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Integrating social networks and human social motives to achieve social influence at scale

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The innovations of science often point to ideas and behaviors that must spread and take root in communities to have impact. Ideas, practices, and behaviors need to go from accepted truths on the part of a few scientists to commonplace beliefs and norms in the minds of the many. Moving from scientific discoveries to public good requires social influence. We introduce a structured influence process (SIP) framework to explain how social networks (i.e., the structure of social influence) and human social motives (i.e., the process of social influence wherein one person's attitudes and behaviors affect another's) are used collectively to enact social influence within a community. The SIP framework advances the science of scientific communication by positing social influence events that consider both the "who" and the "how" of social influence. This framework synthesizes core ideas from two bodies of research on social influence. The first is network research on social influence structures, which identifies who are the opinion leaders and who among their network of peers shapes their attitudes and behaviors. The second is research on social influence processes in psychology, which explores how human social motives such as the need for accuracy or the need for affiliation stimulate behavior change. We illustrate the practical implications of the SIP framework by applying it to the case of reducing neonatal mortality in India.

science communication | global health | network intervention | social sciences

There is compelling evidence that both in the developing and developed world the day a baby is born is the most dangerous of the child's life. In 2012, 2.9 million children died in their first month of life and over a third on their first day. India alone accounts for more than a quarter of the world's neonatal deaths, with 31 of every 1,000 children dying before age 28 d. Although the neonatal mortality rate (NMR) in India has been declining, it is still 10 times higher than in the developed world.

From Scientific Discovery to Public Good

Scientific discoveries stand to drastically reduce NMR, greatly improving the lives of the next generation of children living in the world's largest democracy. Although there is a substantial portfolio of actionable insights, often bolstered by multiple randomized control trials (RCTs), a pressing challenge confronting funders, health-care administrators, and workers is to scale up these practices from pilot projects to widespread practices. Ideas, facts, practices, and behaviors need to go from accepted truths on the part of a few scientists to commonplace beliefs and norms in the minds of the many health-care workers as well as the populace at large in places most in need of them. For instance, it is well documented that over a third of all neonatal deaths are caused by infection, and umbilical cord infection is a major risk factor for many of these (1). It is also well established in RCTs that applying an inexpensive topical solution of 4% chlorhexidine (CHG) to cleanse the cord reduced neonatal mortality in developing countries such as Nepal by 24%, with comparable effects found in Bangladesh and Pakistan. Unfortunately, even when they are made available innovations such as CHG can be "slow ideas" to spread (2).

We began with the case of neonatal mortality to illustrate that even when science has made substantial strides in identifying life-saving changes in attitude and behaviors the challenges faced in communicating that science remain formidable. We return to the case of CHG later. First, we advance the notion of a structured influence process (SIP) that builds on two influential, but for the most part distinct, intellectual approaches to transform scientific discoveries into societal breakthroughs by changing people's attitudes and behaviors.

The SIP Framework

The SIP framework explains how social networks (i.e., the structure of social relations) and human social motives (i.e., the process of social influence that occurs when the actions of one person or group prompt changes in others' actions) can be used to enact social influence within a community. Such a framework has important implications for advancing the science of scientific communication. This framework builds on core ideas from two areas of social science. The first is research on social networks, which explores how individuals' network of contacts shape their attitudes and behaviors. The second is research on social influence within psychology, which explores how basic human social motives stimulate attitude and behavior change. Whereas both areas are concerned with social influence, they have taken very different perspectives. Synthesizing these perspectives, as we do with the SIP framework, enables the formulation of social influence events to move from scientific discovery to public good.

The SIP framework identifies the "who" and the "how" of social influence. This approach uses principles of social structure to first identify the opinion leaders who need to be influenced to change norms in the community along with who among their peers is structurally best positioned to do so. Once pivotal opinion leaders and their peers have been identified, we posit types of peer social interaction that describe how to socially motivate behavior change among the opinion leaders. Hence, the SIP framework defines a social influence event as a tuple of an opinion leader who needs to be influenced, a peer who is a potential influencer, and a social interaction that triggers a social motive for the opinion leader to change his/her behavior.

Social Networks: Who to Influence? The vast majority of scholarship on science communication has focused on crafting messages to be disseminated to general or large segments of audiences. The assumption of one influential perspective, the deficit model (3, 4), also referred to as the public irrationality thesis (5), is that the public has a deficit in comprehending key scientific facts. The

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aspiration therefore is that the audience would change their behaviors if the scientific facts were conveyed more eloquently. Bob Lalasz, the director of science communication for the Nature Conservancy, notes that the blame for our inability to effectively communicate scientific information is targeted either at the scientists, the media, or the general public and is based on the unsubstantiated underlying assumption that “the public isn’t getting the gravity of the problem—because if they did, how could they fail to act?”

