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A New HIV Prevention Network Approach: Sociometric Peer Change Agent Selection

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Abstract

Internationally, the Peer Change Agent (PCA) model is the most frequently used conceptual framework for HIV prevention. Change agents themselves can be more important than the messages they convey. PCA selection is operationalized via heterogeneous methods based upon individual-level attributes. A sociometric position selection strategy, however, could increase peer influence potency and halt transmission at key network locations. In this study, we selected candidate PCAs based upon relative sociometric bridging and centrality scores and assessed their attributes in comparison to one another and to existing peer educators. We focused upon an emerging HIV epidemic among men who have sex with men in Southern India in 2011. PCAs selected based on their bridging score were more likely to be innovators when compared to other centrally-located PCAs, to PCAs located on the periphery, and to existing peer educators. We also found that sociodemographic attributes and risk behaviors were similar across all candidate PCAs, but risk behaviors of existing peer educators differed. Existing peer educators were more likely to engage in higher risk behavior such as receiving money for sex when compared to sociometrically selected peer changes agents. These existing peer educators were also more likely to exhibit leadership qualities within the overall network; they were, however, just as likely as other non-trained candidate peer change agents to report important HIV intravention behavior (encouraging condoms within their network). The importance of identifying bridges who may be able to diffuse innovation more effectively within high risk HIV networks is especially critical given recent efficacy data from novel HIV prevention interventions such as pre-exposure prophylaxis. Moreover, while existing peer educators were more likely to be leaders in our analysis, using peer educators with high risk behavior may have limited utility in enacting behavior change among sex worker peers or male clients in the network.

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Introduction

Internationally, the Peer Change Agent (PCA) model is one of the most frequently used conceptual frameworks for HIV prevention interventions (Medley, Kennedy, O'Reilly, & Sweat, 2009). Peer change agents (PCAs) are generally trained to use similar strategies to communicate HIV risk reduction messages among targeted peers(Kelly, 2004; Kelly et al., 1991; Latkin, Sherman, & Knowlton, 2003). Change agents themselves, however, can often be more important than the messages they convey. Oftentimes, the messages change agents are trained to promote (e.g., circumcision) may be of limited interest to others, even to those at increased HIV risk (J.A. Schneider et al., 2010). In fact, when messages are of limited interest, those at increased HIV risk will tend to focus more on who the change agent is (Chaiken, 1980). Further, with uncertainty in a particular context or message, the reliance on more transparent change agent attributes within a network, such as obvious status signals, heighten in importance to the recipient (Podolny & Baron, 1997; Stuart, Hoang, & Hybels, 1999). Not only will recipients focus more on the change agent when messages are of limited interest or unclear, but they will base most of their decisions to accept or reject the message based on the agent's more transparent attributes within a network, such as obvious status signals. If we can determine the agents whose message will have the most network impact, we will begin to reduce the transmission rate to a low enough threshold where we can think concretely about HIV elimination (Holtgrave, 2010).

Selection of change agents based upon attributes

PCAs are commonly selected based on their individual attributes, but this method can be problematic. In contrast to similarities in PCA training approaches, PCA recruitment is often operationalized via a heterogeneous assembly of methods: self-selection, peer-nomination, key informants, ethnographic observation, surveys, and other approaches (Valente & Pumpuang, 2007). This heterogeneity in PCA selection reflects a diversity of selection criteria that focuses primarily upon a given individual's attributes. For example, PCAs may be selected because they share common conditions or behaviors with the target population (e.g., race, drug-use) (Colon, Deren, Guarino, Mino, & Kang, 2010; Fritz et al., 2011; Miller, Klotz, & Eckholdt, 1998; Outlaw et al., 2010); they may have superior communication skills (Kelly, 2004; NIMH, 2010); are considered popular or leaders within a community (Kelly, 2004); are charismatic (Cupples, Zukoski, & Dierwechter, 2010) or attractive (Starkey, Audrey, Holliday, Moore, & Campbell, 2009); are particularly motivated to impact their community (Kegeles, Hays, & Coates, 1996); they have connections to specific target individuals within a personal network of interest (J.A. Schneider et al., 2012) or no specific attribute other than being part of an injecting drug user network (Latkin et al., 2003). For example, a successful network intervention among injecting drug users did not select on any attribute or network position (Latkin et al., 2003). These attributes are sought independently or in combination, though the rationale behind each approach is often poorly characterized. The heterogeneity in attributes and referral approaches upon which PCAs are selected may explain why these interventions have had only modest potency and mixed efficacy when tested in resource-restricted settings (Latkin et al., 2008; NIMH, 2010; J. A. Schneider & Laumann, 2011).

Selection of change agents based on network position: The opinion leader

In the context of HIV prevention, the most common approach to selecting change agents based upon network theory is the popular opinion leader model (POL) (Kelly et al., 1991). The POL approach does not sociometrically identify change agents (ie. calculate their positions within networks based upon the patterns of ties), but uses ethnographic observation to identify individuals who appear popular and are thus likely to be leaders. Grounded in social diffusion theory (Rogers, 2003), the POL approach includes recruitment and training of popular network members from a target population to promote HIV prevention messages and behavior change through interpersonal communication. Popular people often occupy important positions of prestige and visibility (Bonacich, 1987) and, as noted in diffusion studies, may be influential in the spread of ideas and behaviors. If a new behavior seems to be one that will be embraced by the community, the opinion leader may adopt it earlier than others in the community. Subsequently, many others will see the behavior of these POLs, which reinforces the acceptability of the new behavior, and its adoption by others will be accelerated (Valente, 2010). Some recommend using POLs to accelerate diffusion of HIV prevention innovations; however, such leaders may already be overburdened given their status as leaders (S. Borgatti, 2006). In addition, behavior changes that are less compatible with existing norms (e.g., unorthodox HIV prevention strategies) or have the potential to change power dynamics may be adopted less by POLs because POLs have a vested interest in maintaining the status quo (Cancian, 1979). The effectiveness of POL interventions can be further limited by several factors, including: heterogeneous and overlapping networks, inadequate network assessments, and the POL's public position. While it has been found to be effective in settings where the social network has well-specified boundaries (E.O. Laumann, Marsden, & Prensky, 1989), recent findings from a transnational randomized controlled POL intervention suggest that the POL condition was no better in changing behavior and incident HIV/STDs than the control condition(NIMH, 2010). There are, however, suggestions that contamination may have occurred between POL and control venues in this study and thus it might be possible that these POLs were serving as bridging actors bringing persuasive HIV prevention messages and behavior change to control groups (J. A. Schneider & Laumann, 2011). This lack of efficacy combined with the potential for change agents to have acted as bridges, warrants newer and more rigorous network approaches to change agent identification and a potential focus on bridging actors.

