, a long tradition of mostly egocentric network studies have documented how reproductive health behaviors and related knowledge are spread by or constrained by network dynamics (e.g., Montgomery & Casterline 1993, Rosero-Bixby & Casterline 1994, Valente 1995, Entwisle et al. 1996, Valente et al. 1997, Bond et al. 1999, Kohler 2001, Kohler et al. 2001, Rindfuss et al. 2004).

Moreover, evidence suggests that health-related emotional states, such as optimism, happiness, depression, or suicidality, also can spread through networks. For example, Larson and colleagues have used the Experience Sampling Method (Csikszentmihalyi & Larson 1992) to trace the dyadic spread of moods over short time intervals within families (Larson & Richards 1994). Similarly, Bearman & Moody (2004) used Add Health data to show that suicidality in adolescents is shaped by their social network position, especially for girls. Specifically, they found that having had a friend who attempted suicide increased the risk of suicidal ideation and suicide attempts for both sexes, whereas having a suicidal relative affected ideation only, and to a lesser extent than if it were a friend. Attending a school with dense social networks reduced suicidal ideation in girls but not boys, but it did reduce the likelihood that a suicidal boy would actually make an attempt on his life. Being socially isolated or having friends who were not friends with each other increased the risk of suicidal ideation for girls only. On the basis of these and other findings, the authors concluded that relational positioning was more salient to girls' suicidality than to boys' and was more predictive of suicidal ideation than of actual attempts, which were largely stochastic.

Selection and Homophily Within Social Networks

Understanding the impact of social networks on health requires not only understanding how networks function, but also how they are formed, which raises the issue of the role potentially played by selection and homophily (the tendency of people to form ties to similar others) (McPherson et al. 2006). Regarding selection, health-relevant traits such as age or income, or even health status itself, can contribute to the creation or dissolution of specific network ties or to the formation of networks with particular features. For example, a study using Add Health data detected a tendency of obese adolescents to be less central in their networks; although the analysis was cross-sectional and could not, therefore, determine the direction of causality (i.e., whether obese individuals had fewer ties or whether those with fewer ties became obese), it nonetheless illustrates the possibility of a health-related trait influencing an individual's network position (Strauss & Pollack 2003). As another example, illness can result in the severing of ties, either because one person actually dies or because a person no longer wishes or is able to be in a relationship with another because one of the two is sick.

Researchers have studied homophily in close relationships ranging from romantic partners, to those who define one another as friends, to those who simply "discuss important matters" with each other (Verbrugge 1977), as well as in the more situational relationships of career support, mere contact, and even just "knowing about" someone (Kupersmidt et al. 1995, Hampton & Wellman 2000). Patterns of homophily are remarkably robust across these different relationship types, and homophily has been found to be critical to the formation of interpersonal bonds, especially in friendships and romantic relationships. Consequently, homophily is important to any consideration of the effects of social networks on health, as it can result in networks being endogenous with health.

To illustrate, research suggests that young children become friends in direct relation to the number of attributes (both demographic and behavioral) they share (Goldman 1981, Kupersmidt et al. 1995), with attitudinal similarity often seen as key (Byrne 1971, Condon & Crano 1988). In addition, decades of sociological research have shown that similarity of attributes can lead to the development of homogeneous networks among adults. For example, in a classic study of friendship formation among individuals who were originally strangers to one another, Newcomb (1961) demonstrated that similarity of background and interests is a potent determinant of attraction among randomly assigned college roommates. Similarly, McPherson et al. (2001) used homophily as a basic organizing principle in their investigations of social networks, social capital, social movements, organizations, and a variety of other areas affected by network processes.

Indeed, early social network studies revealed substantial homophily on psychological attributes and demographic traits such as age, sex, race/ethnicity, and education (Richardson 1940, Loomis 1946). Homophily has since been found to involve characteristics as diverse as political leanings, social class, attitudes, and personality (Byrne & Clore 1970, Caspi & Herbener 1990). Among adult friends, specifically, substantial evidence of homophily exists in the domains of age, religion, education, and occupational prestige (Richardson 1940, Fischer et al. 1977, Chown 1981, Fischer 1982, Marsden 1987, Matthews 1995, Hampton & Wellman 2000, Louch 2000).