Two-step flow of social influence. In fact, research has shown that most individuals are not directly influenced in their attitudes and behaviors based on what is conveyed by the media. In 1944, Paul Lazarsfeld and his colleagues developed a two-step model for the flow of communication to demonstrate that the influence of the mass media on the audience in terms of choosing a presidential candidate was mediated by opinion leaders (6). This early work was heavily influenced by 19th-century French sociologist Gabriel Tarde’s (7) work on the crucial role of interpersonal interaction in social influence. To underscore the importance of the opinion leader as the intermediary in the flow of communication from the mass media to the general audience, Katz and Lazarsfeld published an influential book titled *Personal Influence* outlining the two-step flow hypothesis (8).

Subsequent research has criticized the two-step model, demonstrating strong evidence that all individuals—not just opinion leaders—are directly influenced by mass media messages (9). However, much of this criticism simply leads to a more nuanced version of the two-step flow hypothesis. For instance, agenda-setting theory argues that the role of the mass media was not to help an audience decide what to think, but instead simply what to think about (10). This left open the possibility of intermediaries such as opinion leaders to help shape the audience’s attitudes and behaviors on issues that the mass media prompted them to think about. More recently, a modified two-step flow of communication models argues that whereas most individuals become aware of issues from the mass media they still rely at least to some extent on opinion leaders to help shape their attitudes and behaviors (11). As a result, the fundamental premise of the two-step flow model has been sustained and has spawned a substantial body of research on the ways in which individual’s attitudes and behaviors are shaped specifically by the opinion leaders, and more generally all individuals, in their social networks.

One of the first empirical studies in this genre pertained to science communication; social networks explained how the initial trials of an antibiotic by a few early innovators led to its adoption by the entire medical community (12). This study led, over the past five decades, to a substantial body of research using social network theories and methods drawing largely from graph theory to explain how attitudes and behaviors propagate through communities (13). An early protagonist of this tradition was Everett Rogers with his work on the diffusion of innovations (14).

Identifying opinion leaders. Given the central role of opinion leaders in these models, it is not surprising that a considerable amount of early research from a social network perspective focused on identifying who in the network were best positioned to serve as opinion leaders. In network parlance, these were individuals deemed to be central in the network. There has been a long-standing interest in identifying central individuals in a social network (15). Krackhardt (16) used a “kite network” (Fig. 1) to illustrate the conceptual distinctions between three of the most widely used measures of centrality (17).

When individuals are presented with the kite network and asked to identify who is the most central person, the most common responses are D, H, and F/G. The rationale for D being central is self-evident. D has more direct connections than any other individual. This measure, called degree centrality, makes D a connector. These are individuals who know a lot of others and are therefore well positioned to share knowledge with and influence (as well as be influenced by) a lot of others.

Even though some individuals are able to discern that H is central, they are often at a loss to explain why. In fact, the reason

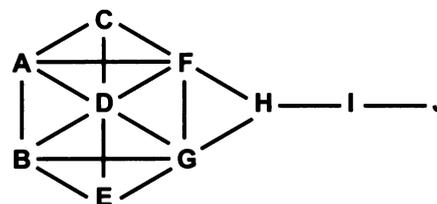


Fig. 1. Network exhibiting a kite structure (16).

why H is central in this network is because H is an intermediary on the shortest path (referred to as the geodesic) between more pairs of individuals in this network (who are not directly connected) than any other member of the network. In essence, these individuals who have high betweenness centrality are brokers who connect individuals not directly connected to each other. As such, these individuals are uniquely well positioned to form opinions based on gathering and combining knowledge from other members in the network who are not able to share knowledge directly. They are also very efficient at influencing others, assured in the knowledge that those individuals will not have direct contact.

Perhaps the least intuitive is an understanding of what makes F and G central in this kite network. Here again we rely on the notion of the shortest path between any two nodes. Both F and G have, on average, the shortest direct or indirect paths (or geodesic distance) to all other members in the network. As a result, these individuals who have high closeness centrality serve as pulse-takers in the network. They are particularly well qualified to take the “pulse” of the network in terms of gossip or opinion. Pulse-takers are also well positioned to disseminate gossip or opinion.

There is a fourth measure of centrality based on the intuition that an individual is central in the network to the extent that he or she connects to other central people in the network. This seemingly circular definition has an elegant mathematical solution. It is computed as the eigenvector of the matrix in which the rows and columns represent individuals in the network and the cell entries within the matrix represent the presence or absence of a link between the two individuals (18).

Whereas the first three measures of degree, betweenness, and closeness centrality are aimed at being at the “center” of the network, this fourth measure is aimed more at being at the “top” of the network (16). Hence, it is not surprising that this measure is often referred to in the social networks literature as prestige centrality. Individuals who have high prestige are the most influential in the network not by virtue of being connected to many others, but instead by being connected to those who are influential and can therefore cascade opinion change. The eigenvector computation is analogous to the “page rank” algorithm used by Google to identify the order in which it presents search results in response to a query (19).

