Transdisciplinarity Among Tobacco Harm–Reduction Researchers

A Network Analytic Approach

Keith G. Provan, PhD, Pamela I. Clark, PhD, Timothy Huerta, PhD

Abstract: Progress in tobacco control and other areas of health research is thought to be heavily influenced by the extent to which researchers are able to work with each other not only within, but also across disciplines. This study provides an examination of the extent to which researchers in the area of tobacco harm reduction work together. Specifically, data were collected in 2005 from a national group of 67 top tobacco-control researchers from eight broadly defined disciplines representing 17 areas of expertise. Network analysis was utilized to examine the extent to which these researchers were engaged in research that was interdisciplinary or transdisciplinary, based on the outcome or product attained. Findings revealed that interdisciplinary network ties were much denser than transdisciplinary ties, but researchers in some disciplines were more likely to work across disciplines than others, especially when synergistic outcomes resulted. The study demonstrates for the first time how tobacco-control researchers work together, providing direction for policy officials seeking to encourage greater transdisciplinarity. The study also demonstrates the value of network-analysis methods for understanding research relationships in one important area of health care.

(Am J Prev Med 2008;35(2S):S173–S181)

Introduction

In tobacco control, as in other areas of health promotion, it is becoming increasingly apparent that in order to make significant progress, a systems approach must be utilized.[1,2] In particular, those who work in discrete areas of tobacco control, like public policy or treatment or aerosol chemistry, must not only recognize the value of the contributions of those in other fields, like smoking topography, economics, and genetics, but they must also learn to work across disciplines in order to coordinate their activities and behaviors. There are increasing pressures to have basic and applied scientists work together to improve clinical and population health practices and outcomes. An idea gaining greater traction is that cross-disciplinary collaborations facilitate exposure to different theories, methodologies, approaches, and research traditions that will result in better-quality science, increased innovation, and the accelerated translation of evidence into practice.[3] Concepts such as collaboration, networks, cross-disciplinary research, and knowledge translation are changing the way scientists, practitioners, and policymakers think about the health-research enterprise.[4]

One key element of a systems approach is working collaboratively through a network.[2] A network comprises three or more individuals or organizations that are connected through any type of tie, such as friendship, resource-sharing, or work interactions. Ties may range from tightly to loosely coupled,[5] may be formally (such as transdisciplinary tobacco use research centers) or more informally structured, and may be goal-directed or serendipitous.[6] In health research, collaborative networks can occur in many different ways and involve many different types of individuals and organizations, ranging from those who conduct basic research to those who make policy and provide funding, to those who provide actual treatment and related services. A truly integrated system would involve a network of collaborative efforts that spans all areas of research and practice within a given health field and involves all key individuals and organizations. While such a system may be a long way off, and in practice may not even be possible, it is not unreasonable to work toward a goal of building greater network integration as a way of enhancing tobacco-control efforts.

One area of tobacco control that lends itself especially well to collaborative efforts is research.[7] Although

From the School of Public Administration and Policy, University of Arizona (Provan), Tucson, Arizona; Tilburg University (Provan), Tilburg, the Netherlands; the Department of Public and Community Health, University of Maryland College Park School of Public Health (Clark), College Park, Maryland; Rawls College of Business, Texas Tech University (Huerta), Lubbock, Texas; and the Child and Family Research Institute (Huerta), Vancouver, British Columbia, Canada

Address correspondence and reprint requests to: Keith G. Provan, PhD, 405 McClelland Hall, Tucson AZ 85721. E-mail: kprovan@eller.arizona.edu.

doi:10.1016/j.amepre.2008.05.015

cross-disciplinary collaboration has always been a fundamental part of creating good research, disciplinary boundaries and narrowly defined areas of expertise often result in silos of researchers who do not work together across disciplinary boundaries or even talk with one another to share ideas.[8] Each discipline has its own theoretical perspectives, jargon, and tools and methods—differences that must be overcome for transdisciplinary teams to make progress. Thus, the content and outcomes of research are heavily affected by the process, which is dependent on the network of interactions among researchers.

The IOM has called for a shift to research that engages investigators from multiple fields in order to "capitalize on expanding knowledge of how genetic, social, and environmental factors interact to influence health."[9] Calls for greater cross-disciplinary collaboration have become an important part of the research agenda of major government-research funding agencies. For instance, several institutes of the NIH and the Robert Wood Johnson Foundation have jointly funded center grants to support Transdisciplinary Tobacco Use Research Centers (TTURC),[10] with actual and planned investments of $145.5 million between 1999 and 2009 (G. Morgan, NCI Tobacco Control Research Branch, personal communication, 2006).