Because homophily occurs around genetically related traits (appearance, intelligence, personality, etc.), it also is important to consider the underlying role of genetics in friendship formation. Genes could affect a person's taste for friendship and connectedness in general, or they could affect the specific nature of the friends a person chooses on the basis of their observable traits. Twin studies, which exploit the natural difference in genetic similarity between monozygotic (MZ) twins, who share 100% of their genes with each other, and dizygotic (DZ) twins, who share (on average) only 50%, illustrate this possibility. For example, one study of mate choice and friendship in twins found that MZ twins chose spouses and best friends more similar on various dimensions to their cotwins' spouses and friends than did DZ twins (Rushton & Bons 2005). Another study used Add Health data to examine similarity among friends on a number of heritable traits and found that the best (same-sex) friends of MZ twins were more alike on measures of academic performance and aggressive behavior than were the best (same-sex) friends of DZ twins (Guo 2006).

The challenge that selection and homophily pose to analyses of social network effects on health is to be able to differentiate between their influence and that of induction and peer effects—the tendency of socially connected people to come to resemble each other. One approach to addressing this problem was utilized by Sacerdote (2001), who used the randomization of peers through college dorm assignments as an instrumental variable method for evaluating the causal impact of peer effects on student achievement. By treating the random dorm assignment of students as a natural selection into treatment (having an academically successful roommate) versus control (having an academically unsuccessful roommate), he found strong evidence of peer effects on grade point average. It is typically quite difficult, however, to find circumstances in which people are assigned social connections for plausibly random (exogenous) reasons. Other approaches, including panel models, exploitation of directionality of friendship nominations (Christakis & Fowler 2007), and the use of genes and Mendelian randomization, are also possible (Davey Smith & Ebrahim 2003, Ding et al. 2006).

FUTURE RESEARCH DIRECTIONS

As noted, social networks have been posited to affect health through five basic mechanisms: social support, social influence, access to resources, social involvement, and person-to-person contagion. Of these, sociological studies have focused predominantly on social influence, access to resources, and social involvement. However, most sociological studies have evaluated only indirectly how networks work through these mechanisms to affect health. Rather than directly observing how these factors are transmitted through networks, they have inferred that the process occurs from the evidence of transmission. In other words, rather than explicitly map out the networks involved, they have inferred their presence on the basis of resources transmitted from one person or group to another. In so doing, they have paid little attention to the role of network structure in determining how and when resources are disseminated or constrained.[7] Additional research thus is needed to explicitly link characteristics of networks and network ties to the mechanisms involved in affecting health.

In addition, Berkman et al. (2000) have called for greater consideration of even more proximate biological and psychological pathways through which networks affect health, which they argue fall into three categories: (*a*) physiological stress responses; (*b*) psychological states including self-esteem and self-efficacy; and (*c*) health behaviors, both positive (e.g., exercise, health service utilization, medical adherence) and negative (e.g., tobacco consumption, overeating). Although numerous social support studies have investigated these mechanisms (see Berkman et al. 2000 for a review), few social network studies have looked at them beyond the dyadic level.

Moreover, one cannot assume that network structures will be consistent across time, space, or population. As an illustration, despite Bearman et al. (2004) and Helleringer & Kohler (2007) both choosing their research sites in part for their relative social isolation, they found strikingly different network structures. A more dramatic example is provided by Entwisle et al. (2007), who documented extensive variation in network structures even across villages within a relatively small, socially homogeneous area.

Similarly, different network properties are relevant to different health phenomena and function differently in different contexts. More specifically, defined attributes of social networks can be salubrious or deleterious depending on the context and the health outcome in question. For example, high network centrality—a structural feature of nodes that describes the extent to which they are highly connected, prominent, or influential in a network—is generally desirable in an information network. In a sexual network through which an STD is spreading, however, to be on the periphery, remote from other nodes and outside the chain of influence, is preferable if one is to avoid infection.

