Published in final edited form as:

Int Public Manag J. 2017 ; 20(3): 467–488. doi:10.1080/10967494.2016.1276034.

SHAPING THE EVOLUTION OF THE INFORMATION FLOW: THE CENTRALIZING MECHANISMS IN THE EVOLUTION OF THE NORTH AMERICAN TOBACCO QUITLINE CONSORTIUM

ROBIN H. LEMAIRE,
VIRGINIA TECH UNIVERSITY

KEITH G. PROVAN,
UNIVERSITY OF ARIZONA

LIESBETH MERCKEN, and
MAASTRICHT UNIVERSITY AND SCHOOL FOR PUBLIC HEALTH AND PRIMARY CARE,
MAASTRICHT, THE NETHERLANDS

SCOTT J. LEISCHOW
MAYO CLINIC, SCOTTSDALE, ARIZONA

Abstract

The research reported here is an analysis of the evolution of the relationships that comprise a single public health network, focusing especially on the position of the network administrative organization (Provan and Kenis, 2008) in the flow of knowledge among a large number of organizations providing similar services. Our study examines the North American Quitline Consortium (NAQC), a multi-sector network that spans the US and Canada and whose members provide telephone-based tobacco cessation services to anyone interested in quitting smoking. Data were collected using web-based surveys at three different points of time. Implications are discussed for network organizing, for both theory and practice, focusing especially on the importance of the network administrative organization in shaping the evolution of the whole network information flow.

Inter-organizational networks have been the subject of increasing research in public administration over the past few decades (Provan and Lemaire 2012). Increasingly as well, studies have employed social network analysis as a method for investigating network structure and processes, including some limited research on how structure impacts outcomes (Varda, Shoup, and Miller 2012). Despite considerable research and theorizing on the quantitative assessment of organizational networks, as recently noted by Ahuja, Soda and Zaheer (2012), the empirical evidence to guide further research, theory, and practice is still lacking in a number of important ways, but especially in understanding how networks evolve over time. Longitudinal network research is still a rare occurrence in the organizational network literature (Kilduff and Brass 2010), and the gap is particularly acute when focusing

¹These numbers are based on in-degree centrality scores not considering whether the tie was of valued at a 2 or a 3. When considering the value of the tie, the average ranges from 13–15 and the NAO had more than 150 ties.

on large, goal-directed, whole networks (Provan, Fish, and Sydow 2007). Understanding highly interwoven systems requires discerning “what types of actors and relationships are most critical in shaping the evolution” of these complex structures (Powell, White, Koput, and Owen-Smith 2005, 8).

The research presented here provides a network analysis of the evolution of the relationships that comprise one large goal-directed whole network, focusing especially on the position of the network governance entity as a centralizing hub. Specifically, we examine the North American Quitline Consortium (NAQC), a goal-directed “whole network” (Provan, Fish, and Sydow 2007) governed by a network administrative organization (NAO) (Provan and Kenis 2008). Spanning the US and Canada, quitlines provide phone-based tobacco cessation services to clients who are trying to quit smoking. Quitlines are comprised of funders and providers, both for-profit and not-for-profit, and thus is an example of a collaborative, multi-sector network. The main goal of the network, NAQC and its NAO is to facilitate the flow of information about evidence-based research practices, both behavioral and pharmaceutical, to the many state and provincial quitlines that comprise the network. In so doing, the expectation is that these quitlines can then enhance their effectiveness in getting people to quit smoking. Drawing on data collected on NAQC across a 3 year time period, we examine the evolution of the network’s relationship structure, based on the flow of information about client services across the network, and in particular, on the importance of its NAO in the dynamics of the network structure.

Network Structure

Understanding and explaining whole network evolution can be especially complicated because the overall network may remain relatively stable over time, even though it might be quite dynamic at the node and relationship level. Network dynamics encompass changes at the node, tie, ego network, and whole network levels, and changes at any one of these levels can have an influence on the other levels. However, the stability of whole network structure might mask internal dynamism, since oftentimes microdynamic changes, or changes at the dyadic tie level, might cancel one another out, as in the dissolution of certain types of ties that are replaced by other ties that may perform some similar functions (Ahuja, Soda and Zaheer 2012) and thus, have no net effect on the architecture of the whole network structure.