Using networks to influence. Whereas the development of additional centrality measures continues to be a robust scholastic enterprise in the network science research community (see ref. 20 for a review), the examples described above demonstrate the ability of social network metrics to identify who has the most potential to be influential opinion leaders in communicating scientific information within a community. It is important to underscore that highly central individuals are not by definition influential (21). Instead, they have, by virtue of their centrality, the potential to induce change (22). The implication is, given limited resources, an effective science communication strategy would be well served by investing resources in shaping the attitudes and behaviors of opinion leaders. One cannot assume that the opinion leaders are already primed with the scientific opinion that one would like to convey to the community. The question that arises next is to identify the peer influencers who are most likely to sway the opinion leaders. For scale-up, it is critical that these opinion leaders are influenced (23). The remainder of this section describes how social networks research has addressed this question.

Even though Katz and Lazarsfeld (8) titled their book *Personal Influence* to describe how individuals are influenced by others in their interpersonal network, the social network research community gravitated to the term “social influence” (rather than personal influence) to describe this phenomenon. In retrospect, this was probably an unfortunate decision because it conflated two very distinct interpretations of the term “social influence.” Social network theories about social influence focus on “who is most likely to influence whom (24),” whereas psychological and communication theories of social influence focused on “how is one most likely to influence/persuade another” (25, 26). Friedkin and Johnsen described this as the tension between social structure and social process respectively. They note, “In psychologists’ research on mechanisms of attitude change (27), social structures rarely appear as important explanatory constructs, and in sociologists’ research on the effects of social structures and personal attitudes, the process of attitude change is rarely attended to in any detail” (ref. 24, p. 29). It is noteworthy that in recent years some in the networks community have introduced the term “peer influence” as an alternative moniker for the study of social influence from a network perspective (28). In the remainder of this section we focus on the social network perspective of who is most likely to influence whom and postpone a discussion of the “how” to the following section.

Contagion. In networks research, the mechanisms for the spread of attitudes and behaviors are often referred to as theories of contagion (29). This invokes an epidemiological metaphor wherein the spread of an idea does not have to be intentional or conscious on the part of the peer influencer or the targeted opinion leader. That said, researchers examining social influence from a network perspective have attempted to draw upon the social mechanisms outlined in several psychological and social psychological theories. Broadly, rather than incorporate those mechanisms of social influence explicitly, they look for network structural signatures that are implied by the mechanisms. Rogers and Bhowmick (30) argued that to understand how individuals influenced one another it is important to take into account the nature of the relationship, as well as the similarities and differences between the two individuals. Burt describes the structural basis of influence as “something about the social structural circumstances of ego and alter [that] makes them proximate such that ego’s evaluation of the innovation is sensitive to alter’s adoption” (ref. 31, p. 1288).

These observations suggest three elements of structural signatures that are implied by social influence mechanisms. The first element is the individual attributes of either the peer or the opinion leader. These attributes could be demographics, personality characteristics, level of expertise, attitudes, or behaviors. For instance, a peer influencer going to a gym is a behavior that can potentially influence the opinion leader. Likewise, an opinion leader’s uncertainty or ignorance about using a technology can make her target more susceptible to influence.

The second element of structural signatures is the similarities (or differences) in attributes between the peer and the opinion leader. Whereas the first element independently considers the attributes of the peer and opinion leader, here we collectively consider their attributes. For instance, do the peer and the opinion leader both belong to the same volunteer organization? In network parlance, looking collectively at the attributes of both the peer and the opinion leader is referred to as dyadic attributes (32). The third element of the structural signatures implied by social influence mechanisms is the relations that connect the two individuals. These could include whether the peer and the opinion leader frequently communicate, or whether the opinion leader frequently seeks advice from the peer, or whether the opinion leader trusts the peer. These reflect progressively stronger ties in terms of the potential for social influence (16). Armed with these three elements, “noteworthy tasks to be addressed by the network approach to social influence include (a) elucidating the substantive processes that underlie claims that there should be structural effects on the attitudes and behaviors of actors, (b) defining interpersonal proximity in a network in an appropriate manner given

these processes, and (c) assessing the predictive success of the approach using available mathematical and statistical models of social influence processes” (ref. 33, p. 128).

Marsden and Friedkin (33) summarize several substantive processes that underlie claims of structural effects on individuals’ attitudes and behaviors. These include social comparison, uncertainty reduction, coercion, dissonance reduction, imitation, and normative control, to name a few. In the networks literature contagion is defined as occurring either via cohesion or structural equivalence (31). Contagion by cohesion implies that the social influence flows via a direct tie between the peer and the opinion leader. Contagion by structural equivalence implies that the social influence from the peer to the opinion leader does not require a direct network tie between them but ties to the same other individuals in the network. The fact that two individuals have ties to the same others in the network implies that they are exposed to similar information and hence are more likely to converge in their attitudes or behaviors. An important demonstration of the efficacy of contagion by structural equivalence was Burt’s (31) reanalysis of the Coleman et al. (12) data to investigate the role of social networks in explaining how the initial trials of an antibiotic by a few early innovators in trials led to its adoption by the entire medical community. Burt (31) found that more of the variance in the adoption of the antibiotic was explained by contagion via structural equivalence than by cohesion.