Another issue to consider is that the creation of social networks is not random. As discussed above, individuals may select their network partners on the basis of qualities such as sex, socioeconomic status, or even health. In fact, the nonrandom nature of networks is what makes them inherently social. Although much substantive work has been conducted on this topic, as reviewed above, additional research is needed to develop still better ways to cope with this issue methodologically. Research is needed into how health-related characteristics affect the creation and structure of networks and into new methods for distinguishing the effects of health on network structure from the effects of network structure on health.

That is, methodological advances are needed to optimally study social networks and health. Work is proceeding on several fronts. Some investigators are experimenting with applying agent-based models to health problems or applying insights from such models to more conventional econometric estimation strategies

[7]For example, particular topological features (e.g., whether the network is a regular lattice or a random graph) may be highly relevant to the spread of information or behaviors (Centola & Macy 2007b).

(Burke & Heiland 2007, Hammond & Epstein 2007, Oswald & Powdthavee 2007, Sánchez et al. 2007). Others are exploring ways to apply instrumental variable techniques to network data, including identifying new instruments on the basis of subjects' (plausibly more exogenous) biological rather than social traits (Davey Smith & Ebrahim 2003).

As a result of these and other developments, we expect to see a new wave of empirical work in the field of social networks and health over the coming years. For example, investigators might even conduct experiments in which they seed networks with health-relevant traits or messages and watch whether and how they spread. These networks could be of real people in face-to-face communities or they could be of individuals assembled over the Internet. Still another tantalizing prospect is the use of entire virtual worlds to conduct social science research; it is not hard to imagine experiments in which avatars in virtual worlds are randomized to different treatments involving either health or network attributes (Bainbridge 2007).

Lastly, the existence of interpersonal health effects and the fact that individuals are embedded in social networks imply developments in research and policy. To explore such effects, new data sets are needed. Currently, most prospective cohort studies and randomized controlled trials include only isolated individuals who are followed to observe outcomes. Some social science and epidemiological cohort studies do ask respondents about the health of their spouses or other social contacts, but few actually include the social contacts in the study cohort. There are, of course, exceptions, not limited to those discussed above (e.g., Add Health and FHS-Net), such as the U.S. Health and Retirement Survey, the Malawi Diffusion and Ideational Change Project, the Nang Rong Household Survey, and others. Nonetheless, developing additional data sets with such features and measurements is necessary to understand fully the effects of social networks on health. **Figure 2** contrasts typical extant data sets with idealized future data collection efforts for the study of egocentric network effects.[8] Compared with the typical network study design shown in the top panel of **Figure 2**, a preferable network-based data set (shown in the bottom panel) would have (*a*) more alters (and alter types) in the sample, (*b*) full bilaterality of data collection, (*c*) subalters (i.e., the alters of the alters) in the sample (and even further connections, potentially culminating in a full, sociocentric study), (*d*) ascertainment of interlevel connections (e.g., between alters and subalters), (*e*) interego connections, and (*f*) a longitudinal design. A still more complex alternative, illustrated in **Figure 1**, is to sample an entire group or community and then discern the ties between the constituent individuals; this latter option constitutes a global or sociocentric study.

POLICY IMPLICATIONS OF A SOCIAL NETWORK PERSPECTIVE ON HEALTH

The existence of social networks in which individuals are embedded and through which germs, ideas, norms, and support can flow suggests that health events and characteristics may have important downstream effects. These health events and characteristics can assume different forms, including chronic illnesses or discrete health events, health behaviors, medical or behavioral interventions, or physical attributes that affect health (e.g., obesity). Consequently, health interventions, quite apart from their effects on a focal individual, can have unintended health effects on others. It is not hard to imagine possible examples: Treating depression in parents may increase their propensity to vaccinate their children, thereby saving children's lives. Replacing a hip or preventing a stroke may mean that a person is better able to care for his/her spouse, thus improving the spouse's health. Delivering a weight-loss

[8]Collecting information about the various contacts of people enrolled in clinical trials or epidemiological studies may represent an extension to study design similar to the extension in the 1990s of including cost-effectiveness analyses as a standard feature of clinical trials.

or smoking-cessation intervention to one person may trigger substantial behavior change in that person's friends. Or giving a patient superior end-of-life care may decrease the stressfulness of the patient's death, thereby decreasing his/her spouse's propensity to die during bereavement.