Understanding the dynamics underlying the whole network structure is important to furthering our understanding of the relationship between network structure and outcomes. For instance, recent empirical scholarship in public health has shown that certain structural characteristics of networks are associated with higher adoption rates of best practices. Valente, Chou, and Pentz (2007) found that decreasing densities of community coalitions were associated with the increased adoption of evidence-based practices in their longitudinal study of drug prevention programs in 23 U.S. cities. In a similar study, Fujimoto, Valente and Pentz (2009) found adoption of evidence-based practices was associated with a decrease in centralization of the advice network, but an increase in centralization of the discussion network. Thus, the authors of both studies concluded that consolidating decision-making around a few prominent leaders led to more efficient discussions of practice adoption. These implications align with findings from public administration studies, especially studies of

similar health-focused networks. For instance, the finding that greater centralization, i.e. when the network is reliant on a few central organizations, is associated with adoption of practices is similar to the finding by Provan and Milward (1995) of the importance of centralization in their classic study of mental health network effectiveness. There is also some evidence to suggest that centralization and hierarchical management practices in general are important to networks outside the health domain as well, such as crime prevention and community safety (Raab, Mannak, and Cambre 2015; Kelman Hong, and Turbitt 2013) and emergency response (Moynihan 2009); though there is also evidence that does not support the effectiveness of centralized emergency response networks (Marcum, Bevc, and Butts 2012).

Integration of a differentiated system is often considered a necessary condition (Lawrence and Lorsch 1967) but integration can occur in different ways, centralization being one form (Raab, Mannak, and Cambre 2015). Centralization can be the structural “glue” that holds the network and its members together by facilitating the transfer of information that is key to overall network goal accomplishment. If centralization is indeed critical to whole network success in some contexts, understanding how overall network centralization occurs and why it is important to the overall network structure is also critical. The focus of our research is, therefore, to examine not simply how a large goal-directed network evolves structurally over time, but to understand if and how centralization occurs and why centralizing forces may be important to achieving outcomes.

Thus, in the present research, we focus specifically on the “hub” component in the network. A “hub” is a node that is more connected than the average node and therefore, a core component of the structure of network centralization. Because a hub has access to a greater quantity of information and greater diversity of information, this node has the ability to aggregate and compare information from various sources (Schilling and Fang 2014). Thus, as Schilling and Fang found in their simulation examining the role of hubs, hubs provide shortcuts that accelerate the diffusion and convergence of ideas. However, because of their prominence, the ability and willingness of hubs to transmit information can also lead to deliberate or involuntary bottlenecks. For instance, excessive convergence around some ideas can limit transmission of newer, more diverse ideas through the hub, supporting Burt’s (2005) idea that both structural holes and closure are important to networks.

Another consideration in examining whole-network evolution is the network inertia that might constrain change due to organizational resistance or the difficulties an organization may face when attempting to dissolve or develop a tie with another organization (Kim, Oh, and Swaminathan 2006). For instance, along the lines of the argument by Podolny (2001), high-status organizations likely have more options and greater discretion in their network choices. Thus, lower-status organizations may be more constrained and have fewer options. This micro-dynamic is similar to degree assortativity, or the extent to which nodes with similar number of ties connect to one another. The impact of degree assortativity on network structure, especially in regard to the inertia facing lower status organizations, also points to the importance of a network hub. Over time, subgroups may emerge with the result of the network being differentiated into a variety of sub-groups (Ahuja et al. 2012). A hub can prevent the disintegration of the whole network into various partitions by ensuring low-

status or peripheral nodes receive the same information as the higher-status or highly connected nodes.

Therefore, while not without shortcomings, the role of a hub in the structure of a whole network may be the underlying force holding the network together, facilitating relationships across network members, and transferring knowledge that is critical to the effectiveness of the network as a whole and its individual members. Thus, in a network like NAQC, a hub has the ability to collect and then aggregate information from various sources and disseminate superior ideas to all organizations in the network. It is important to recognize, however, that a single hub organization may not be the only force underlying network structural centralization.

Taking into account the different counter-forces regarding network evolution, we contend here that the flow of information about practices that are likely to be especially effective, and thus, are likely to have a positive impact on overall network outcomes, can occur in at least three different ways. First, the network can be dense and decentralized, with information flowing widely across and among member organizations without regard to type or status of network members. Second, the network structure may exhibit small world properties (Watts 1999) and be somewhat more centralized, with information flowing primarily within clusters, or subgroups of network members who may have similar characteristics and are highly connected to one another, but are connected to other clusters via bridges. Third, the network as a whole may be highly centralized, with a single prominent network member acting as the primary hub of information about services, both collecting knowledge from multiple network and other sources, and disseminating this knowledge among network members. We argue that given the focus of the NAQC network on transfer of research-based evidence, which does not reside equally among network members, the shift over time from lesser to greater centralization will occur primarily through the third mechanism discussed; that is, toward a hub-centric network.

METHODS

This research examines the structure of information sharing relationships that comprise the North American Quitline Consortium (NAQC). Our focus is specifically on those network ties related to the transmission of a common body of evidence-based information across NAQC organizations, since facilitating the flow of such information across the network is the mission of NAQC. Our study is longitudinal, examining these relationships as they evolved over the three year period from 2009 to 2011, shortly after the network had been established. While individual smoking quitline organizations existed in some states as early as 1991 (Anderson and Zhu 2007), NAQC was formally organized in 2004 with the intent to improve access to and use of telephone-based quitline services across the US and Canada. Its primary mission has been to enhance the flow of practice and research-based knowledge about which quitline practices might be most effective in getting people to quit smoking (<http://www.naquitline.org/>). The provision of information about service delivery; specifically, what to do and how to do it most effectively, is a critical part of that mission.

