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Testing Theoretical Network Classes and HIV-related Correlates with Latent Class Analysis

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Abstract

Scientists designing network-based interventions intending to improve the adoption or maintenance of healthy behaviors are well-advised to classify potential adopters into network roles, such as opinion leaders, brokers, members, and isolates, and to work closely with existing opinion leaders. In past studies focusing on HIV, opinion-leader interventions have had mixed results. This may be addressed, in part, by empirically validating these network roles. To this end, we used latent class analysis to test whether people's social connections fall into mutually exclusive and exhaustive subgroups of social capital that represent theorized network roles well with a dataset collected in Nyangana, Namibia (n = 400). A 4-class model best fit the dataset, but the categories identified do not clearly represent the theorized roles. Rather, this study revealed the following four network classes: single-group members (59%), connectors (24%), single-group loyalists (15%), and selective connectors (2%). The implications of their findings for opinion-leader interventions focused on HIV are discussed.

Social networks provide a promising mechanism to deliver prevention messages. For example, in the Popular Opinion Leader (POL) intervention (e.g., Kelly, 2004), leaders are identified within existing social networks and then trained in persuasive techniques and prevention messages in order to shape the behavior of their affiliated network members. POL is based on the diffusion of innovations in which Rogers (2003) argued that certain types of people (innovative, networked, and risk-taking) and social structures (interconnected with integrated agents of change) are better able to encourage widespread behavioral adoption in a community. Opinion leaders have power to encourage adoption, because they are perceived as more credible and are considered more deeply than others (Rogers, 2003). POL takes advantage of this social dynamic by (a) identifying an at-risk community, (b) identifying opinion leaders in it, and (c) training them to initiate and convey HIV risk-reduction messages to their social network.

Opinion-leader interventions have been shown to reduce risky sexual behaviors in some studies (e.g., Amirkhanian, Kelly, Kabakchieva, McAuliffe, & Vassileva, 2003; Kelly et al., 1997; Kegeles, Hays, & Coates, 1996; Sikkema et al., 2000; Sikkema et al., 2005), but not others (e.g., Hart, Williamson, & Flowers, 2004). These mixed results may stem from difficulties in classifying people into roles such as opinion leaders, brokers, general members, and isolates. These difficulties may be addressed by estimating people's social connections using social network analysis (SNA, Valente, 2010) and testing their viability with latent class analysis (LCA).

It may also be important to consider how people distance themselves from one another. If people socially distance themselves from some groups with their community, their utility as delivery vehicles is challenged and may cause iatrogenic effects. Specific to HIV interventions, what if people in particular network roles distanced themselves from organizations focused on HIV-related issues? The stigma surrounding HIV makes this

rejection a real possibility. The next sections cover SNA, network roles, social distancing, and LCA in turn.

Social Network Analysis

Valente and Fosados (2006) described two models of identifying intervention groups and leaders: group and network. Group-leader models identify cohesive subgroups or clusters within social networks, and then identify opinion leaders within each cluster through nominations. Network-leader models (Valente & Davis, 1999) identify opinion leaders first, and then attach members to leaders based on their closeness to a particular leader. These two models can lead to the identification of different leaders and groups in the same social network (Valente & Fosados, 2006). The emphasis of this study – investigating possible network classes within the entire system – more closely represents the network-leader model. Although actors may hold different roles within social networks, we focus on opinion leaders, brokers, general members, and isolates.

Network Roles

Opinion leaders are those with high visibility, centrality, or prestige within a social network. This position is often identified by degree centrality, which focuses on the number of direct links an actor has to others in the network (Freeman, 1979; Wasserman & Faust, 1994). Often, these types of leaders have direct links to other actors who are also linked; that is, they are central within a cohesive subgroup, because people prefer establishing transitive relationships (e.g., befriending their friends' friends; Burk, Steglich, & Snijders, 2007). For this reason, these types of leaders can align people for a common purpose and, potentially, use their leadership to regulate other group members' behavior.

Burt (e.g., 1992) argued that more connections, even to well-connected others, may not be beneficial to the actor: each network connection has opportunity costs and energy spent on redundant contacts is inefficient. A person with nonredundant contacts, one who is between actors who are not directly connected to each other (Monge & Contractor, 2003), may serve as a conduit for information flow in the network, thereby controlling information and its interpretation (Monge & Contractor, 2003). This brokerage position is encapsulated in the structural measure of *betweenness centrality* (Freeman, 1979). *Brokers*, people who connect different groups, "are able to see early, see more broadly, and translate information across groups" (Burt & Ronchi, 2007, p. 1160). *General members* are connected to others within the network, but without the high centrality levels of opinion leaders or brokers (Wasserman & Faust, 1994). *Isolates* are members of the social network who are not connected to others (Marsden, 1989; Wasserman & Faust, 1994).