The cumulative impact of a therapeutic or preventive intervention is thus the sum of the direct health outcome in the focal individual plus the collateral health outcomes in those to whom he/she is socially connected (**Figure 3**). These collateral health effects, or the benefits and detriments that accrue to the social contacts, can be either positive or negative (e.g., side effects of medication in the individual, herd immunity in social contacts) and are examples of health externalities. Attention to and measurement of unintended outcomes that result from the embeddedness of patients in social networks thus can prompt a rethinking of the relative value of health care interventions.

In addition to increasing our understanding of social determinants of health, the study of health externalities is an important area of research because collateral health effects are often neglected in analyses of the costs and benefits of health interventions. As such, our understanding of the cost-effectiveness of particular interventions might be very different if, rather than only measuring direct effects on targeted individuals, as is currently the typical practice, we also considered indirect effects on those to whom targeted individuals are connected (Christakis 2004). Furthermore, not only policy makers but also individuals experiencing health events might derive value from a greater awareness and consideration of these effects. For example, 89% of patients feel that a good death involves not burdening one's family (Steinhauser et al. 2000); consequently, patients might prefer hospice care over standard terminal care if they felt that it would have health benefits for bereaved relatives (Christakis & Iwashyna 2003).

These social or policy multiplier effects deserve further attention. Are they indeed of sufficient clinical and economic importance to force a reassessment of the cost-effectiveness of certain interventions?

When the cost/benefit assessment is made by policy makers with a collective viewpoint, all the downstream costs and benefits of health care accruing to a group might be relevant, and the argument in favor of accounting for collateral effects might be even more compelling than that perceived by individual doctors or patients. Thus, from a societal perspective, the assessment of the cost-effectiveness of medical interventions might change substantially if the benefits of an intervention are seen as including the collateral positive effects and the costs as including the collateral negative effects. More generally, understanding network effects will contribute to a better understanding of the overall return on medical care and advances in medical knowledge.

Such a concern for collateral effects could, however, lead to unexpected results. For example, preventing a death from heart attack, which is clearly desirable from the individual's perspective, may mean that we have to forego the motivation to improve health habits that would otherwise have accrued to those to whom the patient is connected. Another provocative implication is that, if it can be shown that benefits are multiplicative in such people, policy makers might value socially connected individuals, such as married people, more than social isolates when it comes to providing health care (Crane 1990).

The study of health externalities also is important because it points to ways to improve health habits through exploitation of network phenomena. For example, because person-to-person transmission of obesity appears to play an important role in the epidemic of obesity (Christakis & Fowler 2007), it may be possible to harness the same forces to slow the epidemic. More generally, it may be possible to exploit network phenomena to spread positive health behaviors (Wing & Jeffery 1999, Malchodi et al. 2003, Bruckner & Bearman 2005), in part because people may be aware that their own risk of illness depends on those around them (Montgomery et al. 2003).

CONCLUSION

The evidence reviewed here illustrates some of the many ways that individuals' health and well-being affect the health and well-being of others. Studies of social network influences on health, the role of social support in determining individual health, and spillover effects of illness from one person to others have all documented the interconnectedness or interdependence of health among socially tied individuals. In short, illness, disability, health behaviors, health care use, and death in one person are associated with similar outcomes in numerous others to whom that person is tied, and there can be a nonbiological transmission of illness.

The existence of social network effects on health provides a strong theoretical and practical justification for the field of public health. To the extent that health outcomes in an individual depend not just on that person's own biology and actions, but also on the biology and actions of those around him/her, collective and not just individual interventions become salient. The existence of social networks means that people and events are interdependent and that health and health care can transcend the individual in ways that patients, doctors, policy makers, and researchers should care about.

DISCLOSURE STATEMENT

The authors are not aware of any biases that might be perceived as affecting the objectivity of this review.