Research Setting

When data were collected, NAQC consisted of 63 quitlines, 10 in Canada and 53 in the US (all U.S. states plus 3 territories). Each quitline is comprised of a public funder entity, usually a state or provincial public health agency, and a service provider organization. In 2009, 13 quitline providers were single funder providers, meaning they only served a single state/provincial quitline. In seven other cases, the provider served multiple state/provincial quitlines. The largest of these service providers was a for-profit entity that contracted with 18 state quitlines. In 2010 this and another multi-quitline provider merged, and thus provided quitline services in 23 states, which was also the case in 2011.

While all quitlines have the same basic mission, the specific services they provide to clients vary, depending at least in part on the availability of funds and a determination of what particular services might be most efficacious. What also may affect which services are offered, and especially, the specific ways these services are delivered, is the information available to both funders and providers. The primary goal of NAQC, thus, is to ensure that information about these services is made widely available to NAQC members, ultimately leading to better services and more people quitting.

As an important part of the foundation of NAQC, a network administrative organization (NAO) was established. An NAO is a common network governance form where “a separate administrative entity is set up specifically to govern the network and its activities” (Provan and Kenis 2008: 236). The establishment of an NAO at the founding of NAQC was to facilitate the coordination of the 63 funder-provider quitlines in the network, but in the absence of any hierarchy (Provan, Beagles, Merken, and Leischow 2012).

At the time of data collection, NAQC’s NAO had a full time executive director and four staff people, including a research director, plus an advisory council of a select group of quitline members to help develop strategic direction for the network as a whole. From an organization theory perspective, NAQC is considered to be a “whole network” (Provan et al. 2007), since it is bounded by membership, is formally governed, and has clear goals pertaining to the facilitation of information sharing regarding provision of smoking cessation services using a phone-based quitline methodology.

Given the purpose of the network to facilitate and encourage information sharing among members, this network is an appropriate case for examining how network structure evolves over time to accomplish that purpose. In our conceptual discussion of different network structures, we proposed three different ways information could flow. First, information could potentially flow widely among all network members, providers and funders alike, leading to a dense but highly decentralized network. Alternatively, the network could be relatively centralized through clusters, with information flowing primarily among similar quitline funders and their contracted provider organizations, with prominent funders or providers acting as bridges across clusters. Lastly, the network could be highly centralized across the network as a whole, through a hub. Our research considered all three of these network scenarios, but focused in particular on the position of the NAO in the flow of information and whether it undertook the role of hub and centralizing force over time.

Data Collection

Survey data were collected from all quitline organizations, both funders and providers, plus the NAO, in the summer and early fall of 2009, 2010, and 2011. The total population of NAQC organizations varied somewhat over the course of our data collection, as did response rates. However, our response rates were uniformly high, exceeding 90% in 2001 and 85% in 2010 and 2011 (see table 1 for details). Even for those organizations that declined to participate, we were able to acquire partial network data based on the responses of those organizations that did participate, since participating organizations could report who sent them information. Data were collected from 1 to 5 respondents per quitline organization, although most quitline organizations had 3 or fewer respondents. Respondents were selected carefully by asking the NAO's primary contact at each organization to identify the key informants from their organization best suited to respond to our particular survey.

The data for all three years were collected using a web-based survey developed specifically for this research project. The main network survey was based on reliable methods and measures utilized in prior research by one of the authors and colleagues in other health and human services settings (Provan, K. G., K. Huang and H.B. Milward. 2009; Provan and Milward 1995).

Our questions and methods were also pre-tested on a "working group" of quitline members who provided valuable feedback as to question wording.

For collecting data on the network of relationships, in each year of the data collection respondents were presented with a roster of all quitline funders and provider organizations, plus the NAO. For each organization listed, respondents were asked to indicate if they received information about service delivery from that organization. The absence of a relationship between organizations was coded as 0. Information about service delivery was defined as "ideas about improving or assessing treatment and services, new protocols, new treatment technologies, results of research studies, dealing with problem clients, etc." Respondents were also asked to indicate the level of relationship intensity in terms of frequency and importance of the relationship (on a 1 to 3 scale). However, only responses scored at a level of intensity of 2 (moderate) or 3 were utilized in the final analysis. Data on information ties coded 1, which were "weak" were not considered in our analysis. Since we were unable to confirm network relationships among partners due to the extreme response burden this would have placed on respondents (i.e. in asking about both sending and receiving information), we had concerns that weak tie findings might not be reliable. In fact, these low intensity relationships were highly unstable across the three years, suggesting lack of reliability, in contrast to the moderate and high intensity relationships. We were also much more interested in capturing and assessing those information relationships that were meaningful to quitline organizations, and thus, more likely to have an impact on quitline operations and policy. Very low intensity relationships (defined in the survey as "not an especially important or frequent link"), such as occasional communications, would be unlikely to have this impact.