Using network metrics to select change agents: bridging actors

Advancing upon this network informed logic, an alternative approach to increase the potency of peer influence might be to select PCAs based in whole or in part upon their *network position.* This approach would consider network structure through mathematical formalism (Freeman, 2004) and similar formalist approaches have been successful in business organization-based interventions (Burt, 2005). Network positions are calculated for each person in a network based upon the pattern of ties that link individuals to one another. These can for example represent individuals who are centrally located within a network, those that bridge different groups that are otherwise not connected and those that are on the periphery. By using this approach we move beyond traditional peer outreach models. We aim to identify PCAs based upon particular features of their network positions, positions that

could enhance the diffusion of innovative HIV prevention interventions. A benefit of utilizing a structural approach to identify PCAs is the ability to select them based upon network-measured positions, which are variable, as opposed to the classically-defined and centrally-located "opinion leaders." This method of selection allows us to identify candidates who connect across groups of otherwise disconnected individuals (such individuals are known as "bridging actors"). Locating new bridging actors may be a more effective way to accelerate change (Burt, 2005). Bridging actors may be more efficient diffusion agents than overly burdened centrally located PCAs because they have fewer interconnected alters to persuade (Holme & Ghoshal, 2009); they can thus devote more energy to persuading and thereby be more effective change agents. Additionally, bridging actors may be more receptive to behavior change since they have less pressure to support prevailing norms and behaviors (Cancian, 1979) or incur a reputation cost for advocating new and potentially disapproved behavior (Burt, 2010). Finally, candidates occupying bridging positions may possess useful attitudinal dispositions such as being open to new ideas and practices (E. O. Laumann, 1973; Valente & Fujimoto, 2010). By virtue of their boundary-spanning positions, bridging actors often have both early access to novel information and also experience in communicating this information across diverse audiences (Burt, 2010). Moreover, though bridging actors have access to less direct ties to individuals in a given network than individuals with denser network structures, bridging actors have more potential to spread innovative ideas and effect change because of the nature of their position in the network (Burt, 2010; Fernandez & Gould, 1994). Despite these findings within the organizational/business literature, there is no empirical evidence that we are aware of to support or refute the importance of bridging actors in the diffusion of innovation in HIV prevention. In order to examine how bridging and centrally located positions within a network might be used strategically for PCA interventions, we focus upon whole or sociometric network analyses where all of the nodes and the ties between them are included. This focus allows us to use measured social network structural positions to select candidate PCAs and assess their characteristics in comparison to one another and to existing peer educators.

Study Context

We elected to focus on an emerging HIV epidemic among high-risk men who have sex with men (MSM) in Southern India. MSM in Southern India represent a population with disproportionately high rates of HIV infection (Hemmige et al., 2011; J. A. Schneider et al., 2012) despite existing HIV control efforts and recent decriminalization of anal intercourse. Indian MSM share many similarities with MSM in the West, however, are more often married to women (Kumta et al., 2010), are less likely to be circumcised (J. A. Schneider et al., 2012) and tend to adopt more fixed sex role identities (Hemmige et al., 2011) (Armbruster, Roy, Kapur, & Schneider, 2013) than has been appreciated in the West. This epidemic is indicative of other international MSM epidemics in resource restricted settings where limited HIV prevention interventions targeting these populations are available and where there is great need for new and more effective programs (amFAR, 2013).

Methods

Setting and participants

The setting for this study was in a large city in Southern India in 2011. The study took place at a constellation of 20 well-characterized social venues - "cruising areas" - where men who have sex with men (MSM) congregate to socialize and where paid and unpaid sex is common. The study population consisted of individuals identifying as male greater than 18 years of age who: visit one of the 20 venues, reported anal/oral intercourse with another man within the previous 12 months, and owned and were in possession of at least one cell-phone at the time of recruitment. Phase I of the study included respondent recruitment, interview and generation of the communication network. Phase II included network position-based selection and interview of candidate peer change agents and existing peer educators. Existing peer educators were individuals who worked for a partnering community based organization that provides HIV prevention services to MSM in this region. They are members of the MSM community and conduct outreach to at risk MSM providing general HIV education, condom demonstrations and referrals for HIV testing.

Phase I respondent recruitment

Phase I of the study employed Time Location Cluster Sampling (TLCS) (Diaz, Ayala, Bein, Henne, & Marin, 2001; Valleroy et al., 2000). The sampling frame was previously established by a partnering community based organization and included 20 separate venues and 3 hour periods where MSM can be recruited. The sampling frame was established in the few months leading up to the field period. This covered public venues such as railway stations, theatres, small restaurants, parks, museum grounds, etc., with MSM on a given night ranging from 30–200 at each site. Venues with smaller numbers of MSM (<30), such as massage parlors and private residences, were not included for logistical and cost-efficiency reasons. In concert with two local partners, we identified all major venues frequented by MSM and the days of the week and times of day when frequented. Every month we randomly selected (without replacement) 15 venues from the sampling frame and then randomly selected one of the 3 hour periods associated with the venue. The data collection team approached MSM at the venue and evaluated the inclusion criteria as described above. Men who approached the team for enrollment or who enrolled previously (verified by cell phone number) were ineligible. We recorded limited demographic data on men who refused participation and counted all men passing through. Field-level data were collected regarding attributes of ineligible participants, as well as information about other potential contacts who may not have been digitally listed in a participant's cell phone or cell phone Subscriber Identity Module (SIM) card. A schematic for recruitment of the study sample for Phase I of the study can be found in Figure 1.

Phase I - Communication network generation

In order to determine when the number of respondents recruited was sufficient to include most individuals in this specific network (network saturation), we created a redundancy graph (Figure 2). Network saturation, where each subsequent recruit is >95% likely to already have been linked in the network through another participant's contact list was

achieved with a sample of 245. Once we obtained this sample size, further recruitment was stopped.

Many network studies use what is called a “name generator” to elicit the names of individuals linked to an index respondent. In the General Social Survey respondents were asked to name people with whom they share personal information with (Burt, 1984). Limitations to this approach include the burden of listing network members as well as recall bias in who is named. To overcome interviewer and respondent burden from classic name generators (i.e., “Please list individuals who you share personal information with.”) as well as potential for recall bias, a SIM card reader was adopted to extract contact lists from respondents’ cell phones (Figure 3). This approach has the advantage of eliciting individuals who may not typically be named during a traditional name generator and also includes many more individuals than what is typically elicited in other large social network surveys such as the General Social Survey, which elicits 5 network members (Burt, 1984). SIM cards are utilized in nearly all cell-phones outside of the United States. The SIM card reader was assembled using a kit from Adafruit Industries (Adafruit, 2012). The card reader is operated by means of pySIM (pySIM, 2012), a free open-source SIM card-reading software package. The software is written in Python and modified for compatibility with the SIM card reader. The software allows extraction of phone book entries, the last 10 outgoing calls, and the SIM card serial number. For this study, phonebook entries were extracted and sent directly to a csv file for respondent interview. The cell phone numbers were then linked across study respondents to create the main analytic network which included study respondents (n=241), and their contact list members. Many of the contact list network members were shared between study respondents. This augmented network was then limited to MSM only (n=4991), which resulted in the analytic network from which candidate peer change agents were sociometrically selected.