Cross-Disciplinarity in Networks

While cross-disciplinary research networks have received a good deal of attention as a preferred mechanism for addressing complex problems, very little is known about the nature of collaboration among researchers. Stokols and co-workers[11] have provided a conceptual framework for evaluating transdisciplinary science, and have examined the contextual circumstances faced by participating researchers in several TTURCs, providing a foundation for evaluating the outcomes of transdisciplinary science centers.

Even less is known about the extent of transdisciplinary research that occurs across informal networks outside of funded centers. This lack of knowledge is somewhat surprising, given the importance of the topic and the explosive growth of social-network research in recent years.[6,12] In particular, very little has been done to understand the extent to which research in tobacco control or other scientific endeavors is cross-disciplinary, and if so, what this process looks like. Such knowledge would be extremely helpful not only to those who study research and knowledge-translation networks but also to those who fund, administer, and work in research networks by providing a set of guidelines or best practices for effective network organization, development, and administration.

Cross-disciplinary network interactions and involvement have been especially important in the area of tobacco harm reduction, which has been defined by Stratton et al.[13] as "minimizing harms and decreasing total morbidity and mortality, without completely eliminating tobacco and nicotine use." Because tobacco use is a complex problem—involving such things as tobacco-smoke chemistry, behavior of use, economics and public policy, and epidemiology, among others—researching harm reduction is by definition multidisciplinary. The research presented here is an examination of the extent to which researchers in tobacco harm reduction work together across disciplines, and what outcomes occur as a result. In general, the idea is that research needs to be understood as a network-level phenomenon, involving multiple individuals who work across disciplinary boundaries and develop products and outcomes that could not be attained by working independently.

This research is exploratory and was guided by several research questions. First, what are the nature and extent of the working relationships among the top research scientists who study tobacco use? Second, do tobacco-control researchers collaborate across, as well as within, academic disciplines, and if so, what is the structure of such interdisciplinary networks? Third, what outcomes are achieved through interdisciplinary network collaboration? And fourth, is the tobacco harm–reduction network achieving transdisciplinarity, and what is the structure of this network?

While there seems to be general agreement among those who study the topic that cross-disciplinary research is highly desirable as a way to advance science,[3] there is a lack of clarity on the use of the terms *multidisciplinary*, *interdisciplinary*, and *transdisciplinary*. A useful description of these three forms of cross-disciplinary research has been provided by Rosenfield,[14] whose work is summarized by Stokols et al.[15] in the introductory paper of this supplement to the *American Journal of Preventive Medicine*. The distinctions made by these scholars have been drawn on here to guide the research presented.

Research Methods

The Sample

The National Cancer Institute and the American Legacy Foundation provided funding to create a formal network of researchers involved with the science of tobacco harm reduction. For this study, the top researchers in tobacco-control research were invited to join the Tobacco Harm–Reduction Network. Those invited to participate constitute the sample utilized for this project.

A sampling frame of participants was identified through a key-word search of the NIH Computer Retrieval of Information on Scientific Projects (CRISP) and MedLine of the National Library of Medicine. Through these databases, 167 principal investigators, lead authors, or both were identified as potential

Table 1. Disciplines of Tobacco Harm–Reduction Network members

Disciplines	Fields included	Frequency
Chemistry/toxicology	Physical chemistry; organic chemistry; bio-organic chemistry; geo-organic chemistry; toxicology; biochemistry	12
Epidemiology	Epidemiology	4
Medicine/nursing/dentistry	Medicine; nursing; dentistry	8
Other behavioral	Behavioral sciences; health education; philosophy; communication research; English; public health; education	8
Other bench	Biophysics; physiology	2
Pharmacology	Pharmacology; psychopharmacology	4
Policy/law/ethics	Health policy; social policy; law	4
Psychology/psychiatry	Psychology; clinical psychology; experimental psychology; health psychology; physiologic psychology; social psychology	25

participants in the project. The invited participants for the actual study were drawn from the list using reputational sampling.[16] That is, a team of experts were employed to select from the list of 167 those who represented the most-accomplished researchers in their individual fields of inquiry, based on funding, publications, and general reputation in tobacco harm–reduction research. Thus, the sample is biased in favor of more-established researchers. A total of 68 potential network members were identified and sent a membership application in 2005, which included the questions used. No effort was made to select researchers by area of discipline.