In any year, if even a single respondent in an organization having multiple respondents indicated a relationship existed with another NAQC organization, the relationship was

counted and counted at the maximum intensity indicated by any of the respondents. This decision criterion was based on the presumption that a single individual could be involved in a network connection, and thus establish an inter-organizational network tie, even though others in the organization might not be involved at all (Maurer and Ebers 2006).

In addition to data on network relationships, data were collected on the awareness and subsequent adoption of those quitline practices primarily supported by research evidence. These data were measured by asking respondents in each year to indicate whether they were aware of a practice, and if aware, whether their quitline had decided to adopt the practice. The list of practices included those quitline practices found to be effective in getting people to stop smoking (efficacy) or to get them to contact a quitline to get needed services (reach). For example, a practice with high evidence levels of efficacy is to provide free (or discounted) nicotine replacement therapy (NRT) to callers. A reach practice with high evidence levels is to provide proactive (outbound) telephone counseling. The full list of practices and evidence levels is provided in Saul, Bonito, Provan, Ruppel, and Leischowv(2014). The original list of practices included 23 in Year 1, 27 in Year 2 and 28 in Year 3. However, two practices, which represented divergent approaches and thus could not be simultaneously implemented, were combined for the final total possible list of practices a quitline could adopt; 22 in Year 1, 26 in Year 2 and 27 in Year 3.

The measure for adoption of practices is at the quitline level since practices are adopted and ultimately implemented by the quitline (i.e., funder-provider pairs). Therefore, the data collected were aggregated to the quitline level by using one key respondent from each quitline to maintain across-year consistency. As with prior research by Fujimoto et al. (2009) and Valente et al. (2009), responses were collapsed to reflect adoption or non-adoption of each practice. Using only the 22 practices included in all three years and only the quitlines for which there was a response for all three years, the number of practices adopted by all quitlines was then totaled for each year, thereby allowing comparison of overall adoption rates by the entire network in each year.

Descriptive Analysis and Findings

Evidence-Based Practice Adoption Rates

Examining the factors influencing the structural evolution of this network over time is important because of the upwards trend of the adoption rate of evidence-based practices during this same time period as well. Although this study is primarily structural, examining service delivery information ties across the network, we can compare network structural data with evidence-based practice adoption rates over time.

Table 2 provides the three year comparison of the total adoption rates as well as the changes in percent of adoption rates across the three years. The greatest change in practice adoption rates occurred from Year 2 to Year 3 (+8.4), the lowest from Year 1 to Year 2 (+3.0), for a total increase in the adoption rate of evidence-based practices across all quitlines of 11.4 from Year 1 to Year 3. Most important, though, is the steady increase in the overall adoption rate across the three year period, from 71.4% of the full set of evidence-based practices in Year 1, to 74.4% in Year 2 and finally to 82.8% in Year 3. This upward trend in adoption

rates suggests that the relationships developed within the NAQC network may have helped facilitate the dissemination of evidence-based practices across quitlines.

Thus, examining how network structure evolved over the same period may provide some important clues for understanding how evidence about practices may have spread across the network, resulting in enhanced adoption of practices known to accomplish the network-wide goal of reducing smoking.

Network Structure

Two core network-level statistics, density and centralization, which we used to examine and compare overall network structure, both within each year and across years were calculated using Ucinet VI (Borgatti, Everett, and Freeman 2002). Density indicates the overall connectivity of the network, expressed as a proportion of actual ties relative to the total number of possible ties. Since we were interested in the intensity of the tie, density was calculated using the value of the tie (see formula in table 3). Centralization reflects the extent to which a network is connected primarily through one or a small number of organizations or is more decentralized with ties spread relatively evenly among network organizations.

Degree centrality scores computed for the purpose of centralization clearly indicated that the NAO had the highest number of ties every year, only closely followed by one or two large quitline providers. The average number of ties for each year ranged between 5 and 6 ties and the NAO had more than 50 ties each year. The NAO, therefore, can be classified as a hub in the structure of this particular NAQC network. However, the high number of ties that a few large providers had also indicated that the NAO was not the only prominent central node and examining the structural impact of ties to these large providers was also necessary.

Thus, in addition to the basic full matrices, three separate sets of matrices were also compiled for each year for the purposes of the analysis. Specifically, one set of matrices was compiled excluding the NAQC NAO and its incoming and outgoing ties, thereby allowing direct comparison of network relationships in each year among the quitlines themselves. Another set of matrices was compiled which excluded contractual ties between funders and providers. Using matrix multiplication, any ties between a funder and its contracted funder were forced to equal 0, resulting in matrices with only the relationships among funders, among providers, and among funders and any provider that was not its contracted provider for that year. Two sets of these non-contractual matrices were created, one including the NAQC NAO and one excluding it. Density and centralization scores were also calculated on each of these additional matrices.