Causality in social influence. In their review of social influence studies, Marsden and Friedkin (33) note that virtually all studies of social influence from a network perspective tend to be non-experimental, with the exception of Friedkin and Cook (34). This, as we shall see later, is in stark contrast to the study of social influence in psychology. Perhaps relatedly, in the past two decades there has been growing awareness that contemporary mathematical and statistical network models are incapable of making strong causal claims to assess social influence (35). The fact that a change in attitude by one individual preceded a change in attitude with one of the individual’s network partners is not sufficient grounds to make a strong causal claim of influence. It is likely that the association might be spurious and associated with a common contextual variable that was omitted (36). This insight was illustrated by Weber: “... if at the beginning of a shower a number of people on the street put up their umbrellas at the same time, this would not ordinarily be a case of action mutually oriented to that of each other, but rather of all reacting the same way to the like need of protection from the rain” (ref. 37, p. 23). One could erroneously infer that the opening of umbrellas was a social influence process from one individual to another when in fact they were all independent responses to the rain.

Snijders et al. (38) have attempted to address this challenge, developing longitudinal stochastic actor oriented models to disambiguate causal claims by modeling simultaneously the co-evolution of changes in attitudes and behaviors (social influence) as well as changes in the creation, maintenance, and dissolution of network ties (social selection). Aral and coworkers offer a critical review of some of the novel approaches being attempted, including attempts to leverage big data to conduct “randomized trials” to isolate the causal claims of influence (39) and dynamic matched sample estimation techniques (40). A social network approach highlights the structured nature of influence. However, despite some attempts, it is inadequate in its efforts to explicitly incorporate the processes of social influence. We now turn our attention to the human social motives that enable the opinion leaders to be influenced.

Human Social Motives: How to Influence? The network perspective is useful for identifying pivotal individuals who are opinion leaders and who are the peers within their network that can influence them but it stops short of explaining how peers can influence the behaviors of key opinion leaders. This is an issue of human motivation: Which needs [e.g., earning rewards or avoiding losses (41)] explain the direction and/or intensity of a person’s behaviors? A subset of this area is social motivation

(42, 43): Which needs explain how the direction and/or intensity of a person's behaviors depend upon the attitudes and behaviors of others in their social milieu? We focus here on the subset of social motives because they most directly intersect with network theories of social influence, prescribing types of social interactions that give rise to peer-based attitude and behavior change.

Although many taxonomies and structures have been used to characterize human social motives, most include variants of at least two basic needs that prompt people to look to others: the need for accuracy (27) and the need for affiliation (44). The need for accuracy is a social motive because it prompts us to look to others to determine the correct way to act. The need for affiliation is a social motive because it explains our decision to act in ways that cultivate acceptance, belongingness, and intimacy in our relations with others. This distinction parallels social motives suggested by others, including McClelland's needs for achievement and affiliation (45), Bakan's agency and communion (46), Hogan's "getting ahead" and "getting along" (47), and Fiske's need to enhance the self and need for belongingness (48).

Different types of social interactions activate these two social motives. Next, we discuss six types of social interactions that illustrate the "how" of social influence. Consistent with calls for an evidence-based science of science communication (5), many of the social interactions described below have been tested in RCTs (49, 50).

Human Social Motive 1: The Need for Accuracy. The accuracy motive triggers social influence because people look to others to determine the correct way to act (27, 51, 52). We describe below two types of social interactions by which people determine the correct way to act: information about what others are doing (social proof) and information about what others with expertise or holding positions of power are doing (authority).

Social proof. Individuals continuously evaluate themselves (51), and they often use what others are doing as a basis for evaluating the correctness of what they are doing (52). Individuals pay particularly close attention to what similar others think and do. This tendency gives rise to influence by social proof: Individuals are more likely to engage in a behavior supported by scientific research if similar others are doing it than if they are not. This principle has been used to explain individuals' crowdfunding choices (53), their preferences for online digital microproducts (54), investors' impressions of newly public firms (55), and securities analysts' decisions to continue or abandon firm funding (56) and voting behavior (50). Social networks have important implications for this principle. Social proof triggers behavior change when the opinion leader's peers engage in the desired behavior.

Authority. Influence can also occur by authority: Individuals are more likely to engage in a behavior supported by scientific research if it comes from a legitimate authority than when it does not. The authority principle has been shown to convince students to administer electric shocks to their classmates (57), nurses to dispense knowingly harmful drugs to their patients (58), or patients to make (even incorrect) decisions that they believe align with their doctor's preferences (59). Leveraging network ties is a powerful way to reinforce the authority principle, although authority can be used to enact influence even when the opinion leader does not have links to the peer influencer.

