Title: **Leadership in Neurology: A Social Network Analysis**

Running Head: Social network analysis of AAN and ANA presidents

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Appendices—2

Abstract

Objective: Two important leadership posts in American neurology are the presidents of the American Academy of Neurology (AAN) and the American Neurological Association (ANA). In this paper, we use social network analysis, based on graph theory, to map the professional ties of presidents in the AAN and ANA since 1948. We examined whether institution ranking was related to being president of either organization, and whether there were core groups of presidents, institutions of employment during presidency, or training programs (residency and fellowship) in the combined and separate AAN and ANA networks.

Methods: Using archival data, we constructed a series of relational tables of the presidents and their affiliations. We used a chi-square analysis to test the relation between institution ranking and organization affiliation. For network data, we used a two-mode analysis with measures of node, dyad, and network characteristics.

Results: 1) ANA presidents were more likely to be employed at ~~prestigious~~ ranked institutions compared to AAN presidents; 2) Ten presidents bridged both organizations, and therefore had the highest centrality in the combined network; 3) Presidents trained in a core group of similar residency and fellowship programs that included Harvard, Columbia, Cornell and Mayo Clinic for AAN presidents, and Harvard, Columbia, Yale, and University College London for ANA presidents; 4) In contrast, during their presidency, AAN and ANA presidents worked at a diffuse set of institutions without a core group.

Interpretations: Training programs are leadership hubs, and should be targeted to develop future presidents and influence trends in the neurology leadership network.

Introduction

There has been little empirical research on leadership in modern neurology. Most accounts are biographies focusing on individual leaders with minimal attention to larger leadership networks (1,2). This paper provides a 60-year analysis of neurology leadership networks using social network analysis. We map and analyze the multi-tiered professional ties among presidents in the two most prominent professional organizations in the field—the ANA and the AAN.

Derived from graph theory, social network analysis is the quantitative study of pairwise relations between people or groups. Whereas traditional epidemiology focuses on attributes of individuals (monadic attributes), network analysis studies the attributes of pairs of individuals (dyadic attributes) and the overall pattern of connections among individuals (network attributes) (3). For instance, researchers used this approach in the Framingham Heart Study to show the spread of obesity (4), the cessation of smoking in groups of interconnected people (5), and the dynamic spread of happiness in collectives (6). In this paper, we use a distinct type of network analysis called two-mode analysis. This is the analysis for two-mode data in which researchers record ties between two sets of entities (e.g., presidents and organizations), and then make interpretations about the entities individually and co-jointly based on the relational data (7).

This study examines the leadership structure in the ANA and AAN by asking the following questions: 1) Are presidents who work at institutions ranked by US News and World Report (USNews) more likely to be presidents of the ANA or the AAN? 2) Is there a core group of

presidents in the network constituting all ANA and AAN presidents? 3) Among AAN and ANA presidents, respectively, is there a core group of institutions in which they are employed at time of Presidency? 4) Among AAN and ANA presidents, respectively, is there a core group of residency and fellowship training programs in which they trained?

Methods

We utilized archival data of ANA and AAN presidents after 1948, the year the AAN was established. We collected these data through historical books on both organizations (1,2), obituaries from neurology journals, online professional biographies, and the 2013 US ~~News and World Report~~ News rankings of best hospitals in Neurology and Neurosurgery (8). For all ANA presidents and some AAN presidents, the ANA archivist verified our results with comparison to each person's curriculum vitae. Notably, we used the academic institutions instead of hospitals to categorize training programs and places of employment (e.g., Harvard included Boston City Hospital and Massachusetts General Hospital) because this allowed for more relevant comparisons. For best viewing, we abbreviated all names to a single word or set of letters (See Appendix 1 and 2 for the legends).

We used USNews rankings out of necessity due to a lack of validated alternative measures. The limitations of this measure include the use of neurosurgery data and mortality statistics; further, there is well-recognized discordance with other hospital quality rating services (9). Nonetheless, by using the rankings as a binary variable (ranked or not ranked), we felt it was reasonable for this analysis.

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We made a series of relational data tables in Excel, such as presidents-by-organizations, presidents-by-institutions of employment, presidents-by-training programs. We then entered these data as 'nodelists' into UCINET, a social network analysis software package (109). We did early data exploration using NetDraw (110), a network visualization and analysis package. We performed traditional, non-network analyses in SPSS.

Research question 1) listed above was a non-network question that we answered using a chi square test of cross tabulations of categorical variables "USNews ranked (yes/no)", "President of AAN (yes/no)", and "President of ANA (yes/no)."