Data Measures – Phase I

The following characteristics were collected as in previous work on respondents and the MSM network members in their contact lists (Dandona et al., 2005; Medley et al., 2009; Simoni, Nelson, Franks, Yard, & Lehavot, 2011): age, caste (Indian system of hierarchically ordered social classes), religion, residence location, marital status, sexual position (mostly insertive, mostly receptive, versatile), and any previous sex work history (whether exchange of money or other resources for sex). Respondents were asked to designate the category that best described each individual in their contact list (friend, sex partner, colleague, family, other). With an average of 20 MSM contacts per participant, the network component of the interview took approximately 60 minutes to complete.

Cell phone-specific information was also collected: number of handsets/SIM cards per respondent, duration of SIM card possession, whether handsets/SIM cards are shared, and previous SIM card numbers. In order to address potential limitations of incomplete network data, we also collected information on social and sexual network members who may not utilize cell phones and network members who may utilize cell phones but may not be in respondents’ contact lists. Cell-phone teledensity in India is quite high at 71% overall and nearly 100% in urban areas (TRAI, 2013).

Phase II - Selection of candidate peer change agents from the MSM communication network

Using the final network of 4991 MSM, we calculated two network positional metrics for each individual in the network. These positional metrics were then used to select candidate peer change agents into the second phase of this study. These two metrics included a measure of centrality used for global networks, betweeness centrality (Freeman, 1979), and a new measure of bridging within global networks using a link deletion approach (Valente & Fujimoto, 2010). Betweeness centrality is a long-standing centrality measure which is calculated by counting the frequency a node lies on the shortest paths connecting all other nodes in the network (Freeman, 1979). Freeman described this specific centrality metric as a gate-keeping function with members who are positioned as high betweeness centrality controlling the diffusion of ideas to other segments of a group. Bridging is a distinctly different measure that is calculated by systematically deleting links and calculating the resultant changes in network cohesion (measured as the inverse average path length). The average change for each node's links provides an individual level measure of bridging, which can be normalized to control for network size (Valente & Fujimoto, 2010). It should be noted that all nodes in a network have bridging and centrality scores, and larger networks with more complex tie patterns do not allow for one to visually examine the network for these positions – they must be calculated.

Thus, the list of 4991 MSM network members was first ranked from highest to lowest betweeness centrality (hereafter, centrality) and a second time from highest to lowest bridging. A third category of candidate peer change agents was created as a reference group and included individuals who had the lowest centrality and the lowest bridging measures within the network. Individuals in this latter category were thus randomly selected from network members who usually had one tie into the large component of the network and were thus on the network periphery.

Following these separate rankings of network members and the generation of a low centrality/bridging reference group, we selected the top ranking mutually exclusive centrally-located network members (n=100) and the top ranking bridging network members (n=100) from which we would be able to randomly select a sub-sample of candidate PCAs. Based on their position in the distribution, these 100 top ranking centrally-located members (defined as "high centrality") had centrality scores exceeding 4.6 (median, 11.3) and bridging scores below 3.5 (median, 2.6). Similarly, the 100 top ranking bridging network members (defined as "high bridging") had bridging scores exceeding 3.5 (median, 6.4) and centrality scores below 4.6 (median, 0). The 100 participants ranking lowest on both centrality and bridging had centrality scores below 4.6 (median, 0) and bridging scores below 3.5 (median, 0). Thus cut-offs were determined by network position and not by a set point *a priori*. Individuals who were members of *both* of these categories were limited in number (n=20) given the previously described lack of overlap in these two metrics (Valente & Fujimoto, 2010) and were excluded from further analysis. This was done in order to compare mutually exclusive network positions based upon centrality and bridging. High centrality network members and high bridging network members were then randomly selected from the two non-overlapping pools (n=100 each) of candidate PCAs and invited to

participate in the follow-up Phase II interview. Existing peer educators and a random sample of network members with the lowest centrality and lowest bridging were also invited for the Phase II interview and to serve as comparison groups to the candidate PCAs. Existing peer educators included individuals from the local MSM community who were previously hand selected by community based organization leadership and trained by the Indian Government AIDS control Program to provide HIV prevention programming to the local MSM community (NACO, 2007).

Data measures – Phase II

We measured several features of candidate change agents and existing peer educators that might be important for HIV prevention as well as features that might distinguish bridging PCAs from centrally located "opinion leader" type PCAs. Leadership was assessed using an existing 6-item scale (King, Summers, & Childers, 1999). The items of this scale inquire about the nature of the respondent's interaction with friends and reflect the extent to which information individuals give information about a topic and the extent to which information is sought by others from those individuals. (e.g., "In general, when you think about your interactions with friends, are you often used as a source of advice?"), with each item scored on a 7-point Likert-type scale (see Appendix). The scale is computed as the sum of the items, with the scores ranging from 6–42. In prior work, the scale's test-retest reliability (King & Summers, 1970) and internal consistency (Cronbach 0.83) (Childers, 1986) have been adequate, it has a coherent internal structure (Childers, 1986), and construct validity has been demonstrated in its correlation to conceptually similar constructs of opinion leadership (Darden & Reynolds, 1972; Flynn, Reinecke, Goldsmith, & Eastmen, 1994). Innovativeness was assessed using an existing 10-item scale (Hurt, Joseph, & Cook, 1977) that measures global innovativeness (see Appendix). The items of this scale inquire about the nature of the respondent's original thinking and openness to new ideas (e.g., " I am generally cautious about accepting new ideas", with each item scored on a 5-point Likert-type scale. The scale is computed as the sum of the items, with the scores ranging from 10–50. In prior work, the scale's test-retest reliability and internal consistency have been adequate (Cronbach 0.83) (Payne & Beatty, 1982), it has a coherent internal structure, and construct validity (Goldsmith & Nugent, 1984) has been demonstrated in its correlation to conceptually similar constructs such as consumer innovativeness and domain specific innovativeness (Goldsmith & Hofacker, 1991; Manning, Bearden, & Madden, 1995). Bridging potential was also assessed based on a newly created 7-item scale developed by the first and last author that assessed respondents' self-description of their network position (see Appendix for all scales). In order to assess PCA intravention capability (health-directed efforts to protect others), we determined whether respondents encourage condom use among their peers (Friedman et al., 2004) (J. Schneider, Michaels, & Bouris, 2012). This intravention measure - encourage condom use - is one that has been validated previously and can benefit public health practitioners by helping them understand the environments that they are working with (Mateu-Gelabert et al., 2008).