Human Social Motive 2: The Need for Affiliation. The affiliation motive triggers social influence because people's actions are often driven by the human social motive to belong, to form meaningful interpersonal relationships, and to connect with others (44). Because people experience aversive states such as anxiety and depression when deprived of these bonds, they often act on the basis of affiliation, even if it might undermine their underlying beliefs. We describe below four such types of social interactions: those wherein people act similar to others they like (liking), act to return obligations (reciprocity), act in ways that are consistent with their espoused beliefs or prior behaviors (consistency), or act to conform with social norms when they are being observed by others (accountability).

Liking. One of the most prevalent and potent social influence mechanisms is liking. The basic idea is that individuals are more likely to engage in a behavior supported by scientific research if similar and/or proximate others support it than if dissimilar or distant others support it. In general, we act like those who are similar to us (60), who hold similar views as ours (61, 62), and even those to whom we are repeatedly exposed (63, 64). In addition to engaging in a behavior because we like the person supporting the behavior, there is also evidence that we engage in a behavior if we like the person who stands to benefit from our engaging in a behavior (65). Indeed, research on the identifiable victim effect indicates that people are more likely to engage in behaviors that help "the" personified victim at a greater rate than "a" statistical victim (66).

The liking strategy can be enhanced by understanding an opinion leader's existing network relationships. Knowing who they communicate with, go to for advice, and trust will determine which contacts are most likely to succeed in bringing about a behavior change. In addition, liking can be used to identify potential peers who are "likely to be liked" by the opinion leader because they share common individual attributes.

Reciprocity. A second social interaction resulting from individuals' drive to affiliate is reciprocity. The reciprocity principle holds that individuals are more likely to engage in a behavior supported by scientific research if it repays a favor, gift, or concession than if it does not. The catalyst for the reciprocity rule is a sense of obligation. When the opinion leader receives a gift or concession, s/he immediately feels a sense of obligation to repay it. The reciprocity principle is rooted in social exchange theory, one of the most influential theories in social psychology (67). According to Blau, social exchange "refers to voluntary actions of individuals that are motivated by the returns they are expected to bring and typically do in fact bring from others" (ref. 68, p. 91).

There is a robust body of research at the intersection of social exchange theory and social network approaches that explores the emergence of status, power, and dependence among individuals (69). Whereas leveraging social networks can augment the effectiveness of reciprocity in producing behavior change, reciprocity can work without relying on prior social network relationships. Furthermore, reciprocity has been shown to motivate behavior even when the requestor is dissimilar from the opinion leader or even disliked by her (70).

Consistency. Multiple theories in psychology have posited that people have an innate desire to appear consistent—to behave in ways that are consonant with their prior statements and behaviors (71–73). This desire creates the consistency principle: Individuals are more likely to engage in a behavior supported by scientific research when the behavior is consistent with a public position to which the opinion leader has previously committed. This principle has been used to induce a wide variety of behavior by first asking for a very small, low-effort behavior such as wearing a local charity's lapel pin, following which people are more likely to comply with a larger request, such as donating money to the charity (74). A meta-analysis demonstrates that clarifying the when, where, and how of implementation intentions makes the individual's initial commitment to a course of action more binding (75).

Networks can augment the effectiveness of the consistency drive. People are even more driven to be consistent with those with whom they have an existing relationship. Making a public commitment to quit smoking is more effective in producing a subsequent reduction in smoking when the commitment is made to those with whom they have strong ties, such as loved ones (25).

Accountability. Individuals' need for affiliation can also motivate their behavior if they perceive they will be publically accountable for their actions. The accountability principle states that individuals are more likely to engage in a behavior supported by scientific research when the behavior is consistent with an accepted norm, and the individual believes others are observing their compliance with the norm. Experiments in voting (76–78) and charitable giving

(79) indicate that knowing that one's behavior is being observed exerts social pressure. Hence, the social pressure of accountability can serve as a powerful motivator for behavior change.

Bond et al. (78) argue the social pressure of accountability varies depending on who in one's network is observing the behavior. They found strong ties exert more social pressure than do weak ties. Relatedly, field studies of voting behavior find the amount of social pressure is proportional to the number of one's contacts who are watching (77).

The Case of Neonatal Mortality in Bihar, India. Returning to our opening example, CHG is an inexpensive topical solution that reduces the risk of potentially deadly infection when applied to the umbilical stump shortly after birth. The Bill and Melinda Gates Foundation is currently supporting a large-scale program in Bihar, India to scale up a number of family health innovations such as CHG application. Each innovation began with a scientific discovery, which, to realize public good, must take root in the thoughts and actions of individuals in the community. We have been involved in a project to help the foundation and its development partners scale up these innovations from a few so-called innovation districts to the remaining so-called scale-up districts in the state of Bihar.

As a preamble to our current project, we used the techniques described above to identify the key opinion leaders among the network of government officials engaged in family health activities. We identified specific opinion leaders within the scale-up districts, and for each of them we identified a set of key peer influencers in the innovation districts. We believed that providing a list of key peers from the innovation districts for each opinion leader within the scale-up districts would have considerable practical value to our development partners. However, when we shared this information with them we began to recognize the practical limitations of our contributions. As one of our partners put it, "It is nice to know which peer influencer should be connected with a specific opinion leader, but then what?" We soon realized that to be actionable it is not sufficient for us to simply engage in matchmaking for a date, but to go the extra mile and choreograph what happens on the date. This latter challenge led us to delve deeper into the social motives that would influence the opinion leader's desire to act in a certain way.