It is important to note that while the Tobacco Harm–Reduction Network does have members in the formal sense of the term, consisting of the 68 top researchers selected for the study, the findings and analysis focus on the network of relationships established by these researchers on their own as they conducted their research. There was no formal meeting of the Tobacco Harm–Reduction Network prior to data collection, and members were asked only to report their past work-based interactions with each other.

Measures

The membership application requested information on the field of the highest earned degree, areas and extent of expertise, and the nature of relationships among the members and the products of those relationships. Of the 68 members identified, 67 returned the application (98.5% response rate).

Discipline was defined as the field in which the respondent earned his or her highest academic degree. Researchers were from a range of eight broadly defined disciplines identified by the authors, including psychology, medicine, policy, economics, pharmacy, epidemiology, other behavioral, and other bench. The distribution of disciplines within the sample is reported in Table 1.

Seventeen areas of expertise were identified a priori. Respondents were asked to indicate their level of expertise (*none or limited, some*, or *strong*) for each of the 17 categories identified by the authors. The frequencies and percent of Tobacco Harm–Reduction Network researchers who reported their expertise as *strong* in each area are reported in Table 2.

The membership application listed all 68 members of the broadly-defined network, and each was requested to indicate if he or she had had any previous work-related interaction with any other member. If the respondent answered *yes* to any interaction, she or he was asked about the nature of the interaction (*shared information, worked as part of a team without a formal arrangement,* or *worked as part of a team with a formal arrangement like a contract, memorandum of agreement, joint funding, or formal sharing of resources*).

Three additional items were asked about those with whom respondents had interactions: *Did the interaction help shape your thinking or your approach to your work?* (*yes* or *no*—the measure of interdisciplinarity); *Did the interaction lead to the production of a product, such as a journal article or research proposal?* (*yes* or *no*), and, if *yes, Does the product contain perspectives or elements that go beyond what you could have developed on your own?* (*yes* or *no*). These

Table 2. Frequencies and percent of Tobacco Harm–Reduction Network members reporting *strong* expertise in 17 tobacco harm–reduction content areas

Area of expertise	Frequency	%
Preclinical	13	19.4
Smoke chemistry	16	23.9
Smoking topography	20	29.9
Physiology	11	16.4
Addiction	35	52.2
Genetics	9	13.4
Clinical trials	12	17.9
Cessation	33	49.3
Adolescent smoking	21	31.3
Biomarkers	14	20.9
Advertising and promotions	9	13.4
Program evaluation	11	16.4
Tobacco industry	12	17.9
Population surveillance	14	20.9
Economics	4	6
Tobacco-control law	16	23.9
Ethics	9	13.4

Table 3. Items for indexes of multidisciplinary, interdisciplinary, and transdisciplinary relationships among Tobacco Harm–Reduction Network members

Item	Multidisciplinary relationship	Interdisciplinary relationship	Transdisciplinary relationship
Highest degree from different discipline	Yes	Yes	Yes
No interaction	Yes		
Shared information		Yes	Yes
Worked on team with or without contract		Yes	Yes
Resulted in a product			Yes
Product contained elements beyond what you could have developed on own			Yes

last two questions were both considered to be measures of transdisciplinarity, although because they were highly correlated (0.94), only the second one was used in the analysis. An overview is provided in Table 3. Multidisciplinary relationships occurred simply by virtue of having multiple disciplines represented in the Tobacco Harm–Reduction Network, regardless of whether or not interactions took place.

To increase the reliability of responses, network interactions were counted only if both parties in the relationship agreed that there was indeed a relationship. This confirmation procedure minimized the likelihood that results would be affected by respondents who claimed network relationships, when, in fact, such relationships did not actually exist. When there was a discrepancy about the exact type of relationship, a conservative approach was used, coding the data based on the least-formal type of tie mentioned by either party. However, more than 70% of all relationships were reported identically by both respondents. Data were also coded so that if one person reported a transdisciplinary tie but the other reported only an interdisciplinary tie, it was counted as interdisciplinary. Finally, because respondents were completing the survey as part of an application for membership in a network into which they had already been accepted, there was little incentive to inflate responses. Network relationships were then arrayed in a matrix form and analyzed using UCINET 6, the most commonly utilized network analysis software. Matrixes were subjected to data and variable quality tests to ensure the robustness of the data-collection practices and to minimize coding errors. Separate network matrices were constructed for interdisciplinary and transdisciplinary outcomes, although analytical efforts focused primarily on the transdisciplinary matrix. Networks were also displayed graphically using a network-visualization tool called NetDraw.