Data analysis

STATA (version 12, StataCorp, College Station, TX) was used for calculation of betweeness centrality and bridging for all network members. To detect group differences between

categories of candidate PCAs and existing peer educators, we used a one-way analysis of variance (ANOVA) for normal data and the Kruskal–Wallis test for nonparametric data. The sample size calculation was based on the ANOVA. A total sample of 60 respondents for three groups of network positions (20 per group) achieves 81% power to detect differences among the means versus the alternative of equal means using an F test with a 0.05 significance level. This is with an expected common standard deviation within a group of 4.1 and the size of the variation in the means by their standard deviation of 1.7. We also conducted sensitivity analyses using the continuous values of the bridging and centrality scores. We computed 6 Spearman's rank correlation coefficients to estimate the association between our bridging measure and each of the 3 outcome measures, and between our centrality measure and each of the 3 outcome measures; and we used the Kruskal-Wallis statistic to assess for differences on centrality and bridging among participants who reported encouraging condom use vs. those who did not. Spearman's rank correlation coefficient was also computed to compare differences in reaching high centrality individuals compared to other respondents. Statistical significance was set at $p \leq 0.05$ for all analyses. IBM SPSS Statistics (version 19, IBM Company, Chicago, IL) was used for all group differences comparisons.

Ethical considerations

All procedures were approved by Institutional Ethics Committees at the University of Chicago in the United States and SHARE-India in India. Close communication and collaboration with key leaders in the local MSM community as well as frequent report-backs and presentations of preliminary and interim findings were conducted with community members throughout the project. As is typical of social network analysis, we collected limited information on third parties that are provided by consented study respondents (S. P. Borgatti & Molina, 2003; Valente, 2010). The key concerns to study participants are: 1) lack of consent on the part of persons named by respondents, and 2) the possibility of identifying individuals by combining collateral information (S. P. Borgatti & Molina, 2003; Kadushin, 2005). We utilized a secure data management system that included password protection, encryption of data and data storage on a secure server. All data at site of collection were destroyed and analytic data subsequently protected by a Federal Certificate of Confidentiality. Phone numbers, but not names were used to match individuals across contact lists. Individuals who were named in Phase I, but recruited into Phase II were contacted through respondents interviewed in Phase I. With respect to the riskiest time for study respondents and third parties - the public presentation of data where "all identifying information" has been removed – we employed several added protections. In addition to creating a dataset with unique identifiers removed, we also presented the network visualizations and study results internally and to local community partners to receive feedback prior to this public release. All figures presented in this manuscript were found to protect personal information. Study respondents received cell-phone recharge worth $4 for participation in the study.

Results

MSM study respondents were recruited until the chance of new respondents already being part of the network was >95%. This process resulted in a network census of MSM (n=241; 706 ties) and an augmented MSM cell phone network (n=4991 MSM; 6548 ties) (Figure 4). There were no differences in sociodemographics between respondents and non-respondents. Less than 10% of our potential sample was ineligible because of a lack of having a cell phone on their person. From field notes, we know that a number of these individuals who did not have their cell phone, own a cell phone but did not happen to have it with them. The phase I augmented cell-phone network included the 241 respondents and all other MSM within their cell-phone contact lists. The average duration of SIM card ownership was 24 months (range 1–180 months). The majority of the sample (61%) reported having only one SIM card. As a precaution, when more than one SIM card was owned, the numbers were collapsed to one unique identifier which designated a given respondent despite the field level finding that there is typically one dominant SIM card number used for socializing within the MSM networks in this region.

From this large communication network, three rosters which included three categories of candidate peer change agents of 100 each (n=300) were created based upon ranked sociometric position of nodes in the network: 1) high centrality; 2) high bridging and 3) low bridging and low centrality. Study respondents were randomly selected from these three rosters (excluding the minority that overlapped) and including a fourth comparison peer educator group made up of existing peer educators at the time of the study. Our response rate was 26/57 (45.6%), 18/46 (39.1%) and 22/94 (23.4%) for high centrality, high bridging and low centrality/low bridging respectively. Compared to high bridging and peripheral individuals, reaching those with high centrality by cell phone to recruit into Phase II was easier (corr .250; $p<0.001$). These relative rates were to be expected given the relative ease in which one might reach highly central individuals as compared to those on the periphery. Thus, the final phase II analyses compared individual and network level attributes across the four groups of respondents (n=91) depicted in Figure 5: those with high centrality (n=26), high bridging (n=18), low bridging low centrality (n=22) and, existing peer educators (n=25). All groups were mutually exclusive except for the existing peer educator group which included some individuals who were members of the original high centrality (n=10) and high bridging (n=2) rosters. Two sets of analyses were conducted one of which excluded the peer educator group.

Sociodemographic and behavioral characteristics of these Phase II respondents can be found in Table 1. Analyses of differences across the three network category typologies (high centrality, high bridging, or low centrality/bridging) demonstrated no statistically significant differences in any of the sociodemographic or risk behavior characteristics. Moreover, there were no sociodemographic differences between the three categories of candidate PCAs when compared to existing peer educators. When risk behaviors of existing peer educators, however, were compared to candidate PCAs, the existing peer educators were likely to have had more sex partners and to have received money for sex (both $p<0.005$). Cronbach's alpha for leadership, bridging and innovativeness were 0.86, 0.61 and 0.52 respectively. Although the sample size was small, within existing peer educators (n=25), there were no differences

by bridging and centrality scores for the number of condoms distributed, the number of behavior change communications conducted, the number of condom demonstrations performed and the number of MSM referred for HIV testing (data not shown).

Comparison of leadership, bridging, innovativeness, and HIV prevention intravention (encouraging condom use among peers) both across candidate PCA groups (model 1) and to existing peer educators (model 2) can be found in Table 2. Bridging network members were consistently more innovative when compared to other network positions as well as when compared to existing peer educators. Existing peer educators, however, were more likely to score higher on the leadership scale when compared to the network positions of other candidate peer change agents, including those who were centrally located in the network. Sensitivity analyses using the continuous values of bridging and centrality scores were broadly consistent with those using the dichotomous measures (P-values ranged from 0.03 to 0.58). For ease of exposition we have chosen to report the findings based on the dichotomous measures which were determined *a priori* by the network generated in Phase I.