For research questions 2)- 4), we conducted a series of 2-mode network analyses including multidimensional scaling, correspondence mapping, hierarchical clustering, and evaluations of core-periphery structure, structural equivalence, cohesion, density, and centrality. Our approach is described in detail in Borgatti, Everett, and Johnson (75). We made final diagrams using NetDraw.

Results

Presidents' institution of employment and organizational affiliation. In a chi-square test, the independent variable was whether the presidents' institution of employment was ranked or not ranked within the first 50 hospitals by USNews. The dependent variables were "President of ANA" and "President of AAN." There was a significant association between the independent and dependent variable for ANA (Pearson Chi-Square 7.486, p=0.006) and not AAN (Pearson Chi-Square 1.890, p=0.169). These findings suggest that presidents of ANA

were more likely to work at an institution ranked by USNews than at an institution that was not ranked. Presidents of the AAN worked at ranked versus non-ranked institutions no more than can be attributed to chance.

Network analysis of AAN and ANA presidents (Figure 1). Non-metric multidimensional scaling showed 3 groups—presidents of ANA only, presidents of AAN only, and presidents bridging both groups (stress 0.077). Hierarchical clustering using the Girvan-Newman community detection algorithm (124) identified the same three clusters. Centrality analysis gave the highest degree and eigenvector scores to the bridging presidents. Overall, these results suggest that presidents Baker, Carter, Fishman, Foley, Joynt, Pedley, Rose, Rowland, Sahs, and Whisnant were bridging presidents who had the highest centrality, and, as a group, were identified as a cluster and clique in the network. These bridging presidents were employed at USNews-ranked institutions more frequently (90%) than single-organization presidents (63%), but a chi-square test for significance of the difference between these proportions was inconclusive due to inadequate cell distribution.

Network analysis of AAN presidents' institutions (Figure 2a). A network graph of AAN presidents and their institutions of employment reveals a diffuse and unconnected system consisting primarily of president-institution dyads. In such networks, more formal network analysis is unwarranted. Overall, there was no evidence of a prominent core institution.

Network analysis of AAN presidents' training programs (Figure 2b). Non-metric multidimensional scaling showed a grouping of Columbia-trained presidents and Harvard-

trained presidents (stress=0.015). Hierarchical clustering with single link similarities identified 1 large cluster of interconnected nodes, and 7 peripheral clusters unconnected to the large cluster. In a core-periphery analysis, Harvard- and Columbia-associated presidents were considered the core group. In a structural equivalence model, the standout schools were Columbia and Harvard followed by Cornell, Mayo, and Yale. In centrality analysis, the highest betweenness was for Kane, Foley, Fishman, and Swift. The hubs with the highest degree and eigenvector centrality were Harvard, Columbia, Cornell, and Mayo. Overall, these findings suggest that there was a core group of residency and fellowship programs that trained presidents of the AAN, and this group consisted of Columbia, Harvard, Cornell, and Mayo.

Network analysis of ANA presidents' institutions (Figure 3a). A network graph of ANA presidents and their institutions of employment reveals a diffuse and unconnected system consisting primarily of president-institution dyads. Overall, similar to the AAN institutional network, there was no core group of institutions at which ANA presidents were employed at the time of their Presidency.

Network analysis of ANA presidents' training programs (Figure 3b). Non-metric multidimensional scaling showed groupings of Harvard-trained, Columbia-trained, Cornell-trained, and Mayo-trained presidents (stress=0.023). The hierarchical clustering with single link similarities identified 1 large cluster of interconnected nodes and 10 peripheral clusters. In a structural equivalence analysis, the unique schools were Harvard followed by Columbia, and then UCL and Yale together. In centrality analysis, the highest betweenness was for

Aring, Sahs, Drachman, and Wolff. For institutions, degree and eigenvector scores were highest for Harvard, Columbia, Yale, and UCL. Overall, this suggests that there was a core group of residency and fellowship programs that trained presidents of the ANA, and this group consisted of Harvard, Columbia, Yale, and UCL.

Discussion

Our analysis suggests that (a) ANA presidents were more likely to work at ~~prestigious~~ USNews-ranked institutions, (b) a subgroup of presidents bridged both organizations, and (c) presidents trained in a core group of programs, but worked in a diffuse set of institutions.

The first of our findings concurs with the respective membership and goals of each professional society. With a mission of "advancing the goals of academic neurology" (132), the ANA membership ~~is comprised of~~comprises academic neurologists. Such neurologists usually hail from large research institutions that are well recognized on national polls such as USNews. This is in contrast to the AAN which serves academic and community neurologists, the latter of whom may be in small clinics and connected to regional hospitals not ranked in USNews.