Motivated by this challenge from our development partners, and inspired by Lewin's famous quote "There is nothing so practical as a good theory" (80), we outline the SIP framework. This framework can serve as a springboard for future theoretical development integrating prior research on social influence from a network perspective with that of social influence from a psychological perspective. Next, we describe how we intend to apply the SIP framework as part of our ongoing work in Bihar. Specifically, we describe how the SIP framework offers specific actionable strategies to help scale up neonatal family health solutions in Bihar by identifying "who" to influence and "how" to influence.

The Structured Influence Process Framework: Application to Scale-Up in Bihar. As discussed previously, network approaches help us identify opinion leaders in the community. We assume that one or more of these opinion leaders are not a priori primed with the relevant attitudes and behaviors to scale-up a scientifically informed initiative. Hence network approaches are also used to identify who would be the most appropriate sources of peer influence for each of these opinion leaders. The social motives literature reviewed above suggests what social interaction would be most effective in helping peers change the opinion leader's behaviors. As mentioned previously, we define a social influence event as a tuple of an opinion leader, a peer, and a social interaction. Fig. 2 presents six sources of peer influence and six social motives, yielding 36 possible social influence events to bring about behavior change among the opinion leaders. The specific behavior we consider is to influence the decision of those expectant mothers who are identified as opinion leaders to use CHG at childbirth and advocate its use within the community.

The building blocks on the left side of Fig. 2 identify the existing or possible network ties (advice, trust, and communication) between the opinion leader and a potential peer influencer. The opinion leader's existing advice, trust, and communication ties are the ideal sources of social influence (16, 28). Data on the existing advice, trust, and communication ties of the opinion leader are typically collected via surveys (81), although novel digital trace techniques hold some promise (82). However, when an individual's existing ties do not possess the desired attitudes and behaviors, an alternative source of social influence is community members who have endorsed the desired attitudes and behaviors. Hence a second source of peer influence is other community members, not directly connected to the opinion leader, who have positive attitudes and behaviors about the initiative. The intuition here is that even though these members in the community do not have existing ties some of them are well positioned to forge new ties with the opinion leader. When choosing community members as peer influencers, it is important to consider the type of new tie that can be formed. If the opinion leader has many friends in common with a potential influencer, then a trust tie can be formed between the influencer and the opinion leader, because each individual is wary of being called out by all of his or her common partners (83). The creation of a new communication tie is facilitated if the influencer has one friend, or at least a few friends, in common with the opinion leader or has common attributes that foster similarity-based attraction (60).

The building blocks on the right side of Fig. 2 present six illustrative social interactions based on the two social motives driven by the need for accuracy (social proof and authority) and the four social motives driven by the need for affiliation (liking, reciprocity, consistency, and accountability). Social motives are somewhat universal in that most people are motivated by the needs for both accuracy and affiliation. However, there are differences in the extent to which individuals' behaviors are socially motivated by these two needs. Hence, there is merit in tailoring social interactions to particular opinion leaders based on the relative strength of their accuracy and affiliation needs.

Every combination of a building block on the left in Fig. 2 paired with a building block on the right characterizes a social interaction event. The selection of a specific social interaction event would be based on (i) existing or possible ties between a potential peer influencer and the opinion leader, coupled with (ii) the opinion leader's propensities for accuracy- and affiliation-based social motives. The social interaction events are based on a scenario where the science communication goal is to influence the key opinion leaders within the community of expectant mothers to adopt and champion the scale-up of CHG within the populace.

The lines (marked a and b) in Fig. 2 indicate the circumstances leading to the selection of two possible social interaction events. The first example (a) indicates a scenario where one needs to influence an opinion leader among expectant mothers whose social motivation for behavior change is predominantly driven by a need for accuracy. In this case, one appropriate strategy would be for a person who is listed by the opinion leader as a communication tie to inform the expectant mother that she should decide to adopt and champion the use of CHG because many new mothers have used it. The second example (b) indicates a scenario where one needs to influence an opinion leader among expectant mothers whose dominant social motive is a need for affiliation. Further, in this case the opinion leader does not have existing advice, trust, or communication ties with others with the desired attitude toward CHG. This necessitates the creation of a new tie with a peer influencer who shares many common ties with the opinion leader and is therefore likely to be trusted by the latter. In this case the peer influencer gives the expectant mother a wristband to wear promoting a new campaign supporting CHG use. Having worn the wristband promoting CHG, and given her motivation to be consistent based on her need for affiliation, she is more likely to adopt and champion the use of CHG among other expectant mothers.