Prior to the analysis of network structure, we performed a QAP (Quadratic Assignment Procedure) correlation analysis of network ties in one year compared to another. A QAP analysis indicates the extent to which one network is correlated to another while correcting for the bias network data poses since observations are not independent as is assumed by standard inferential statistics (Krackhardt 1988). Very strong QAP correlations would suggest little difference in the network from time 1 to time 2, and thus, little need to compare network characteristics across the time periods. Very weak correlations would

suggest a randomness to the data. Our QAP results indicated a moderate positive relationship when comparing network ties across the three time periods for the full network (Y1-Y2, $r = 0.571$; Y2-Y3, $r = 0.617$; Y1-Y3, $r = 0.549$), justifying the rationale for exploring network change.

Structural Analysis and Findings

To explore how the network changed over time, we compared the NAQC network in years 1, 2, and 3 in several different ways, varying which specific relationships were considered. Analyzing various sets of relationships was carried out, because while the basic analysis reflects information ties among providers, funders, and the NAQC NAO, we also wanted to examine the extent to which funders and providers interacted with each other on their own over time, without depending solely on their contractual funder-provider relationships or their ties to the network's governance entity, the NAO. Specifically, by separately considering ties both with and without each quitline's contractual funder-provider relationship, we could examine the part these contracts play in the structure of the information flow. But especially important for our study was the role of the NAO. By separately considering ties both with and without the NAO, we were able to examine how reliant on the NAO the network is and whether it held a central hub position in the network that was important to maintaining the structure of the network as a whole, especially over time.

When the NAO was excluded from the network of ties, the QAP correlations were slightly weaker than the QAP correlations for the full network of ties, but still moderately positive (Y1-Y2, $r = 0.543$, Y2-Y3, $r = 0.529$; Y1-Y3, $r = 0.501$), as was the case when funder-provider contractual ties were deleted (Y1-Y2, $r = 0.479$; Y2-Y3, $r = 0.557$; Y1-Y3, $r = 0.463$). The weakest relationship was found when comparing the networks when both NAO and contractual ties were excluded (Y-Y2, $r = 0.336$; Y2-Y3, $r = 0.400$; Y1-Y3, $r = 0.283$). Overall, the intermediate strength positive QAP correlations from our data suggests a general consistency in the pattern of network ties over time, but with enough variance to warrant more in-depth analysis to try to understand how the micro-dynamics of the network structured changed.

To examine any changes over time, we focused on the two basic network statistics: density and centralization. Table 3 provides an overview of the findings. First, as table 3 shows, overall density did not change between Year 1 and Year 2 ($= 0.19$) but decreased between Year 2 and Year 3 (from 0.19 to 0.16), for a change in density from Year 1 to Year 3 of 0.03. For centralization, the centralization of the network slightly increased over the 3 year period, from 0.49 to 0.52 to 0.54.

The relative stability of the overall network structure over the 3 year period can be seen in figure 1. Figure 1 shows the plots for the full network at both the first and last time periods studied. Each plot shows all the network organizations, or "nodes," including providers (triangles), funders (circles), and NAQC's NAO (square). The lines, or "edges," indicate the existence of a tie between two organizations based on the reported flow of information about service delivery, at either moderate (2) or high (3) intensity. The arrow for each tie indicates

the direction of the information flow. The size of each node indicates the relative outflow of information from that organization to others in the network. The larger the size, the more the organization is a major sender of information. In network analysis terms, and perhaps counter intuitively, this refers to “in-degree” centrality since it is based on the ties reported by organizations on the receipt, or inflow, of information from a target organization. The organizations from which a response to the questionnaire was received are colored gray whereas the white nodes indicate organizations from which no response was received. As noted earlier, we include network data on non-respondents since responding organizations named them as information senders. The plots do not, however, include any ties based on information that the non-responders might have received from others in the network.

Although the full networks are moderately dense, 15–20% of possible ties present, it is apparent that many organizations have only very few ties and though slight, it can be seen that Year 3 has fewer ties (i.e. lower density) than Year 1. What is more apparent is that there are two basic network clusters – one large cluster, which is the US network, and a smaller cluster, which is the Canadian network of quitline organizations. These two subgroups are connected, but tenuously enough so that the sub-network structure is easy to notice; though easier to notice in Year 1 than Year 3, possibly to do with the greater centralization of the network in Year 3 than in Year 1.