Results and Discussion

The overall network findings (Table 4) include a number of statistics indicating the network structure, or the relative positioning of actors within the network. The table reports statistics for both the interdisciplinary (no outcome) network and the transdisciplinary (a synergistic outcome) THR network.

Using the confirmed linking process described above, network density for any type of tie (interdisciplinary or multidisciplinary) was 0.326. Density refers to the connectivity of the full network. If every one of the 67 researchers responding to the questions was linked to every other researcher listed, the network would be completely connected. This would result in a network density score of 1.00. The finding that slightly less than one-third of total possible network connections were actually occurring may seem low to those unfamiliar with network analysis, but it actually indicates a well-connected network, especially because the network studied has so many members. Overall density breaks

Table 4. Comparative statistics for interdisciplinary (no outcome) and transdisciplinary (synergistic outcome) tobacco harm–reduction networks (n=67)

Network measure	Inter-disciplinary	Trans-disciplinary	Concept definition
Network density	32.56	7.10	Total actual number of connections as a percentage of total possible connections
Degree centrality	0–0.79	0–0.30	Range of number of individual connections (normalized)
Network betweenness	1.10	1.80	Extent to which actors mediate, or fall between, any other two actors on the shortest path between those actors
Network centralization index	0.06	0.18	The extent to which a network is centralized around one or a few actors
Fragmentation	0.36	0.68	The percentage of pairs of actors that are unreachable from each other
Inclusiveness	0.98	0.85	The percentage of actors connected to others

down to network-density scores of 0.226 for shared-information ties, 0.061 for working as part of a team with no formal arrangement like a contract, and 0.038 for working as part of a formal team with a contract or similar formal arrangement. Thus, the vast majority of ties involved relatively low-intensity interactions based on shared information.

Several measures of centrality are presented. The first, degree centrality, is simply the number of connections maintained by any individual in the network. Table 4 reports the range of these scores, normalized. It can be seen that the most central individual in the interdisciplinary network was more than 2.5 times as connected to others as the most central individual in the transdisciplinary network (0.79 vs 0.30). It is likely that this is because interdisciplinary ties are less intensive, allowing some individual researchers to develop a large number of relatively weak ties. Betweenness centrality provides a somewhat different measure of the degree to which individuals within the network are connected to other individuals. With betweenness, an individual is more central if he or she brokers the connection between two individuals along the shortest path (i.e., fewest links). Thus, unlike degree centrality, indirect ties are considered. When reported at the network level, the statistic represents the prevalence of betweenness centrality across all possible connections in the network. A higher number means that there are fewer direct routes between people, and thus brokerage is more essential to bridge across network members. The results indicated that individuals in transdisciplinary relationships were 61% (1.1/1.8) more likely to be on a brokered path linking any two other members of the network, indicative of the increased interdependency on specific actors to facilitate communication in sparser networks. The transdisciplinary ties were also more centralized (0.18 versus 0.06), meaning that they tended to cluster around fewer individuals, as opposed to interdisciplinary relationships, in which central actors were more dispersed across the full network. Consistent with these findings, the transdisciplinary network was also more fragmented and less inclusive.

A comparison of the multidisciplinary and the transdisciplinary networks can best be demonstrated by examining plots, or graphs, of the two networks (Figures 1 and 2). What is visually evident from these plots is that connectedness is much more widespread across the network when using interdisciplinary rather than transdisciplinary criteria, which is reflected statistically in the density scores of the two networks. Specifically, the transdisciplinary network density is only 0.071 versus 0.326 for the interdisciplinary network. Many more researchers are involved in network interactions that involve no product as an outcome, with many fewer involved in product-based interactions. This, of course, is to be expected, given the complexity and intensity of developing and maintaining transdisciplinary, synergy-based interactions.

What can also be seen from Figures 1 and 2 is that researchers from all disciplines are involved in both types of networks. However, especially with the transdisciplinary network, it can be seen that many of the interactions that result in a research product were not actually occurring across disciplines. For instance, although psychologists (solid blue square) are actively involved in the network (Figure 2), many of their interactions were with one another, rather than across disciplinary boundaries. Chemists (black triangles) engaged with one other in much the same way. Notably, there were few connections between chemists and psychologists, indicated by their relatively opposite positioning in the network map. Finally, the figures show that there is only one isolate (in policy—the grey box marked with +) in the interdisciplinary network, while in the transdisciplinary outcome-based network, there are ten isolates from a broad range of disciplines. Thus, fewer researchers are involved at all in these more complex, outcome-based relationships, which are difficult to build and maintain. Getting more of these isolates involved in transdisciplinary research would seem to be a highly desirable policy goal. Isolates are displayed in the left column of the figures and reflect those individual researchers who are not connected in any way to others within the network. This phenomenon is identified in Table 4 as inclusiveness.