Discussion

Two interesting findings emerged from the sociometric peer change agent selection strategy described in this study and are worth further discussion. First, candidate change agents selected based on their bridging network position were more likely to be innovators when compared to other centrally-located PCAs, to PCAs located on the periphery of the network, and to existing HIV prevention peer educators. Second, we found that sociodemographic attributes and risk behaviors were similar across candidate PCAs, but risk behaviors of existing peer educators differed from the other sociometrically established groups. Existing peer educators were more likely to engage in higher risk behavior such as receiving money for sex and having higher numbers of male sex partners when compared to sociometrically selected peer changes agents. These existing peer educators were also more likely to exhibit leadership qualities within the overall network; they were, however, just as likely as other non-trained candidate peer change agents to exhibit important HIV intravention behavior (encouraging condoms to their network members). All of these findings must be considered in the context of a smaller sample size for our Phase II analysis, as well as the potential differences that MSM networks in India have to other geographic locations.

The finding that sociometrically located bridges are more innovative is new in the field of HIV prevention but it has been described previously in the context of other business or corporate organizational networks (Burt, 1992, 2005). The importance of identifying bridges who may be able to diffuse innovation more effectively within high risk HIV networks is especially critical now due to recent efficacy data from novel HIV prevention interventions such as circumcision and pre-exposure prophylaxis (Bailey et al., 2007; Grant et al., 2010). Such efficacious interventions have yet to be introduced for HIV prevention in India (J. Schneider, R. Kumar, et al., 2012). The introduction of these interventions may be challenging, however, since new information and behaviour can potentially get stuck within network sub-groups (Vonhippel, 1994). Bridges may mitigate this phenomenon and work to enhance the diffusion of these innovative interventions. Leveraging existing bridges, however, is not a guarantee for successful diffusion of innovative prevention interventions.

In practice, a focus on bridges reflects an increased probability that connecting across the network improves the chances of encountering a new opinion or practice not yet familiar to a group or of envisioning a new synthesis of existing opinion or practice (Burt, 2010).

There are several important implications for HIV prevention programming based upon findings that sociometrically identified peer change agents did not differ in their sociodemographic or risk behaviour characteristics. First, similar sociodemographic characteristics among network members who were centrally located, bridging the network, or on the periphery, suggests that processes which select candidate peer change agents based upon sociodemographic attributes may not be useful for network intervention. Selection of peer change agents based upon these or other endogenous attributes is just one common way that change agents have been selected previously (Valente & Pumpuang, 2007), and is in contrast to selecting candidate peer change agents based upon their sociometric location (Becker, 1971).

Another important finding which has implications for current international peer change agent programs is that existing peer educators differed significantly on risk behavior from candidate peer change agents. The difference stemmed from the fact that they had larger numbers of male sex partners and were more likely to have exchanged sex for money. These existing peer educator risk behaviors are congruent with the government strategy of selecting change agents that share a phenotype with the most visible MSM community members in local sex market venues (Boyce, Chakrapani, & Dhanikachalam, 2011; NACP, 2011). While these individuals were more likely to be leaders in our analysis, the utility of using core sex market members such as male sex workers may not be effective in enacting behavior change among sex worker peers. In fact, there was no difference in encouraging condom use among one's peers when the existing trained group of peer educators was compared to other sociometrically identified groups of peer change agents. This may be due to the potential dissonance between messages and observed behaviors as well as the "sticky" nature of knowledge and behaviors within groups as previously described. Communication is more frequent and influential within than it is between groups, which results in people in the same group developing similar views of proper opinion and behaviour, and similar views of how to move into the future (Burt, 2010).

Moreover, ignoring clients of sex workers as candidate change agents is also problematic when attempting to intervene with these less visible MSM. Despite being "MSM" in this community, these mostly insertive only clients have a different phenotype (Asthana & Oostvogels, 2001), lower rates of HIV infection (Hemmige et al., 2011; J. A. Schneider et al., 2012), and play different roles in the sex market (Lorway et al., 2010). This is coupled with the status duality of sex work and peer educator which dominates most prevention programs in this region. This dual status individual who has agreed to be a peer educator may be driven solely by monetary incentives to take the job. Moreover, these individuals may be less connected to those who receive the fewest HIV prevention messages outside of the high centrality sex worker core group. In fact, bridging network members were found to have a greater proportion of their network made up of insertive MSM (data not shown), a group typically not accessed through existing HIV prevention programs in this context. Some have called upon a change in current MSM HIV prevention programs in India to move

away from the receptive only dual sex worker peer educator and include others in the network (Boyce et al., 2011). Our approach of selecting bridging network members may help identify key individuals who are able to intervene with harder to reach insertive MSM and other MSM sub-networks.

We did not recruit a category of individuals who were both highly central and high bridging in this study. Because we aimed to compare the specific positions of high centrality to high bridging, findings from the combined group would have been difficult to interpret; further, in previous research there has generally been limited overlap between these two distinct network positions (Valente & Fujimoto, 2010). Some of the existing peer educators were members of this combined group, but despite this we are unable to comment on the importance or the features of individuals located in dually bridge and central network positions. Because we expect these high-risk networks to be dynamic, one might expect that the dual bridge centrality position might be a transition position, perhaps moving to more centrally located positions over time (Burt, 2005).

We did not compare our approach to the popular opinion leader (OL) peer change agent selection approach because the OL approach was not found to be effective in this setting(NIMH, 2010), and the approved standard for peer change agent selection in this context is a government model (NACO, 2007) that generates peer educators like those in one of our comparison groups. It is possible that our high centrality group may be similar to an OL group. Both reflect the output of numerous nominations either collected directly from cell-phones as in our case or ethnographic observations of popular individual communications in the OL model. Core opinion leaders and bridges are distinct network positions and it is not surprising that their signals vary. Core opinion leaders, however, may be too embedded to respond to novel signals (Cancian, 1979). However, bridges may require the presence of opinion leaders or centrally located persons as these key players tend to be the early adopters in a network, and they may be necessary to initiate the diffusion process (Valente, 2010). Once the early adopters create diffusion within a group, it may be that bridges are able to bring diffusion across different sub-groups within the network. Bridges could act as bottlenecks within a network and limit diffusion if they have not adopted or are resistant to full adoption. Regardless of the PCA selection approach (Valente & Pumpuang, 2007), individual agency and the predictability of this agency would likely need to be considered in the determination of effective peer change agent potential.

The concept of innovation and how it relates to contexts of diffusion of new interventions needs much more study. Not knowing what specific components of innovation are salient in the Indian context, we used a measure of innovation that measures global innovation (Hurt et al., 1977). This measure had lower than anticipated reliability. We do not believe that the lower reliability scores are due to survey item translation because of our utilization of professional frontwards/backwards translation and again the good reliability for the leadership scale. We expect that the lower reliability may be due to using this scale in the Indian context where concepts of innovativeness and bridging may be less commonly used than concepts such as leadership which had higher reliability. Some have suggested that high collectivism and uncertainty avoidance in Indian culture might create different understandings and levels of innovativeness (Sinha, 1982). Others have also found that

Asian consumers are less prepared to take social risk to try new products (Schutte & Ciarlante, 1998). These culturally specific understandings of innovativeness and its usefulness may make response to innovativeness items unpredictable. Individuals in this sample scored lower on innovativeness than in other health related surveys in western contexts (Clement-O'Brien, Polit, & Fitzpatrick, 2011).