The density trend for the full network was similar to the density trend once we removed the contractual provider ties and the NAO ties. The density decreased in much the same way when examining the network of relationships without the contractual provider ties included. However, the density more steadily decreased over the 3 year time period when the ties to the NAO were removed (from 0.16 to 0.15 to 0.12). Density dropped much more precipitously once ties to the NAO and contractual provider ties were both excluded (from 0.12 to 0.11 to 0.08, or a drop of 33.3% from Year 1 to Year 3, which is statistically significant at $p=0.002$). While the overall connectivity of the network declined somewhat over time, it is apparent that much of the strength of the network, at least in terms of the flow of information regarding services, is based on ties to the NAO and to a lesser extent, through the contractual relationship between individual quitline funders and their providers. Once these two information connections are excluded, network density drops substantially, suggesting that both providers and funders are generally not reaching out to many other similar organizations in other states and provinces to send and receive service information related to their common efforts to reduce smoking.

The changes in centralization scores further support the finding that much of the connectivity in the network depends on contractual provider ties and ties to the NAO. Not surprisingly, since the formal role of the NAO is to hold the network together, facilitating interactions and the flow of information, centralization decreased in all years when the NAO alone was dropped from the analysis. In addition, contractual provider ties are an important factor in centralizing the network, especially for those quitline providers that contract with multiple funders. However, since there are many providers that contract with only one or a small number of quitline funders, the effect of removal of contractual ties on network centralization has the opposite effect of removal of the NAO. When not considering the

contractual provider ties, overall network centralization increases due to the enhanced impact of the NAO as a primary source of quitline information.

As shown in figure 2, when the contractual ties between funders and their provider organization are removed from the plots, the overall density of the network in each year is lower than what is shown in figure 1. But even with the removal of these contractual ties, the network holds together quite well, with only two to five isolates (shown as unconnected to other network organizations in the figure) found in each year. What is apparent from figure 2 is the critical role that the NAO plays for keeping the network connected in ways that go beyond the contractual ties between funders and their provider. This can be seen visually in that the plots reported in figures 1 and 2, in which the networks for each year appear to have similar overall patterns of relationships. This visual conclusion is indicated mathematically by the high network centralization scores (reported in table 3 and the data boxes shown in the figures) when contract ties, but not the NAO, are dropped.

Contractual ties provide an alternative and more dispersed source of information that reduces the impact of the NAO on centralization scores. In contrast, when both NAO and contractual ties are dropped, the networks in both years are no longer centralized at all, with scores of 0.14 in Year 1, 0.16 in Year 2, and 0.13 in Year 3. The key role of the NAO can be seen most clearly in figure 3 when the information ties through both the contractual relationship between funder and provider and the ties through the NAO are dropped from the analysis. When both the NAO and contractual providers are removed, there is still information exchange among quitline organizations, but overall network density is not high, as indicated in table 3. Visually, this is somewhat difficult to discern, because the networks appear to have many ties. However, while information still flows among those remaining in the network, removal of the NAO results in many organizations having no service delivery information connections at all in the network, especially in Year 3 (8 isolates in Year 1 but growing to 11 isolates two years later).

Second, the figure demonstrates quite clearly the importance of the NAO in connecting the US and Canadian quitline funders. While there was evidence of two national clusters in the previous figures, the clusters are much more distinct when the role of the NAO is eliminated. Third, the figure also suggests the emergence of a cluster within the US cluster. This cluster, at the lower left-hand side of the US cluster, suggest the differentiation occurring within the US community with a group of highly connected quitlines receiving information from one another, but that information not being shared directly with the quitlines at the periphery or the isolates, the effect of degree assortativity. Instead, the structural role of the NAO and service providers seems critical for ensuring that all quitline funders, and not just a sub-set of highly connected funders, receive needed service information in order to counter the effect of degree assortativity, where those with a high number of ties share information with each other and not with those with a low number of ties. Ultimately degree assortativity could lead to the disintegration of the whole network into a variety of sub-group based on low-status or peripheral nodes and higher-status or highly connected nodes.

Overall, the findings for centralization are consistent with those for density. Both demonstrate the important and enhanced (from Year 1 to 3) role of the contracted providers,

but especially, the NAO, as conveyers of information about quitline services. Within the NAQC network, our findings indicate that this information is not especially likely to flow in a decentralized manner. That is, the many providers and funders that comprise the network acquire information from relatively few of their peer organizations in other states and provinces, relying mainly on their contractual partners and especially, the NAO who acts as a hub in the overall structure of the network.

DISCUSSION

This research has examined the evolution of whole network structure focusing specifically on the position of the NAO in the network. Drawing on our specific research findings, and consistent with prior research linking network centralization with network outcomes, we found that greater centralization over time in the flow of key information, especially through the NAO, was consistent with higher rates of adoption of evidence-based practices by network members. However, our primary focus was in examining the changes in network structure over time, and specifically, the increasingly important role of the network governance entity, the NAO, in connecting network members to the flow of knowledge about services across the network. While other factors undoubtedly influence decisions to adopt practices, since the purpose of the network and especially the NAO was specifically to enhance the adoption of evidence-based practices by quitlines, the evolution of network structure, based on relational ties, may at least be one important factor to consider for influencing the adoption of practices considered to be effective.