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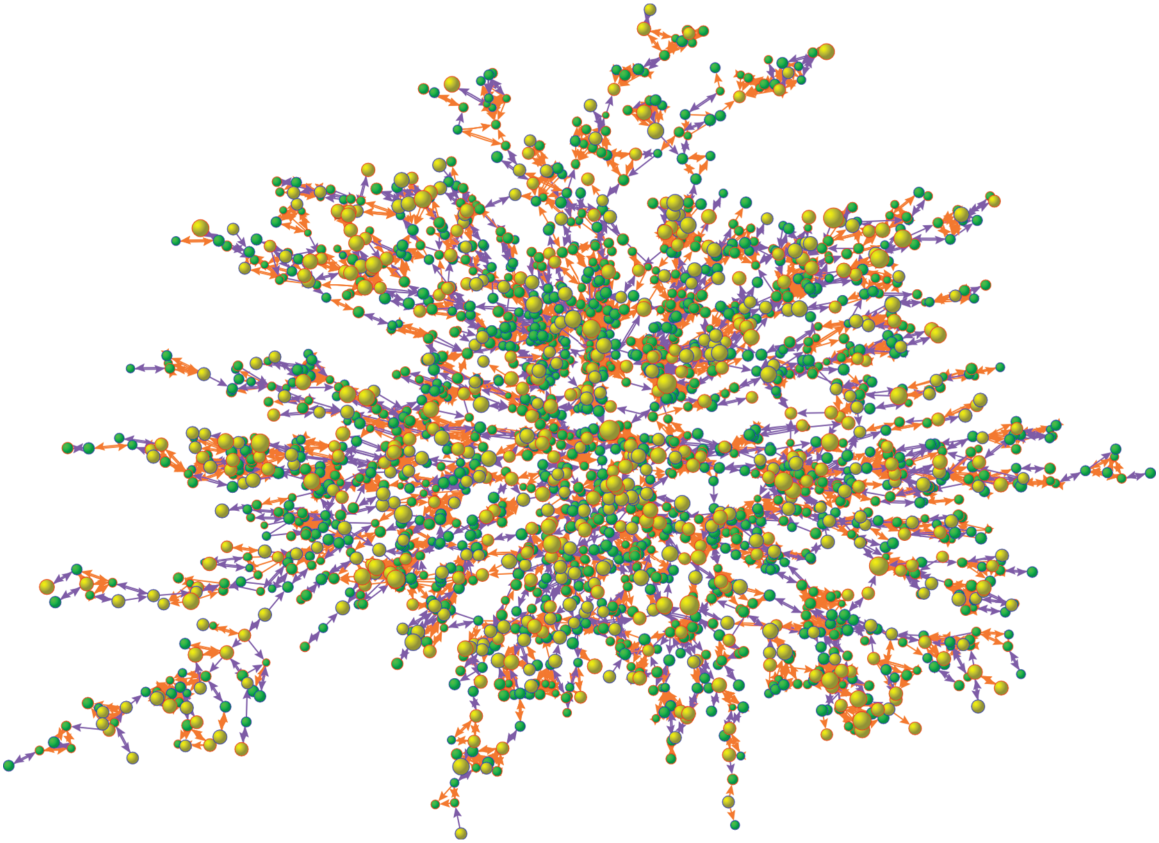

Figure 1

This subcomponent of the Framingham Heart Study (FHS) social network in 2000 contains 2200 individuals. Node borders indicate sex (red = female, blue = male), node color indicates obesity (yellow = BMI > 30), node size is proportional to BMI, and arrow colors indicate relationship (purple = friend or spouse, orange = biological kin). (Adapted from Christakis & Fowler 2007.)