In addition to contextual variation in the interpretation of global innovativeness in different contexts, it is unclear what the clinical significance is of a 3 point change in innovativeness. Out of 122 manuscripts we are aware of which have cited the Hurt innovativeness scale, only three are related to health/medicine and report scale findings (Clement-O'Brien et al., 2011; Collins & Stiles, 2011; Conners, Barker, Mushlin, & Goepp, 2000). All three did not find any differences in innovation across groups so we are unable to determine the potential for clinical significance. There are some other health/innovation studies that use more specific innovativeness scales, such as medical technology innovativeness(Groeneveld, Sonnad, Lee, Asch, & Shea, 2006), or a personal innovativeness (Armstrong, Weiner, Weber, & Asch, 2003). In the medical technology innovativeness scale, a difference of 3 points (13.2 vs. 15.6) was associated with statistically significant innovativeness differences across racial groupings. In the personal innovativeness example, the odds of seeking genetic breast cancer testing was 2 times higher in innovators than non-innovators. In the latter study the innovativeness scale was reduced to 3 items and individuals dichotomized as "high" or "low" innovators. This makes interpretation of their findings difficult and comparison across studies limited. Future studies may need to isolate components of innovativeness such as what has been done in the Indian context around information technology utilization(Agarwal & Prasad, 1998) to better understand differences in innovativeness across groups. From the organizational literature we simply do know whether those who are bridges with higher innovation are more likely to be promoted, make more money and have higher job satisfaction(Burt, 2005, 2010). We explain the usefulness of the innovativeness measure as a way to identify individuals with bridging potential within a social network. This is in contrast to the bridging construct that has items which are focused on a self-perception of a structural position rather than innate characteristics such as innovativeness or leadership. Accurate and reliable measures of innovativeness could be developed as an alternative strategy to identify these structural positioned individuals, particularly when network data is unavailable.

The feasibility of our sociometric selection process could understandably be questioned. Additionally, use of scales or other survey data that have the potential to identify individuals with a propensity for certain structural positions could be useful. However, because social networks are dynamic, it may be necessary to employ real time network evaluation, assessment, and recruitment. Moreover, because bridging actors are typically thought of as moving towards a more central part of the network to achieve closure (Burt, 2005), the extent to which bridges become leaders, remain as bridges, or move to another network position is unknown in this context. The process we describe, however, was not burdensome and would generate similar costs as determining network structure through analogous ethnographic field research aiming to identify opinion leaders or other individuals with specific attributes within a network (NIMH, 2007). Moreover, the sociometric approach that we utilized to select PCAs is becoming increasingly feasible, even in resource-restricted

settings, as network data moves to archival type digital communication data (e.g. Facebook, cell phones). This digital data type would enable the collection, manipulation, and ability to sociometrically identify individuals over time and it would not require in-depth interviews that include complex name generators and interpreters (Marsden, 2005). Future research will undoubtedly leverage this type of data, making our approach even more feasible, rapid, and once automated through an application, useful for community-based organizations or other public health field operatives.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Highlights

- Describe a new cell-phone contact list network characterization approach
- Develop a method for selecting peer change agents based upon sociometric locations
- Confirm that individuals in bridging positions tend to be more innovative
- Demonstrate that existing peer educators in government run HIV prevention programs may have specific attributes that may have limited utility in creating change within high-risk networks

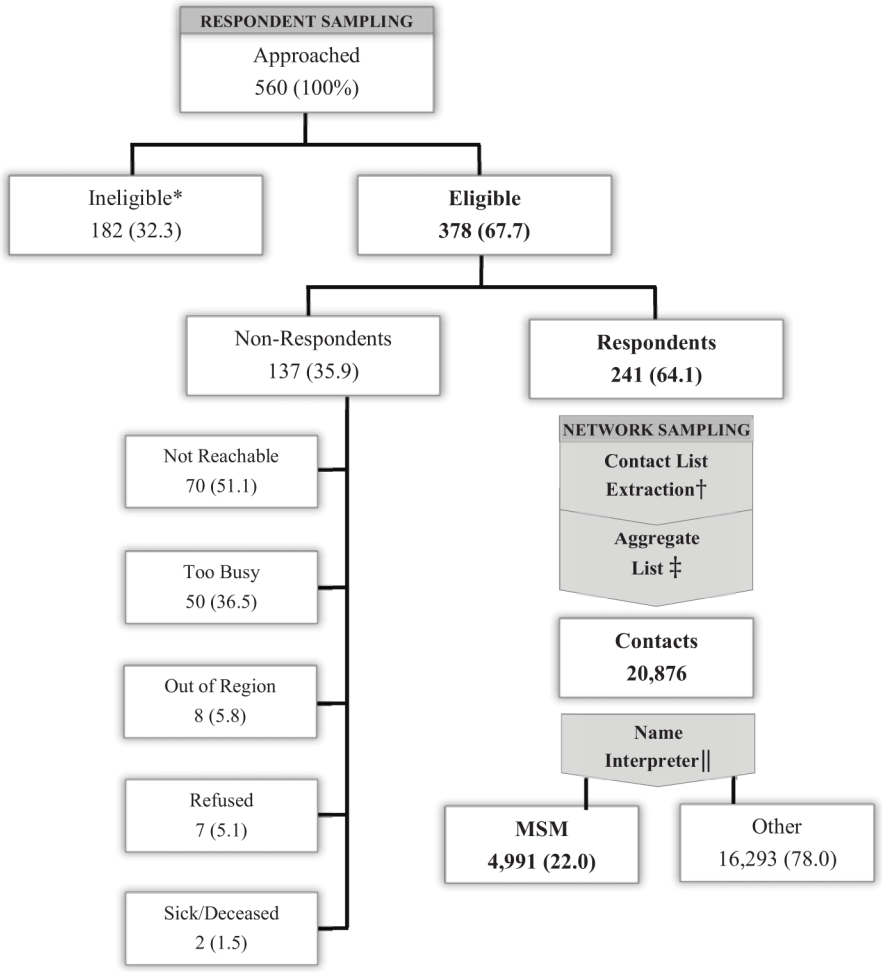

Figure 1.

Phase I respondent recruitment and MSM network generation.

*Respondents were ineligible if they approached the study team, were under 18 years of age, were not willing to visit the interview area, or did not have a cell phone in their possession.