A more centralized information dissemination structure, like reliance on the NAO as hub for information about service delivery practices, is a relatively efficient means of ensuring that all network members are receiving information about effective practices. A decentralized structure would allow for information to flow freely without concerns of bottlenecks (Borgatti, 2005), but could also be taxing on network members in having to maintain many relationships with other network members. Another possible structure we considered was a small world type structure consisting of clusters and short bridges connecting the clusters. The structural importance of several large service providers in the NAQC network suggests there are elements of this small world type structure as well. Many funders relied heavily on their contracted service provider or funders contracting with the same service provider for their information (self-reference). Therefore, the largest service providers provide indirect paths along which information can flow across funders. However, the large providers alone do not hold the network together and the greater centralizing force is the NAO, which as hub prevents the whole network from disintegrating into sub-groups of highly connected members and those less well connected or even isolated from the flow of information. The importance of understanding this critical role of a hub applies not only for the consortium of smoking quitlines, but also in a variety of other contexts where facilitating and enhancing the flow of knowledge across a large number of organizations providing similar services is essential for diffusion of evidence-based practices and ultimately, achieving overall network goals.

Our findings have important implications for theory and practice. In particular, a hub may be necessary when the goal of the network is the diffusion of evidence-based practices. One

way to achieve this structure is through a key integrator and knowledge disseminator for the network as a whole, a role which may be most easily filled by a central network governance entity, especially when the network is large and geographically highly dispersed, as was the case with NAQC. Having a hub and/or other centralizing forces, such as the service providers in the case of NAQC, is key to maintaining the integration of the network as a whole. Provan and Milward (1995) found network integration via centralization to be a condition of network effectiveness, a finding supported by Raab, Mannak, and Cambre 2015. Our findings offer an explanation as to why centralization may be important to the long-term stability and effectiveness of the network; a central hub can ensure *all* network members have access to the whole network information flow. A central network hub may not be important because they are central in the structure, but may be central because their role is to counter the disintegration forces that may be natural in network evolution (Gulati, Sych, Tatarynowicz 2012).

There is vulnerability in relying on a hub for facilitating the information flow. Hubs are in a position to both accelerate and impede the diffusion of information (Schilling and Fang 2014). Distinguishing between a hub that is accelerating the information flow from one that is impeding it is likely not possible by structural analysis alone. For this reason, we also analyzed the rate of adoption of evidence-based practices over time as a way of assessing whether the flow of information about evidence-based practices was indeed being diffused across the network. However, it is very likely that the NAO in this case may also be impeding the dissemination of information around practices that are not evidence-based. The desire to impede the information flow may be especially strong when the information is not directly tied to the information agenda of the hub. Thus, it is important to consider the agenda of the hub and their trustworthiness. This may be why an NAO, an entity that exists solely for the purposes of the network, is positioned to take on the structural role of a hub. The form of network governance and the agenda of the network governance entity is a factor to consider in whether playing the role of hub is right for a network.

In addition, the characteristics of the hub actors are also important to consider. In this study we only focus on the structure, but the competence and skills of the individual or individuals are likely to influence the structure of a network and whether a hub is able to facilitate rather than impede the diffusion of information (O'Leary, Choi, and Gerard 2012). For instance, in this case, the position of the NAO as hub likely has a great deal to do with the skills and characteristics of the NAO staff, which in turn likely influence the effect the hub has on the information flow. Although we focus only on a structural analysis with this paper, future research should examine the link between hub structure and the characteristics of the hub agents.

Another important caveat is that a highly centralized network may not necessarily be the most effective structure in all respects. In our study, the network was still only moderately centralized (around the 50% range), even in Year 3 when centralization was the highest. Information bottlenecks could readily be created by an overly centralized network that could impede the flow of at least some information and ideas (Borgatti 2005). In addition, the quick accumulation, dissemination, and convergence around a specific set of established practices such as those studied here can lead to the exclusion of diverse ideas and new,

emergent practices that could be effective as well (Schilling and Fang 2014). Thus, it seems reasonable to suggest that there may be a curvilinear relationship between network centralization and effectiveness in which moderate overall levels of centralization may be ideal. Further research on the evolution of network structure is necessary to determine the shape of the relationship between centralization and outcomes and the dual role of network hub as both lubricant and obstacle.

CONCLUSION

This article has sought to contribute to research on whole networks by examining changes in a whole network structure over time and why a hub, such as an NAO, may be an important centralizing force in a network. It is important to recognize, though, that our conclusions are limited by the design of this study. First, although we studied the network longitudinally, ours was a case study of one network, and therefore, generalizations must be limited. The design allows for conclusions demonstrating the impact of time, but the period of time studied may have been a unique time period for the network. Since we only examined the network over a three year period in the early stages of network evolution, our conclusions may only apply to the organizing of networks in their early stages of development. It may indeed be the case that a fully mature and robust network is one in which enough relationships have been facilitated among network members that a key hub or integrator is no longer essential to the structure of the whole network information flow. However, our findings are broadly consistent with previous findings in network structure research, especially in public health and public administration (Fujimoto et al. 2009; Provan et al. 2007; Raab et al 2015, Varda et al 2012), strengthening our overall conclusions.,

Longitudinal network research is also still a rare occurrence in the organizational network literature (Kilduff and Brass 2010). Despite the limitations, our study is one of a few longitudinal studies of network structure and it demonstrates the importance of examining the forces influencing structure over time.