To examine in greater depth the extent to which synergistic outcomes are occurring due to interactions across disciplines (i.e., transdisciplinarity), within-discipline network ties were analyzed versus across-discipline ties for both no outcome and synergistic outcomes. The findings (Table 5) indicate that what is known in the network literature as *homophily*, or the tendency to interact with people having similar backgrounds, is much more prevalent in some disciplines than others, at least regarding research on tobacco harm reduction.

The scores in Table 5 reflect the actual mean number of ties of each type maintained by researchers within each discipline. For instance, for the discipline labeled *medicine*, the mean number of ties to other medicine researchers was 2.13 for relationships where there was no outcome versus 11.2 mean connections (also no outcome) with Tobacco Harm–Reduction Network researchers outside the discipline of medicine (see also the red circles in the two figures). The actual numbers should be compared with the total number of respondents in that discipline. In the case of medicine, there were eight researchers, so the maximum number of ties to others in medicine could be seven (excludes ties to one's self). This compares with the potential number of transdisciplinary ties, which is quite large. Specifically, it is equal to the full size of the Tobacco Harm–Reduction Network (n=67) minus the total

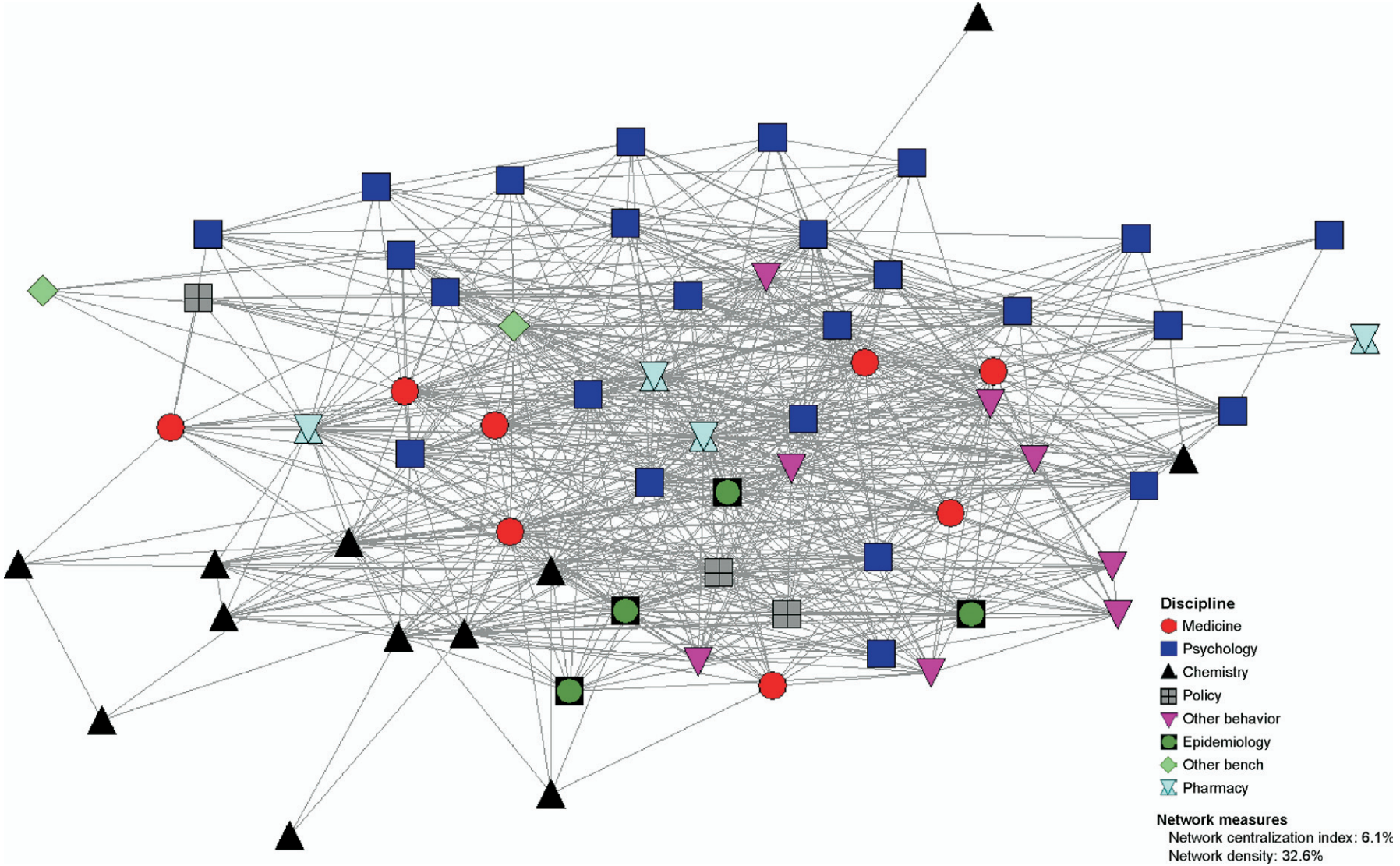

Figure 1. Plot of the Tobacco Harm–Reduction Network by discipline—any type of link, no outcome (interdisciplinarity)

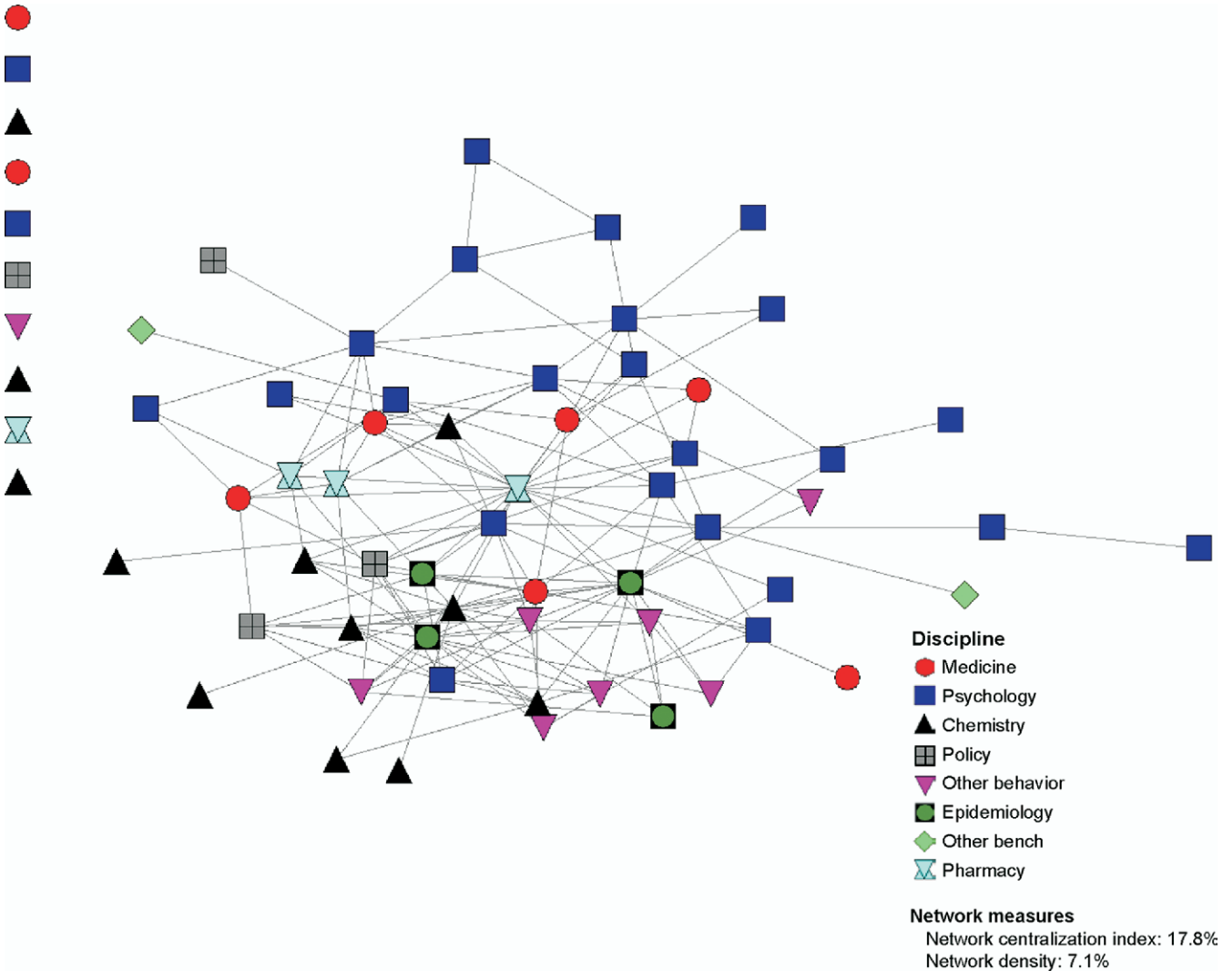

Figure 2. Plot of the Tobacco Harm–Reduction Network by discipline—any type of link, synergistic outcomes (transdisciplinarity)

number of respondents in a particular discipline (eight in medicine).