† Contact lists were extracted from the cell phone of each respondent.

‡ Contact lists were combined with matching across contacts to create an aggregate list.

|| Name interpeters are questions asked to respondent about each contact list member (ie. age, type of relationship etc.)

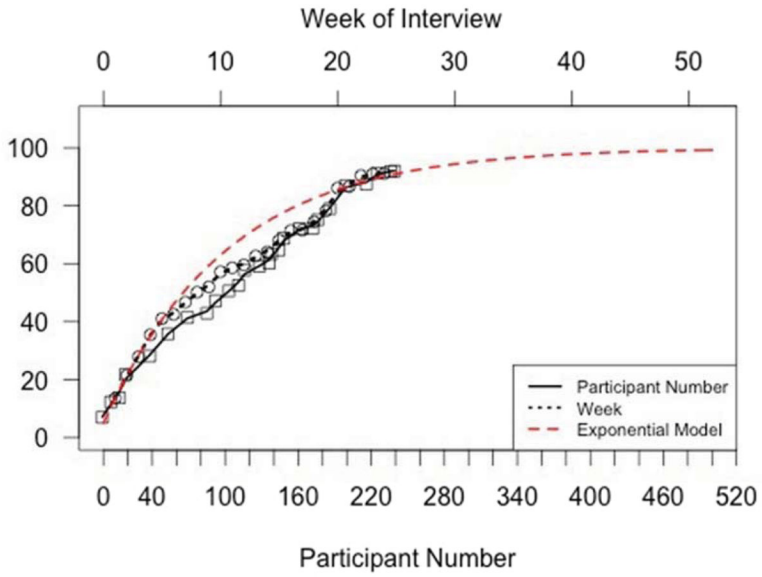

Figure 2.

Network redundancy curve of study respondents used to determine adequate sample size for network model (n=241). Curve fit from data on index of respondents and week of respondent interviews versus network size to exponential model. The data was fit to a scaled/shifted exponential cumulative distribution function f(x)=99.2−95.9e^(−4.9x) where x represents the index of the respondent and f(x) represents network size. Data approaches horizontal asymptote at approximately 240 respondents.

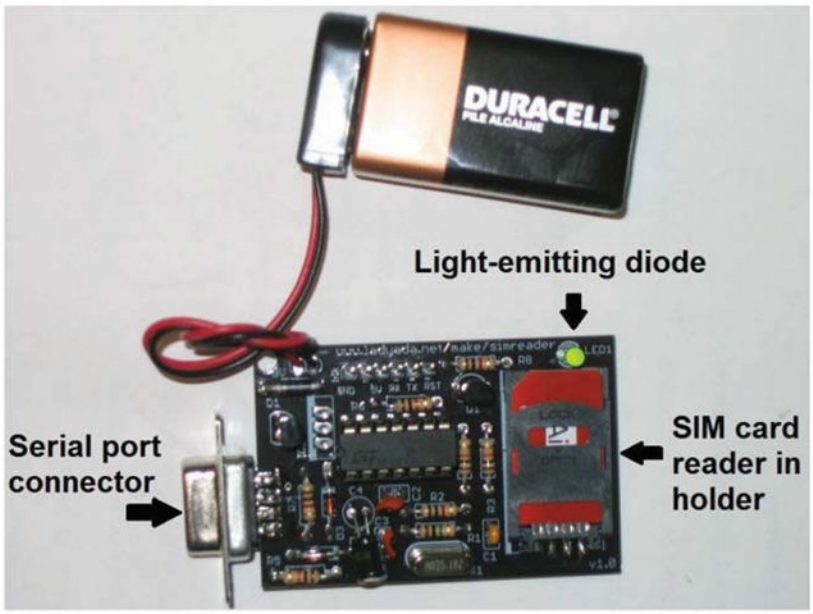

Figure 3.

Subscriber Identity Module (SIM) card reader. The SIM card reader was assembled using a kit from Adafruit Industries (New York, NY). The card reader is operated by means of pySIM, a free open-source SIM card-reading software package.

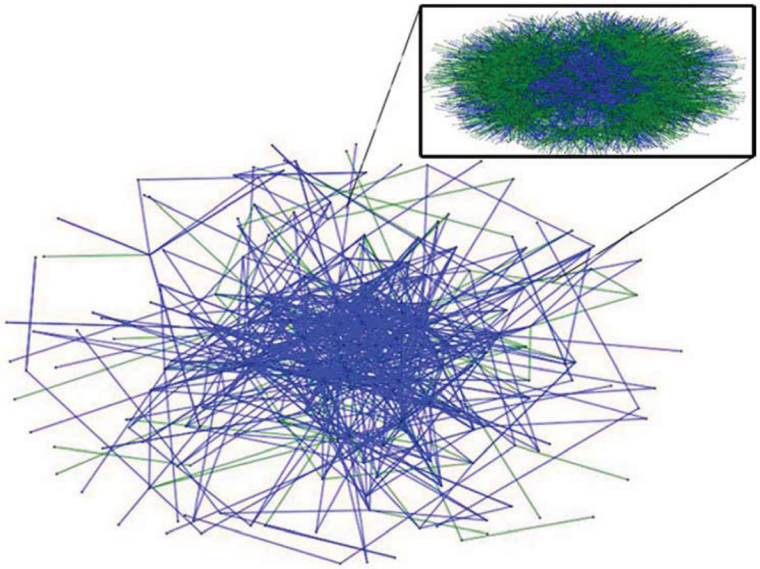

Figure 4.

Digital communication network of MSM respondents (n=241; 706 ties). Ties are designated by blue for social and green for sex. Inset network is of the augmented network which includes MSM respondents and all MSM from respondent cell phone contact lists (n=4991; 6458 ties).

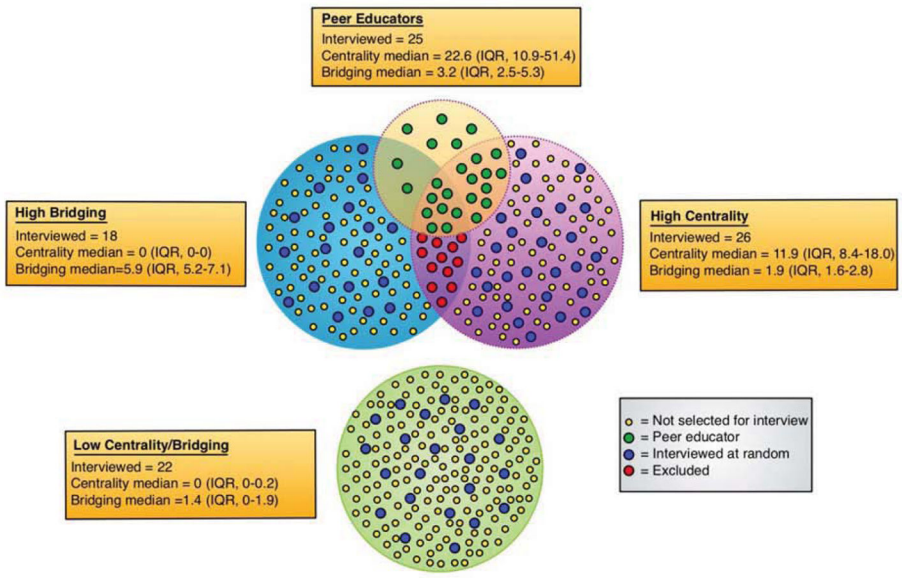

Figure 5. Phase II candidate peer change agent groups from a large communication network in Southern India comprised of men who have sex with men (MSM)