Second, though we found both an upward centralization trend and an upward trend in adoption rates, we did not establish a direct causal link between the evolution of network structure and practice adoption. This study involved an examination of overall network structure and the micro-dynamics of centralization, and thus, other work is needed to delve into more of the micro-dynamic details of the types of relationships that are associated with decisions to adopt practices. Specifically, it is not necessarily the service delivery information ties to the NAO that are the type of relationship associated with decisions to adopt certain practices; rather other types of relationships or contextual conditions influence those decisions (Mercken, Saul, Valente, Lemaire, and Leischow 2015).

Decisions about the adoption of practices can only be made, however, if an organization has information about practices and understanding whole network structure is important for understanding the transmission of key information across the entire network.

Despite some shortcomings, this study contributes to a greater understanding of the evolution of whole network structure and the important role the network governance entity

may play in maintaining the connectivity of a network. If a moderately centralized network is in fact an effective structure for achieving certain network-level outcomes, as has been found in this and in previous studies (Provan and Milward 1995; Raab, Mannak and Cambre 2013), then the network governance entity appears to have an important role in shaping the overall evolution of the network structure so that desirable end-state outcomes, especially related to client well-being, can be achieved.

ACKNOWLEDGEMENTS

Work on this paper was funded by a grant from the National Institutes of Health (R01CA128638–01A11). Additional support was provided by Cancer Center Support Grant (CCSG - CA 023074). The authors would like to thank Jessie Saul and Gregg Moor for their invaluable assistance on the project.

ABOUT THE AUTHORS

Robin H. Lemaire (rlemaire@vt.edu) is an assistant professor in the Center for Public Administration and Policy in the School of Public and International Affairs at Virginia Tech. She holds a PhD in Public Management from the School of Government and Public Policy at the University of Arizona. Her focus is on organization theory and the management of public, nonprofit, and health care organizations, with a particular interest in inter-organizational networks and network analysis.

Keith G. Provan was McClelland Professor in the Eller College of Management at the University of Arizona, co-director and co-founder of the Center for Management Innovations in Health, held a joint appointment in the School of Government and Public Policy, and was a senior research fellow at Tilburg University. His research focused on inter-organizational and network relationships, especially in the domain of health and human services. He published over 70 academic journal articles and scholarly book chapters over his career and was a charter member (one of only 33 scholars) of the Academy of Management Journal's Hall of Fame.

Liesbeth Mercken (liesbeth.mercken@maastrichtuniversity.nl) is a senior researcher at Maastricht University, Department of Health Promotion. In 2009, she received her PhD at the School for Public Health and Primary Care, Maastricht University. Her past and current research focuses on the spread of (un)healthy behaviors in social networks. She also is interested in the effects of change in networks of Public Health organizations on Public Health outcomes over time.

Scott J. Leischow, Ph.D. (leischow.scott@mayo.edu) leads the Research on Health Equity and Community Health (REACH) Program at Mayo Clinic Arizona, and co-leads Cancer Prevention and Control within the Mayo Clinic Cancer Center. He completed his doctorate in Health Education from the University of Maryland, and a postdoctoral fellowship in Behavioral Pharmacology from Johns Hopkins University. Most of his research focuses on pharmacologic and behavioral treatments for tobacco dependence and systems/network approaches to public health.

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Service Delivery Information Sharing, All Ties (Year 3)

Figure 1.
Service Delivery Information Sharing, All Ties (Year 1)

Non-Contractual Service Delivery Information Sharing (Year 3)

Figure 2.
Non-Contractual Service Delivery Information Sharing (Year 1)

Non-Contractual Service Delivery Information Sharing, No NAO (Year 3)

Figure 3.
Non-Contractual Service Delivery Information Sharing, No NAO (Year 1)

Table 1.

Response Rates for Each Year

	Year 1	Year 2	Year 3
Total NAQC Organizations	94	97	98
Total Number of Respondents	85	83	84
Response Rate	90.42%	85.57%	85.71%

Table 2.

Comparison of Evidence-Based Practice Adoption Rates

	Year 1	Year 2	Year 3	Change in % Adopted Y1-Y2	Change in % Adopted Y2-Y3	Change in % Adopted Y1-Y3
Total Adopted %Adopted	912 71.4	950 74.4	1056 82.8	3.0	8.4	11.4

Total number of practices = 22 (practices that were included in survey for all 3 years)

Total number of Quitlines = 58 (Quitlines for which there was a response for all 3 years)

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