Social Distancing

This review has focused on positive connections within a social network. Yet, in an ethnographic study of people talking about their social connections, Warr (2005) noted that: "While many participants nominated 'the people' as the most positive aspect of the neighbourhood, they often immediately placed a caveat on this by drawing a line between 'good' people and the 'no-hopers'" (p. 294). Thus, people may be quite aware of with whom they do and do not connect.

Social distancing refers to efforts to generate psychological space between oneself and others (Simmel, 2008). Despite its potential to interfere with network-based interventions, social distancing has not appeared in studies of network roles. Yet, the desire to create social distance results from the normal processes of identification (Brewer, 1991) and in-group bonding (Hogg & Reid, 2006). When people interact closely, they are likely to seek out and

to act favorably toward positively regarded people, and to exclude and act unfavorably to negatively regarded people (Carter & Feld, 2004).

Persons living with HIV or AIDS (PLWHAs) have been viewed negatively in Namibia (e.g., Smith & Morrison, 2006) and around the world (UNAIDS, 2006). PLWHAs can have difficulty maintaining close personal relationships because of stress associated with the disease (Haas, 1999) and rejection from close ties (Brashers, Neidig, & Goldsmith, 2004).

Latent Class Analysis

Latent class analysis (LCA; Collins & Lanza, 2010) is a statistical model used to identify underlying latent classes, or subgroups of individuals with shared characteristics. This model posits that the grouping variable cannot be observed, but can be inferred from multiple, measured variables. The model yields two sets of parameters: class membership probabilities (i.e., the prevalence of each subgroup) and item-response probabilities (i.e., the correspondence between each item and the latent variable). The latent classes form mutually exclusive and exhaustive subgroups (Lanza, Collins, Lemmon, & Schafer, 2007). Each person has some probability of belonging to each latent class, thus one's actual subgroup membership is not known with certainty (Collins & Lanza, 2010; Lanza, Flaherty, & Collins, 2003).

If LCA were used as a way to segment an audience for an HIV intervention and to identify opinion leaders to encourage HIV prevention behaviors, it would be important to know whether participants' health behaviors (e.g., HIV testing, sexual behaviors, and drinking) predicted their odds of membership in different network classes. LCA allows one to test whether individual characteristics (covariates) predict the odds of membership in one class relative to a reference class. A latent class measurement model and a logistic regression model predicting classes from covariates are modeled simultaneously without actually assigning individuals to a particular latent class (Lanza et al., 2007). Covariates can be included to test whether education is predictive of membership in the opinion leader class (Rogers, 2003); or if those who believe they have contracted HIV have higher odds of membership in the isolates class in order to avoid social distancing and rejection. Thus, two research questions are investigated:

RQ 1: Can a meaningful set of network classes be identified based on reported social capital among citizens in Nyangana, Namibia?

RQ 2: (2a) Is membership in network-role classes predicted by perceptions of HIV stigma and HIV transmission risk and reported HIV testing, sexual behaviors, and drinking? (2b) Are individual characteristics (age, gender, education level, travel, and church membership) predictive of class membership?

Method

Participants and Procedures

Participants were recruited from households (N = 400) adjacent to Sacred Heart Hospital located in Nyangana, Namibia (see Smith & Nyugen, 2008 for more details on the sampling procedures). Interviewers selected an eligible household member (those aged 15 and older) via roll of a die. Consent was received and interviews occurred in a private location. The survey was conducted orally in English, Afrikaans, or a local language. At the conclusion of the interview, respondents were given a household food item.

Respondents, on average, were 35 years of age (M = 34.75, SD = 12.45, *Range* = 45). This sample over-represents adults in a young Namibian population (43% aged below 15years;

MOHSS, 2003). The sample is 46% male, closely approximating gender proportions in the region (51% male) and the country (48% male).

Indicators of the Network Classes

One scale often used for social networks, social support, and social capital (in part because of the conceptual overlaps) is Berkman and Syme's (1979) social network index (SNI). It has four items: (1) marital status, (2) sociability (frequency and number of friend and family contacts), (3) membership in community groups, and (4) church group membership. The items below, which are summarized in Table 1, attempt to reflect these concepts.

Relationship status—Respondents were asked about their marital status. Those who answered single or widowed (50%) were coded differently from those who indicated a current relationship (50%; i.e., married, engaged, or living together).

Group and HIV-group memberships—Respondents were asked to name all the groups in which they hold memberships, including HIV-identified groups, sporting clubs, professional organizations, and religious groups. Every respondent claimed membership in at least one social group, and this number was categorized into one group or multiple groups. Respondents' memberships in HIV-related groups was recorded separately from their memberships in other social groups, and coded as zero groups or one or more groups. Crossing these memberships, 64% were members of one, non-HIV-related group (64%); 7% were members of one, HIV-related group, 13% were members of two or more, non-HIV-related groups, and 16% were members of two or more groups, including HIV-related groups.