Three categories of candidate peer change agents of 100 each (n=300) were created based upon their ranked sociometric position in the network: 1) high centrality; 2) high bridging; and 3) low bridging and low centrality. Study respondents were randomly selected from these three groups (excluding the minority that overlapped (n=12)) and including a fourth comparison peer educator group made up of existing peer educators at the time of the study. Thus, the final phase II analyses compared individual and network level attributes across the four groups of respondents (n=91) depicted above. Betweeness centrality scores are depicted as 10^4 of calculated values and bridging scores are depicted as 10^{-3} of calculated values.

Table 1

Candidate peer change agent characteristics from a communication network of Indian men who have sex with men in Southern India (n=91)*.

Characteristics	High Centrality (N=26)	High Bridging (N=18)	Low Centrality / Bridging (N=22)	p-value	Peer Educator (N=25)	p-value	Overall (N=91)
Sociodemographics							
Age median (min-max)	25 (20–51)	26.5(20–45)	27.5 (20–62)	0.436	28 (21–47)	0.061	27 (20–62)
Education N (%)				0.277		0.307	
None	4 (15.4)	3 (17.6)	2 (9.1)		1 (4.0)		10 (11.1)
Class 1–10	7 (26.9)	6 (35.3)	11 (50.0)		8 (32.0)		32 (35.6)
Class 11–12	2 (7.7)	4 (23.5)	4 (18.2)		7 (28.0)		17 (18.9)
>Class 12	13 (50.0)	4 (23.5)	5 (22.7)		9 (36.0)		31 (34.4)
Religion N (%)				0.761		0.818	
Hindu	23 (88.5)	16 (88.9)	20 (90.9)		21 (84.0)		80 (87.9)
Muslim	1 (3.8)	2 (11.1)	1 (4.5)		2 (8.0)		6 (6.6)
Christian	1 (3.8)	0 (0.0)	1 (4.5)		2 (8.0)		4 (4.4)
Other	1 (3.8)	0 (0.0)	0 (0.0)		0 (0.0)		1 (1.1)
Caste N (%)				0.525		0.683	
Other Caste	8 (30.8)	4 (22.2)	3 (13.6)		6 (24.0)		21 (23.1)
Backwards Caste	13 (50.0)	9 (50.0)	12 (54.5)		14 (56.0)		48 (52.7)
Scheduled Caste	3 (11.5)	5 (27.8)	7 (31.8)		5 (20.0)		20 (22.0)
Scheduled Tribe	1 (3.8)	0 (0.0)	0 (0.0)		0 (0.0)		1 (1.1)
None	1 (3.8)	0 (0.0)	0 (0.0)		0 (0.0)		1 (1.1)
Married N (%)	5 (19.2)	7 (38.9)	9 (40.9)	0.207	14 (56.0)	0.061	35 (38.5)
Children median (min-max)	1 (0–2)	2 (0–3)	2 (0–6)	0.238	1 (0–3)	0.399	1 (0–6)
Risk							
Sex Role N (%)				0.457		0.059	
Receptive	8 (30.8)	5 (27.8)	11 (50.0)		11 (44.0)		35 (38.5)
Versatile	10 (38.5)	6 (33.3)	4 (18.2)		13 (52.0)		33 (36.3)
Insertive	8 (30.8)	7 (38.9)	7 (31.8)		1 (4.0)		23 (25.3)
Number of Male Sex Partners† median (min-max)	1.5(0–10)	1 (0–15)	1 (0–20)	0.951	5 (0–60)	0.004	2 (0–60)

Characteristics	High Centrality (N=26)	High Bridging (N=18)	Low Centrality / Bridging (N=22)	p-value	Peer Educator (N=25)	p-value	Overall (N=91)
Number of Female Sex Partners median (min-max)	0 (0–5)	0 (0–3)	0 (0–5)	0.575	0 (0–1)	0.250	0 (0–5)
Condom use at last Sex N (%)	16 (100.0)	9 (81.8)	9 (75.0)	0.121	20 (87.0)	0.240	54 (87.1)
Received Money for Sex† N (%)	9 (36.0)	6 (33.3)	11 (50.0)	0.492	20 (80.0)	0.005	46 (51.1)
Last HIV test (months) median (min-max)	6 (0–108)	4 (0–12)	6 (0–18)	0.131	3 (0–45)	0.143	6 (0–108)
HIV+ status N (%)	8 (32.0)	3 (18.8)	4 (18.2)	0.464	9 (36.0)	0.433	24 (27.3)

*Respondents (n=91) include four different groups: high centrality (n=26), high bridging (n=18), low bridging low centrality (n=22) and existing peer educators (n=25).

†Number of male sex partners and having received money for sex were the only two variables in the table that differed across the 4 sub-groups. Existing peer educators had more male sex partners and were more likely to receive money for sex (both $p<0.005$)

‡Betweeness centrality scores are 10^4 of values

§Bridging scores are 10^{-3} of values

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Table 2

Comparisons of candidate peer change agent characteristics across network position categories and to existing peer educators within a communication network of men who have sex with men in South India.

	Model 1				Model 2	
	Category					
Characteristic	**High Centrality (N=26)**	**High Bridging (N=18)**	**Low Centrality/Bridging (N=22)**	**Model 1 p-value**	**Peer Educator (N=25)**	**Model 2 p-value**
Leadership mean (SD)	16.3 (5.2)	16.3 (6.3)	14.8 (5.4)	0.61	21.7 (4.1)	<0.001
Bridging mean (SD)	22.7 (4.0)	21.5 (3.7)	20.0 (3.9)	0.06	21.9 (3.8)	0.7
Innovativeness mean (SD)	31.3 (4.3)	34.6 (4.0)	32.3 (3.8)	0.04	31.4 (4.3)	0.05
Encourage Condom Use N (%)	23 (89)	13 (72)	17 (77)	0.4	22 (88)	0.4

Model 2 adds existing peer educators as a comparison group to Model 1 categories