Not surprisingly, given the large numbers of out-of-discipline respondents, the findings indicate that there were always more ties across disciplines (heterophily) than within disciplines (homophily), regardless of whether or not there was a synergistic outcome. However, for both psychology and chemistry, the two largest groups, cross-disciplinary ties were only slightly greater than ties within the discipline. This suggests that these two groups of researchers tend to favor work among themselves more so than the other disciplinary groups studied. In contrast, for medicine, policy, pharmacology, and epidemiology, working across disciplines was much more commonplace.

Finally, Table 5 shows that although transdisciplinary ties with synergistic outcomes occurred far less frequently than did interdisciplinary ties with no outcomes, when synergistic outcomes did occur, they were far more likely to result from cross-disciplinary, heterophilous relationships than from homophilous ones. This was also true of no-outcome links, but to a much lesser extent. Specifically, the mean relationships per individual for interdisciplinary, no-outcome ties increased from 2.90 to 7.85 when ties were heterophilous, an increase of 271%. In contrast, mean relationships for transdisciplinary synergistic outcome ties increased from 0.34 to 1.82, a jump of 535%. Thus, for researchers seeking synergistic outcomes, there appears to be a substantial benefit to working with others outside their discipline rather than working solely within their discipline.

Conclusion

This is a first effort to examine, using network analytical techniques, how health researchers in tobacco control collaborate, and ultimately, how such collaborative

Table 5. Comparison of homophily versus heterophily: network ties across disciplines

	Interdisciplinary: no outcomes		Transdisciplinary: synergistic outcomes	
Discipline	**Average number of connections to researchers in the same discipline (Homophily)**	**Average number of connections to researchers in other disciplines (Heterophily)**	**Average number of connections to researchers in the same discipline (Homophily)**	**Average number of connections to researchers in other disciplines (Heterophily)**
Medicine (n=8)	2.13	11.20	0.00	2.19
Psychology (n=25)	5.00	5.72	0.84	1.16
Chemistry (n=12)	2.17	4.71	0.50	1.46
Policy (n=4)	0.25	7.38	0.00	2.00
Other behavioral (n=8)	1.88	10.30	0.63	1.69
Epidemiology (n=4)	1.25	12.60	0.50	5.00
Other bench (n=2)	0.50	8.50	0.00	0.50
Pharmacology (n=4)	1.00	14.12	0.25	3.88
Mean/individual	**2.90**	**7.85**	**0.34**	**1.82**

efforts produce transdisciplinary outcomes. The research has important implications for understanding the nature and extent of collaboration that occurs independent of any policy interventions. Based on findings from this initial mapping of the Tobacco Harm–Reduction Network, network researchers can readily see which types of cross-disciplinary collaborative efforts are most likely and which are most (and least) effective, from an outcome perspective. Health policymakers and funders can also draw on this information to provide incentives to researchers to collaborate more effectively, thereby resulting in transdisciplinary outcomes that can help advance the study of tobacco harm reduction.

Network analysis has been utilized in the past to examine relationships among health services organizations,[17,18] but not in previous work about health researchers.[15] The current study has shown that network analysis can be utilized to help understand, in a detailed way, both the extent and nature of collaborative relationships among individuals working within a particular health field, like tobacco control. Future research should build on what has been done in this study, possibly examining in greater detail the outcomes of transdisciplinary collaborations. In addition, longitudinal research efforts would demonstrate the shifting patterns of research from interdisciplinary ties to greater transdisciplinarity. Longitudinal research is especially appropriate for examining transdisciplinary relationships that are newly formed. Such relationships are likely to be cautious at first, then evolve toward greater involvement and more synergistic outcomes as trust builds and knowledge-sharing becomes more intensive.[18,19]

There are clear limitations to the work presented here. For one thing, it is unclear whether or not the results found are generalizable to other groups of health researchers. This study is exploratory and designed primarily to demonstrate the usefulness of network analysis for understanding cross-disciplinary engagements among researchers within a single health research field. Work on researchers in other fields is clearly called for, building on the methods and findings used in this study. Second, the issue of transdisciplinarity must be explored further, using more sophisticated methods. This study has operationalized both the outcomes and cross-disciplinarity of transdisciplinary research. However, it is clear that more detailed measures of outcomes could be assessed, and the issue of what actually constitutes a discipline might be refined. In particular, while the logic of transdisciplinarity is well-accepted, there has been little actual evidence that such relationships result in more or better outcomes than more traditional interdisciplinary work.