The SIP Framework: A Decision Aid. To make the SIP framework actionable for practitioners engaged in scale-up we developed

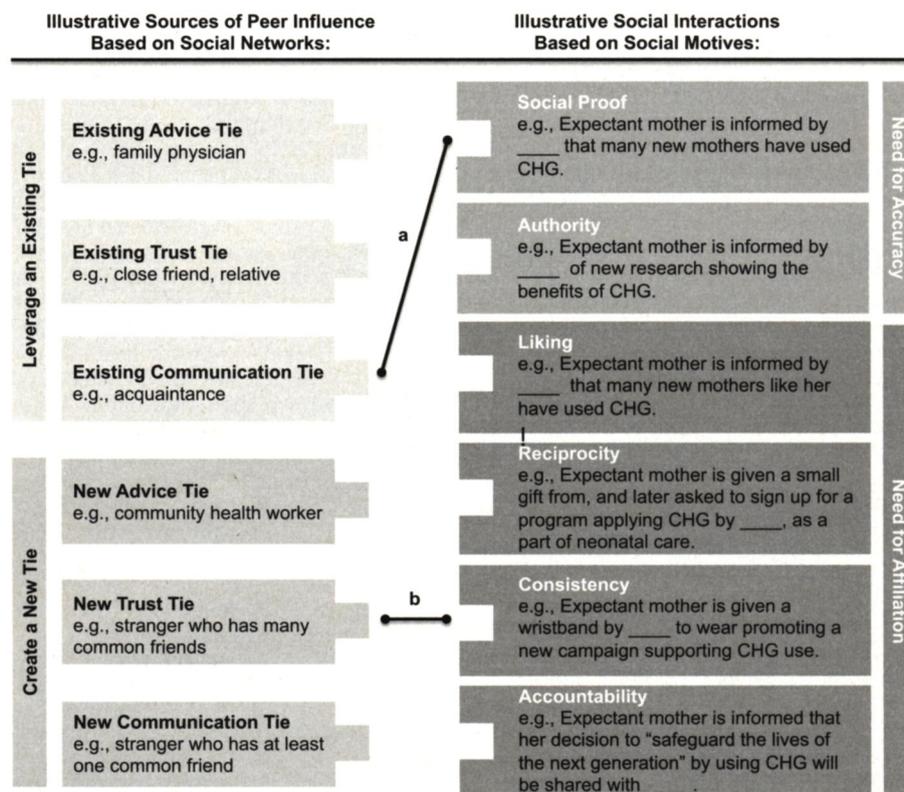


Fig. 2. Creating social influence events by pairing sources of peer influence (based on social networks) with social interactions (based on social motives).

a series of questions that suggest specific influence strategies based on the existing or potential network ties between the potential influencer and the opinion leader as well as the social motives that trigger social influence in the opinion leader. The answers to these four questions reveal the structure (i.e., who) and process (i.e., how) pairings likely to be the most efficacious. These questions presume that the opinion leaders in the community and the peers who can influence them have been identified using the network methods described previously. These are the people who need to embrace the ideas that ultimately transform the findings of rigorous science into practical solutions to human problems and the peers who can influence them.

Hence, the first decisive question is: Has the opinion leader embraced the idea? This question allows us to determine the subset of opinion leaders who need to be influenced to embrace the idea. We assess this using scales that operationalize the four key components of the theory of planned behavior (84): attitudes toward the behavior (e.g., my belief that using CHG is critical in reducing neonatal mortality), subjective norms (e.g., perceptions of the degree to which others important to me believe using CHG is critical in reducing neonatal mortality), perceived behavioral control (e.g., how easy or difficult would it be for me to adopt this behavior?), and behavioral intentions (e.g., how ready am I to engage in this behavior?). For opinion leaders who have not embraced the idea, the next question is: Does the opinion leader have existing ties with individuals who have embraced the idea? Answering this question allows us to determine whether we can use existing ties as sources of peer influence, or whether new ties need to be created. An opinion leader's existing ties are obtained via surveys where individuals reported on their advice, trust, and communication network ties. We assess the extent to which those people who are identified as network ties have embraced the idea using the same scales that operationalize the four key components of the theory of planned behavior enumerated above. If the opinion leader currently has ties to individuals who have embraced the idea, we then ask: Are these

advice, trust, or communication ties? We assess these ties using a network survey (85). Next, we ask: Is the opinion leader most likely to be motivated by a social interaction that invokes the individual's drive for accuracy or affiliation? We assess social motives by measuring the extent to which individuals' core values are driven by agentic needs that align with accuracy (e.g., competence or achievement) and/or communal needs that align with affiliation [e.g., harmony or loyalty (86)]. The responses to these four questions suggest exemplar social interactions such as those presented in Fig. 2 for the case of CHG. It is important to note that these are illustrative and by no means encompass the full range of possible social interactions.