Our second finding highlights a group of "bridgers." In network analysis, such individuals are important because they link segmented networks into a larger network and serve as conduits for ideas that might otherwise remain rooted where they originated (143). In networks, such individuals are crucial because they spur innovation and growth (154). Many

of the bridgers identified here were pioneers who catalyzed neurology in other parts of the United States. For instance, Dr. Rose founded the University of California, Los Angeles department of neurology; Dr. Sahs introduced neurology in Iowa; Dr. Fishman initiated a new era of innovation at the University of California, San Francisco. Together, these bridgers were likely particularly influential individuals, and instrumental in the diffusion of ideas.

The finding that presidents trained in a core group of programs but worked in a diffuse set of institutions can be interpreted in multiple ways. The core groups of training programs were leadership hubs for neurologists-in-training, but not necessarily for those employed there. In other words, there was a select period for leadership capital to form. Further, there was partial overlap in the hubs for both organizations (Harvard, Columbia), but also variation (Cornell, Mayo, UCL, Yale).

~~One~~ However, three confounders may bias the core group effect. First, one might suppose that we have uncovered a founder's effect—Harvard and Columbia, as two of the oldest neurology training programs, may have had more opportunity than others to produce presidents simply by virtue of existing the longest. But given that the period of study here was 1948 onwards, the number of training programs available at the start makes this explanation implausible. Another confounder may be the size of the training programs and the number of graduates produced. To analyze this possibility, from 1975 data, we calculated the ratio of active residents from these programs compared to the total residents. We picked this year because the numbers were recorded (2), and it represented a year in the middle of our analysis. We found that excluding UCL and fellowship data (not available), the number

of graduates from the 5 programs were 12.7% of the total. ~~We believe this proportion does not fully explain the core-group effect~~The 5 programs represent about 8.3% of the roughly 60 residency programs for neurology in the U.S. (again excluding fellowships) (16). Such a small discrepancy is unlikely to account for the core-group effect.~~.~~ Lastly, we considered whether among academic neurologists, in particular, there was disproportionate representation from these training programs. Based on cross-sectional data from 2011 (17~~6~~), we calculated that, excluding UCL and fellowships, the number of graduates from the 5 programs was 14.9% of total academic neurologists. Again, ~~we felt this was not large enough in isolation to explain the patterns observed here~~though the disparity is somewhat larger for academic neurologists than for neurology residents in general, it is unlikely that a 7% disparity in these proportions would account for the strong core-group effect uncovered in the present analysis.

The mechanism of this phenomenon deserves further study, because there are a ~~.~~number of possible explanations. Perhaps these training programs are particularly good at producing leaders, or perhaps they attract future leaders by means of prestige. It may be the case that ~~professional organizations~~the~~'~~ selection processes of the AAN and ANA attempt to protect against institutional monopoly, but not training program monopolies. An ~~particularly~~ intriguing hypothesis is that current leaders replicate themselves through like-trained individuals who work in diverse institutions.

The limitations of this analysis are: 1) we only analyzed relationships between presidents and two organizations. There is a wider set of groups and interactions not captured, such as board

certification committees, research groups, funding agencies, and education organizations, which, if included, may better define the relationships among these individuals; 2) the temporal variable is not analyzed, and so any change in network structure is not presented; and 3) although status rankings change slowly, the 2013 ranking data may not correlate to the institutional rank when the president was in office.

This study shows how neurology leadership may be modeled in network terms. Specifically, the findings suggest that leadership development is best targeted at training programs. One way or another, residencies and fellowship are where social networks influence future leadership trends. Some scholars argue that networks build social identity as individuals' self-image is connected to the group's image (1875). This analysis reveals that a social identity of leadership may be centered in training programs—a time and place ripe for developing future leaders.