Third, the findings reported here are based on self-reports. A conservative approach of requiring confirmation of a tie by both partners was utilized, thereby enhancing the reliability of the interaction data. However, a more conservative approach would have been to examine actual working relationships as well, based on existing publication and grant data. Finally, it would be quite helpful to focus on transdisciplinary research networks in a more narrow way. Specifically, it would be useful to know if transdisciplinary relationships in various health fields occur across a full network of researchers or within more narrowly defined subnetworks, or cliques, consisting of, perhaps, no more than four or five researchers. It seems unreasonable to think that transdisciplinarity in any field should occur across a full network of scores of researchers rather than within more tightly specified clusters.

No financial disclosures were reported by the authors of this paper.

References

1. Best A, Tenkasi R, Trochim W, et al. Systemic transformational change in tobacco control: an overview of the Initiative for the Study and Implementation of Systems (ISIS). In: Casebeer AL, Harrison A, Mark AL, eds.

Innovations in health care: a reality check. New York: Palgrave MacMillan, 2006.
2. Leischow S, Best A, Trochim B, Clark P, Gallagher R, Marcus S. Systems thinking to improve the public's health. Am J Prev Med 2008; 35(2S):S196–S203.
3. Bozeman B, Corely E. Scientists' collaboration strategies: implications for scientific and technical human capital. Res Policy 2004;33:599–616.
4. National Cancer Institute. Greater than the sum: systems thinking in tobacco control. Tobacco Control Monograph No. 18. Bethesda MD: USDHHS, NIH, National Cancer Institute. NIH Pub. No. 06-6085, 2007. dccps.nci.nih.gov/TCRB/monographs/18/index.html.
5. Weick KE. Educational organizations as loosely coupled systems. Adm Sci Q 1976;21:1–19.
6. Kilduff M, Tsai W. Social networks and organizations. London: Sage Press, 2003.
7. Stokols D, Harvey R, Gress J, Fuqua J, Phillips K. In vivo studies of transdisciplinary scientific collaboration: lessons learned and implications for active living research. Am J Prev Med 2005;28(2S2):202–13.
8. Satterfield D, DeBruyn LM. The malignment of metaphor: silos revisited—repositories and sanctuaries for these times. Am J Prev Med 2005; 29:240–1.
9. Committee on Assessing Interactions Among Social, Behavioral, and Genetic Factors in Health. Hernandez LM, Blazer DG, eds. Genes, behavior, and the social environment: moving beyond the nature/nurture debate. Washington DC: The National Academies Press, 2006. www.nap.edu/catalog/11693.html.
10. National Cancer Institute. Transdisciplinary tobacco use research centers. 2004. cancercontrol.cancer.gov/tcrb/tturc/.
11. Stokols D, Fuqua J, Gress J, et al. Evaluating transdisciplinary science. Nicotine Tob Res 2003;5(1S):S21–S39.
12. Monge PR, Contractor NS. Theories of communication networks. New York: Oxford University Press, 2003.
13. Stratton K, Shetty P, Wallace R, Bondurant S. Clearing the smoke: assessing the science base for tobacco harm reduction. Washington DC: National Academies Press, 2001.
14. Rosenfield PL. The potential of transdisciplinary research for sustaining and extending linkages between the health and social sciences. Soc Sci Med 1992;35:1343–57.
15. Stokols D, Hall KL, Taylor BK, Moser RP. The science of team science: overview of the field and introduction to the supplement. Am J Prev Med 2008;35(2S):S77–S89.
16. Scott J. Social network analysis. Thousand Oaks CA. Sage, 2000.
17. Provan KG, Milward HB. A preliminary theory of interorganizational network effectiveness: a comparative study of four community mental health systems. Adm Sci Q 1995;40:1–33.
18. Provan KG, Nakama L, Veazie MA, Teufel-Shone NI, Huddleston C. Building community capacity around chronic disease services through a collaborative interorganizational network. Health Educ Behav 2003;30: 646–62.
19. Ring PS, Van de Ven AH. Developmental processes of cooperative interorganizational relationships. Acad Manage Rev 1994;19:90–118.