Rejected social groups—After identifying their current memberships, respondents were asked to name the groups in which they would not be members. Respondents could name as many groups as they wanted. Respondents' rejection of HIV-related groups was coded separately from their rejection of other groups.

Brokerage—UCINET 6.0 (Borgatti, Everett, & Freeman, 2002) was used to calculate normalized betweenness centrality for each respondent based on their group affiliations. Betweenness centrality was coded as low (0.19 or lower) or high.

Covariates

Roman Catholic Church (RCC) membership—Using a two-mode data analysis, the RCC showed the highest centrality of the social groups (eigenvector centrality = .97, degree centrality = .67). This membership was coded separately and used as a covariate (0 = *nonmember*, 1 = *member*). 66% of the respondents reported membership.

Perceived HIV stigma—Respondents were asked to evaluate three questions about people living with HIV/AIDS on a 5-point scale (1 = *definitely no*, 5 = *definitely yes*). The questions included "If a member of your family became sick with AIDS, would you be willing to care for him or her in your household?"; "If you knew that a shopkeeper or food seller had HIV, would you buy fresh vegetables from him or her?"; and "If a teacher has HIV but is not sick, should he or she be allowed to continue teaching in school?" The items were averaged into a single score ($\alpha = .73$), recoded so that stronger scores indicated greater stigmatization ($M = 1.45$, $SD = 0.88$), and standardized.

Education—Respondents reported how many years of school they completed ($M = 7.51$, $SD = 3.81$); this variable was standardized.

Travel—Respondents were asked if they have been away from their homes for more than one month in the past year (0 = *no*, 1 = *yes*); 45% had traveled for more than one month.

HIV risk—Respondents were asked about their likelihood of contracting HIV in the future (0 = *not at all likely* or *slightly possible*, 1 = *very likely* or *certain it will happen*); 47% were coded 1.

Sexual abstinence—Respondents were asked if they had purposely avoided sex during the past year (0 = *no*, 1 = *yes*); 68% had abstained.

Multiple sex partners—Respondents were asked how many different persons they had sex with during the past year. Their answers were coded (0 = *one* or *none*, 1 = *multiple*); 19% had multiple partners.

HIV test—Respondents were asked if they had ever been HIV tested (0 = *no*, 1 = *yes*); 19% had been tested.

Drinking—Respondents were asked if they have ever drunk alcohol other than for religious purposes (0 = *no*, 1 = *yes*); 47% drank alcohol.

Results

Network Classes

To address RQ1, models with two to six latent classes (using 100 sets of random starting values for each) were tested with PROC LCA (Lanza et al., 2007). The fit indices for these models appear in Table 2. The four-class model best fits the data, with $G^2 = 32.65$, $df = 96$, $AIC = 94.65$, $BIC = 218.39$, and entropy $R^2 = 1.00$. These findings suggest that there are underlying classes of network roles.

To interpret the network classes, the item-response probabilities for response category 2 in the four-class model was used (see Table 3). Participants in the largest class (59%), labeled *single-group members*, are likely to be members of only one social group, which is not an HIV-related group, and do not reject memberships in other social groups. Participants in the second class, labeled *connectors* (24%), likely belong to multiple social groups (which likely includes membership in an HIV-related organization), do not reject memberships in other social groups, and their memberships give them higher betweenness centrality in the community network. Participants in the *single-group loyalists* class (15%) belong to only one group, which is not HIV-related, and actively reject memberships in other social groups including HIV-related ones. Finally, participants in the *selective connectors* class (2%) tend to have multiple group membership, while actively rejecting memberships in other social groups, including HIV-related ones, and strong betweenness centrality. These individuals are more likely to be single and male. The primary distinction between the last two classes - single-group loyalists and selective connectors – is that selective connectors report memberships in multiple social groups, which allows them to liaise between different sectors of the community.

Covariate Analysis

To answer RQ2, a number of covariates were investigated (see Table 4). Many of the covariates differed statistically between network classes: age, travel, HIV risk, abstinence, HIV testing, membership in the RCC, and drinking (all at $p < .05$). For example, when compared to the single-group members class, members of the connectors class have

increased odds of being older, traveling, abstaining from sex, and belonging to the RCC, but lower odds of perceiving themselves as at-risk for contracting HIV and HIV testing.

Interestingly, perceived risk of contracting HIV, age, and traveling comprise the difference in probability of membership in the connectors and selective connectors classes: selective connectors perceive their risk as higher, are younger, and travel less often. For selective connectors, the potential for contracting HIV, such as through multiple partnerships, translated into perceptions of HIV risk, but both groups still exhibit lower HIV testing levels than the single-group members.

Discussion

Researchers are developing and deploying many network-based interventions. This study investigated the existence of latent classes of network roles within a community and how well those classes represented theorized network roles from the existing literature. In addition, it tested whether individual characteristics correlated with membership in particular network classes.