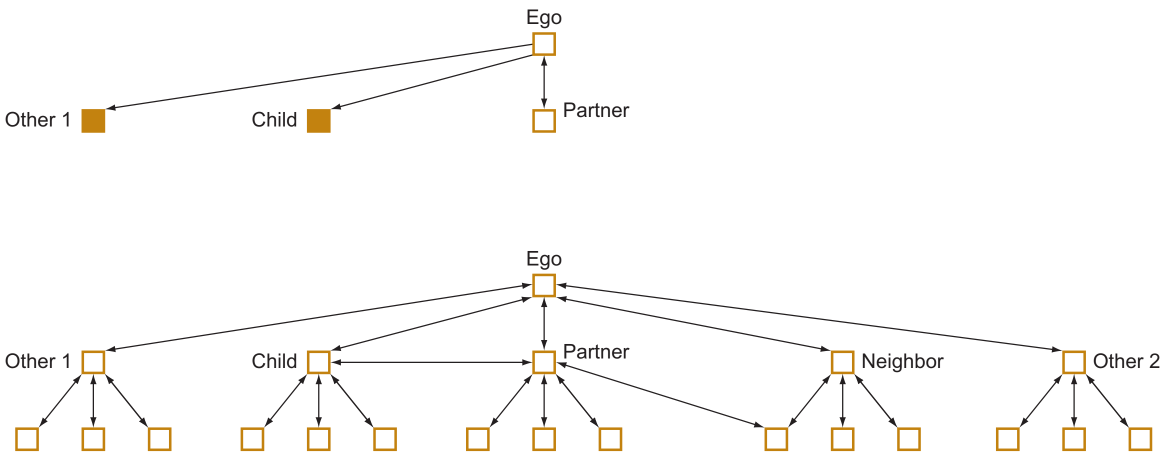

Figure 2

Individuals included in a data set are indicated with open squares, and excluded individuals are indicated with closed squares. The arrows indicate whether information is sought from a respondent about the specified other. (*top*) Most large-scale, representative data sets containing network data are configured as shown here: Either information is sought from egos about specified, unobserved alters (e.g., friends with whom the ego discusses a particular topic), or a specific alter (typically, a spouse) is identified and impaneled into the data set, allowing for information to be collected directly from him/her, as well. (*bottom*) In contrast to the more typical network designs shown in the top panel, the bottom panel illustrates an alternative data architecture in which the sample is initiated by impaneling a set of egos but then captures more individuals within the network.

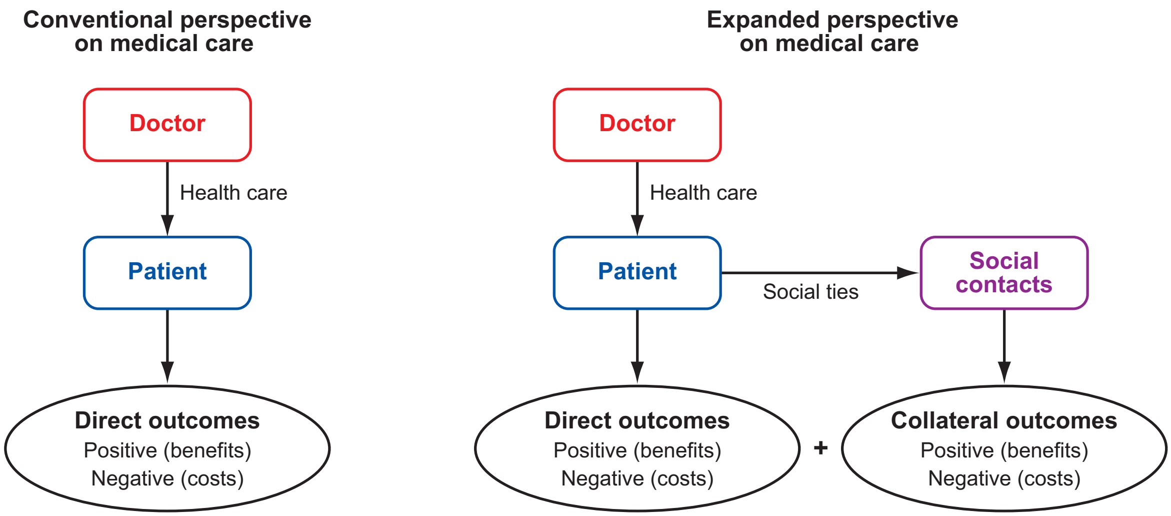

Figure 3

In the conventional perspective on medical care, the costs and benefits of health care are judged according to their ability to achieve direct, intended outcomes in patients. However, because patients are connected to others via social ties, health care delivered to one person, quite apart from its effects on that person, may have health effects on others. The cumulative impact of the intervention is thus the sum of the direct outcomes in the patient plus the collateral outcomes in others. (Adapted from Christakis 2004.)

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