Appendix 1: Presidents' abbreviations and full names

Adams	Raymond D. Adams	Martin	Joseph B. Martin
Alpers	Bernard J. Alpers	McKhann	Guy M. McKhann
Aring	Charles D. Aring	Merritt	H. Houston Merritt
Asbury	Arthur K. Asbury	Millikan	Clark H. Millikan
BaileyPea	Pearce Bailey	Munsat	Theodore L. Munsat
BaileyPer	Percival Bailey	Nielson	Johannes M. Nielson
Baker	A.B. Baker	O'Leary	James L. O'Leary
Baringer	J. Richard Baringer	Olson	Sandra F. Olson
Bender	M.B. Bender	Pedley	Timothy A. Pedley
Brown	Joe R Brown	Penfield	Wilder G. Penfield
Bucy	Paul C. Bucy	Penn	Audrey S. Penn
Carter	Sidney Carter	Plum	Fred Plum
Cobb	Stanley Cobb	Posner	Jerome B. Posner
Cohen	Maynard M. Cohen	Reese	Hans H. Reese
Daroff	Robert B. Daroff	Richards	Nelson G. Richards
DeJong	Russell DeJong	Richter	Richard B. Richter
Denny-Brown	Derek E. Denny-Brown	Ringel	Steven P. Ringel
Drachman	David A. Drachman	Rose	Augustus S. Rose
Dyck	Peter J. Dyck	Rosenberg	Roger N. Rosenberg
Fabing	Howard D. Fabing	Rowland	Lewis P. Rowland
Fahn	Stanley Fahn	Sahs	Adolph L. Sahs
Feldman	Eva L. Feldman	Scheinberg	Peritz Scheinberg
Fishman	Robert A. Fishman	Schmidt	Richard P. Schmidt
Foley	Joseph M. Foley	Sergay	Stephen M. Sergay
Forster	Francis M. Forster	Sigsbee	Bruce Sigsbee
Gilman	Sid Gilman	Swift	Thomas R. Swift
Glaser	Gilbert H. Glaser	Toole	James F. Toole
Greer	Melvin Greer	Trufant	Samuel A. Trufant
Griffin	John W. Griffin	Viste	Kenneth M. Viste
Griggs	Robert C. Griggs	Walker	A.Earl Walker
Hauser	Stephen L. Hauser	Wechsler	Israel S. Wechsler
Johnson	Richard T. Johnson	Whisnant	Jack P. Whisnant
Joynt	Robert J. Joynt	Whitaker	John N. Whitaker
Kane	Charles A. Kane	Wilson	George Wilson
Katzman	Robert Katzman	Wolff	Harold G. Wolff
Kittredge	Francis I. Kittredge	Woltman	Henry W. Woltman
Klingman	Walter O. Klingman	Wortis	S. Bernard Wortis
Landau	William M. Landau	Yahr	Melvin D. Yahr
Macdonald	Robert L. Macdonald	Young	Anne B. Young
Mackay	Roland P. Mackay	Ziegler	Dewey K. Ziegler

Appendix 2: Institutions' abbreviations and full names

Alabama	University of Alabama at Birmingham	ME2	Private practice in Maine 2
Amsterdam	University of Amsterdam	Miami	University of Miami
Boston	Boston University	Michigan	University of Michigan
Breslau	University of Breslau	Minnesota	University of Minnesota
Brussels	Brussels	Munich	Deutsche Forschungsanstalt
Cambridge	Cambridge University	NINDS	National Institute of Neurological Diseases and Blindness
Case	Case Western Reserve University	Northwestern	Northwestern University
Chicago	University of Chicago	NYU	New York University
Cincinnati	University of Cincinnati	Oxford	Oxford University
Colorado	University of Colorado	Pennsylvania	University of Pennsylvania
Columbia	Columbia University	Rochester	University of Rochester
Cornell	Cornell University	Rush	Rush University
Duke	Duke University	Saskatchewan	University of Saskatchewan
Einstein	Albert Einstein College of Medicine	Sinai	Mount Sinai Hospital
FL	Private practice in Florida	Stanford	Stanford University
Florida	University of Florida	Tufts	Tufts University
Georgetown	Georgetown University	UCL	University College London
Georgia	Medical College of Georgia	UCLA	University of California Los Angeles
Graz	University of Graz	UCSD	University of California San Diego
Hamburg	University of Hamburg	UCSF	University of California San Francisco
Harvard	Harvard Medical School	Umass	University of Massachusetts
Hopkins	Johns Hopkins University	USC	University of Southern California
Illinois	University of Illinois	Utah	University of Utah
InstPasteur	The Institut Pasteur	UTGalveston	University of Texas at Galveston
Iowa	University of Iowa	UTSW	University of Texas Southwestern
Jefferson	Thomas Jefferson University	UWash	University of Washington
Kaiser	Kaiser Permanente	VA	Private practice in Virginia
Kansas	University of Kansas	Vanderbilt	Vanderbilt University
Leningrad	Leningrad	Vienna	University of Vienna
Louisville	University of Louisville	Virginia	University of Virginia
LSU	Louisiana State University	Wake	Wake Forest University
Madrid	Madrid University	Wisconsin	University of Wisconsin

Mayo	Mayo Clinic	WUSTL	Washington University St. Louis
McGill	McGill University	Yale	Yale University
ME1	Private practice in Maine 1		

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Figure Legends

Figure 1: AAN and ANA presidents with bridging presidents in the middle.

Figure 2a: AAN presidents' places of employment at the time of presidency showing a diffuse, unconnected network.

Figure 2b: AAN presidents' training programs showing a core group of programs including Columbia, Harvard, Cornell, and Mayo Clinic.

Figure 3a: ANA presidents' places of employment at the time of presidency showing a diffuse, unconnected network.

Figure 3b: ANA presidents' training programs showing a core group of programs including Harvard, Columbia, Yale, and UCL.