The results showed that a four-class model of network roles explained the heterogeneity in social capital among participants. This four-class model, however, did not clearly represent general roles of opinion leader, broker, isolates, and general members that were proposed in previous studies. First, no isolates appeared. Second, some socially-connected participants actively avoided memberships in other groups. Third, those in multiple groups looked like a combination of opinion leaders and brokers. We labeled this class as c*onnectors*, drawing from Gladwell's (2001) description of individuals who know many people, which fits with the description of opinion leaders or brokers.

The covariate analysis showed that many variables – age, travel, perceived HIV risk, abstinence, HIV testing, and membership in the RCC – varied between network classes. For example, connectors, a likely target for an opinion-leader intervention, were less likely to perceive themselves as at risk for contracting HIV and less likely to be HIV tested, compared to single-group members. Selecting these connectors as opinion leaders, then, may be ineffective, because these perceptions and reported behaviors may prevent them from providing prevention messages in their community.

Implications for Opinion-Leader Interventions

Of note, the difference between connectors and selective connectors is the selective connectors' propensity to reject memberships in other groups. Without asking for this type of social information is it likely that leaders of POL-interventions would have been selected from either network class. The consequence of selecting selective connectors is that they may be unwilling to share messages with groups they reject in the community.

Moreover, connectors should only be used to distribute messages in an intervention if these connectors can convey their intervention's message adequately. Some connectors hold critical positions within their social networks and spread messages within them (i.e., called mavens by Gladwell, 2001), making them particularly influential in spreading ideas and behaviors (Totterdell, Holman, & Hukin, 2008). Intervention designers, then, may want to select particular connectors to distribute messages.

Future Research

Future research should investigate differences in latent network classes using group leader models (Valente & Fosados, 2006) in addition to the network leader model used in this study. Also, there are a variety of options for identifying cohesive subgroups (size and

mutual exclusivity) and opinion leaders (reciprocal ties, connections, closeness, homophily, and affinity). Understanding the choices inherent in these designs and sampling procedures are critical for optimizing network-based interventions.

Conclusion

Many network-based interventions depend on categorizing participants into network roles. LCA provides a useful method by which to identify classes of network roles and personal characteristics correlating with membership in the different classes. This study showed how these methods may be used to understand the challenges in designing opinion-leader interventions for HIV prevention within existing social networks.

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Table 1

Descriptive Statistics

Indicators of latent class	Code	Label	Percentage
Relationship status	1	Single	50
	2	Connected (i.e., married, engaged, or living together)	50
Group memberships	1	One	71
	2	Multiple	29
Rejected social groups	1	None	83
	2	One or more	17
HIV-group memberships	1	No	76
	2	Yes	24
Rejected HIV groups	1	No	91
	2	Yes	9
Brokerage	1	Low betweenness centrality	74
	2	High betweenness centrality	26
Gender	1	Male	46
	2	Female	54

Table 2

Comparison of Latent Class Models

Number of classes	G^2	*df*	AIC	BIC	Entropy R^2
2	176.87	112	206.87	266.74	1.00
3	59.21	104	105.21	197.01	1.00
4	**32.65**	**96**	**94.65**	**218.39**	**1.00**
5	30.04	88	108.04	263.70	.80
6	22.39	80	116.39	303.99	.83

Note. Boldface type indicates the selected model, which has the lowest AIC and BIC. df = degrees of freedom; AIC = Akaike's Information Criterion; BIC = Bayesian Information Criterion.

Table 3

Probability of Reporting each Characteristic Given Latent Class Membership

	Single-group Members (59%)	Connectors (24%)	Single-group Loyalists (15%)	Selective Connectors (2%)
Single status	0.47	0.60	0.53	0.00
Membership in 2+ groups	0.05	1.00	0.00	1.00
Rejected social groups	0.00	0.04	1.00	1.00
HIV-group membership	0.08	0.65	0.17	0.15
Rejected HIV groups	0.00	0.02	0.49	0.62
High brokerage	0.00	1.00	0.00	1.00
Female	0.60	0.48	0.56	0.00

Table 4

Covariate Analysis with Single-Group members as the Comparison Class

	Connectors (24%)	Single-group Loyalists (15%)	Selective Connectors (2%)	$p < .05$
Perceived HIV stigma	0.88	0.89	0.95	
Education	1.29	0.99	0.84	
Age	1.26	0.01	0.00	*
Travel	2.05	0.23	0.21	*
Perceived HIV risk	0.54	2.41	3.95	*
Multiple sex partners	0.61	1.29	0.88	
Sexual abstinence	3.65	6.67	14.00	*
HIV testing	0.37	0.97	0.48	*
RCC membership	1.62	3.77	11.13	*
Drinking	0.85	0.64	0.38	*