Scientific and Practical Contributions. This paper makes two primary contributions. The first contribution is intellectual: We propose a framework to synthesize social influence research from a network perspective with that from a psychological perspective. Although these two literatures are both important for understanding how to transform scientific discoveries into public good, considering either in the absence of the other has limited the utility of any socially based scale-up intervention. Research on social networks holds the key to understanding how to efficiently scale up in innovation. Network thinking allows us to identify who the most potent opinion leaders are within a given community whose buy-in will seed cascades of attitude change and new norms within the community that benefit from scientific discoveries. However, network thinking is limited in its ability to help us understand how to win over these key opinion leaders. This is where social influence from a psychological perspective has much to contribute. Research on social influence in psychology has made great strides in understanding fundamental social motives that, when activated, promote changes in key attitudes and behaviors. However, research on social influence has been relatively agnostic with regard to who is the most qualified peer influencer. The SIP framework is a modest attempt to leverage the strength of each of these perspectives while

addressing their respective limitations. Specifically, we develop the theoretical concept of a social influence event that explicitly incorporates the identification of the appropriate source and target of influence based on social network theories of influence and the relevant nature of social interaction based on the psychological theories of influence.

The second contribution is practical. As mentioned, the motivation for proposing SIP as a conceptual framework that leverages two influential but largely distinct research traditions was prompted by our recognition of its value to practitioners in science communication. We present examples of social influence attempts in Fig. 2. The figure illustrates how strategic selection of a social influence event enables greater scale-up and, ultimately, greater uptake of scientific facts and evidence-based practices within communities.

Limitations and Future Directions. The SIP framework is intended to initiate a dialogue between scholars who study social networks and those who study social motives. The notion of a social influence event illustrates the benefit of such a dialogue. The social influence event encapsulates theoretical drivers of “who to influence” with those stemming from motivational forces that shape “how to influence.” As such, it can serve as an integrative concept for future theoretical development.

The SIP framework as outlined above has several important limitations that suggest next steps and new directions. First, the network approach outlined here focuses on identifying opinion leaders. Valente (87) notes there are at least three additional network-based interventions to enable scale-up: identifying groups of individuals to be influenced (segmentation), stimulating cascades of peer-to-peer interaction to help behaviors go “viral” (induction), and adding or removing nodes or links in the network (alteration). These, along with other social network research on social influence not summarized here, are potent dimensions for extensions to the SIP framework.

Second, we acknowledge emphatically that our review of past research only begins to scratch the surface of what is known about social influence. For instance, an important extension to the psychological approaches to social influence described here is to incorporate the role of affect. Emotions are powerful drivers of behavior (88, 89), intimately tied to the more cognitive processes described in the SIP framework (42). Many of the mechanisms for social influence discussed above have viable cognitive and affective interpretations, particularly those in the liking category (66). The belongingness motive activates both colder cognitive processes alongside hotter emotional reactions. Given Fiske’s admonition that the separation of affect and cognition is “something of a fiction” (ref. 42, p. 341), extensions to SIP need to incorporate emotional processes.

Third, in contrast with prior research on science communication that focused on communicating in general or with segments of a large audience, our discussion of SIP is focused exclusively on peer social influence. However, this is by no means a fundamental limitation of the proposed framework. It would be valuable to extend this thinking to the case of social influence from one to many. There is a robust literature on the design and efficacy of public communication campaigns, many of which are explicitly

about science communication (90). However, with a few exceptions (91) these studies do not examine broadcast messages that explicitly take into account the social motives that trigger social influence.

A fourth limitation is the lack of consideration of contextual and cultural differences on the efficacy of the various social influence attempts. Whereas the science being communicated is largely global in its veracity, the science of science communication is necessarily constrained by context and culture. For instance, the social media explosion brought on by Web 2.0 technologies opens up new channels for transmitting influence. Extensions of the SIP framework should consider how the selection of channels is contextually and culturally informed. For instance, based on our preliminary work in Bihar, there is strong evidence that although many of the health-care workers are familiar with the use of social media for their personal recreational use they were largely averse to its use to learn about new family health solutions.

A fifth limitation is that the SIP framework has not considered how the content of the scientific facts to be communicated shapes the selection of influence strategies in terms of the who and the how and through what channel. For instance, Rogers (92) attempted to explain the diffusion of innovations based on five dimensions of the innovation: relative advantage, observability, adaptability, trialability, and compatibility. More recently, Berger and Milkman (93) found news items that were awe-inspiring, positive, surprising, and useful were more likely to spread rapidly via peer-based mechanisms (specifically, making the *New York Times*’ “most emailed” list). Addressing these limitations is critical to the advance of the SIP framework in particular and the science of science communication more generally.

Conclusion

Achieving social influence at scale requires an integrated understanding of both networks (who to influence whom) and mechanisms of influence (how to influence). The SIP framework bridges the network view of social influence structures with the psychological view of social influence processes to understand both aspects of social influence using the concept of a social influence event. The science of networks reveals the touch points, the opinion leaders, who can serve as the multipliers for scaling-up behavior change within communities, and the peers who can influence them. The science of social influence processes provides actionable strategies based on core social motives to ensure that the opinion leaders are likely to adopt and champion desired behaviors within the community. As such, this integrated framework of social influence holds great potential in translating scientific information into actionable solutions that advance the public good in communities.

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