Highlights of Research Findings on Faculty Networks, Climate, and Organizational Commitment Coordinated by Dr. Christina Falci

Background

The purpose of our research is to use Network Theory and Methods to gain insights into how to *retain* and *promote* faculty, especially women and racial minorities. We do this by asking four general categories of research questions. It is often theorized that a lack of inclusion in critical department networks disadvantages underrepresented faculty in STEM. Yet, no research has collected *complete network data* with the goal of describing the network structure of academic departments and the variation in actor network positions across race and gender. It is also unknown how department network structure and actor positions within those networks are associated with climate. We need to understand these basic research questions to aid in tailoring institutional transformations that promote and retain under-represented faculty in STEM.

Prior to the initiation of ADVANCE-Nebraska, Dr. Christina Falci was awarded an Internal UNL Faculty Seed Grant in spring 2008 entitled "Faculty Networks and Departmental Climates in STEM." This internal grant provided the funding to collect baseline survey data from UNL STEM faculty for ADVANCE-Nebraska. The baseline data collection was comprised of two surveys (a network and a climate survey) and archival data from UNL's Institutional Research and Planning (IRP). The network survey contained a network mapping instrument to identify connections among faculty within STEM departments at UNL. The climate survey was administered by the Collaborative on Academic Careers in Higher Education (COACHE). UNL's COACHE survey administration was unique because it surveyed *all* tenured and tenure-track faculty. Prior to UNL's COACHE survey administration only pre-tenure faculty comprised the population for COACHE surveys administered at other institutions. Information from the two surveys and IRP data were merged into a single data file used in our research.

A *social network* is a bounded set of actors and the sampled relational ties among the actors. In our study, a network is confined to full-time tenured or tenure-track faculty who share a tenure home department. Our study included 452 faculty in 26 STEM departments. We measured three different relational ties among faculty within their department: committee co-membership, research exchange and friendship. Specifically, faculty were asked to identify: 1) who they serve together with on service or graduate student committees; 2) who they receive research related help, advice, or equipment from (or who they provide it to); and 3) with whom they engage in non-work related interactions (e.g., spend free time or discuss personal matters).

Network theory predicts that both an actor's location within a network and the overall structure of the network will present opportunities and impose constraints on an actor's behavior and shape the actor's perception of his or her environment. *Network analysis* is a set of statistical methods for systematically identifying connections among actors in a network. The network measures created from network analysis can describe the structure of an entire network or describe the position of actors with a network. There are multiple ways to describe an entire network (e.g., department) and how actors (e.g., faculty) are positioned within it. The research results reported below will show considerable variation in department network structures and actor positions across race and gender that have important implications for climate perceptions.

<u>Research Question #1:</u> What are the characteristics of department network structure?

Department Structure Network Measures

The graphs below exemplify four different ways of describing department network structures. The network structure of a single department may differ across relational ties. For example, research exchange networks may have high levels of clustering, whereas committee co-membership networks may manifest a core-periphery structure. Moreover, the network structure of a single relational tie (e.g., friendship) can vary across departments. For example, one department may have a very dense friendship network, whereas another may manifest a centralized network. Below are descriptions of each network structure and hypotheses about the potential character of social interactions occurring among actors within each structure.

Fig.1: Dense

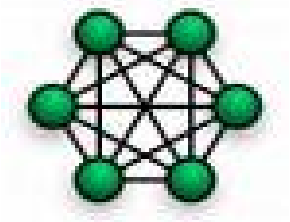


Fig.2: Core-Periphery

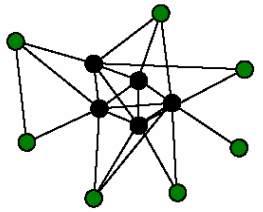


Fig.3: Clustered

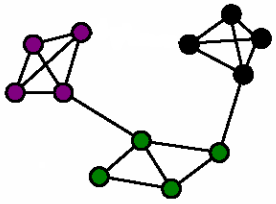
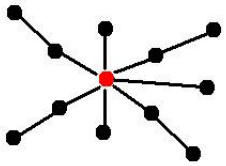


Fig.4: Centralized



Density measures the degree of interconnections among actors within a network by identifying the percentage of all possible ties within a network that are actual ties within the network. This measure ranges from 0 indicating complete fragmentation to 1 where all actors in the network are connected to one another (Fig.1). High density should promote trust and cooperation, and increase the ability to impose informal sanctions on poorly behaving actors. Low levels of density can lead to group instability (i.e., low organizational commitment).

Core-Periphery measures the extent that an inner core set of actors can be identified with the remaining peripheral actors only weakly connected in the network. This measure ranges from zero indicating no sign of a core-periphery structure to one indicating an archetype (Fig.2). Core-Periphery structures can set up a two class system privileging the core group members over peripheral actors. Such a network could lead to feelings of hostility or discrimination among the peripheral actors who may also manifest low organizational commitment.

Clustering measures the degree to which a network is segmented into subgroups. This measure ranges from zero indicating no clustering to one indicating complete clustering (no connections across clusters). Figure 3 illustrates a highly clustered network. Sub-groups within a department represent a set of faculty who interact more frequently with other members of the subgroup than with faculty outside of the subgroup. Clusters can lead to mistrust and/or factions where very different ideas about the department policies and norms might emerge within each subgroup.

Centralization measures the extent to which one actor in the network is more prominent than all other actors in the network. This measure ranges from 0 indicating no centralization to 1 indicating complete centralization where one actor dominates all connections in the network (Fig.4). Central actors can accelerate the diffusion of information if prominent actors are also important actors. At the same time, within highly centralized networks the most central actor can become a single point of failure for the entire network. Within academic departments we might expect higher levels of centralization as the chair of the department is likely to be a prominent network actor.

Descriptive Findings for Department Network Structure

Table 1 reports summary statistics to describe the typical configuration of department network structures and the variability of those configurations across STEM departments. Note: we have not yet conduced core-periphery analyses. Also, only nineteen of the twenty-six departments had adequate response rates to the Network Survey to be included in these Social Network Analyses.

Table 1: Descriptive statistics of department network structure aross three types of relational ties

	Department Network Structure			
Relational Tie	*Mean*	*Standard Deviation*	*Min*	*Max*
Research Exchange				
Density	.40	.18	.15	.71
Clustering	.65	.10	.39	.83
Centralization	.46	.17	.19	.79
Friendship				
Density	.36	.19	.13	.75
Clustering	.65	.13	.40	.87
Centralization	.42	.11	.24	.63
Committee Co-membership				
Density	.43	.16	.24	.89
Clustering	.66	.13	.38	.90
Centralization	.44	.14	.14	.67

N= 19 STEM departments

On average, UNL STEM departments are highly clustered with moderate levels of density and centralization. There is a large degree of variability in department network structures. For example, some departments have very dense connections (> 70% of all possible ties are actual ties), whereas others are quite fragmented (< 20% of all possible ties are actual ties). Similar variability patterns are shown for clustering and centralization. Moreover, the variability in network structure occurs across departments of different size. The network graphs on the next page illustrate this variability across medium sized (~20 faculty) and small sized departments (~10 faculty).

These graphs map various relations among faculty within UNL STEM Departments. They are created using a force directed layout algorithm, also called a spring embedding algorithm. The lines of the network are represented as springs. The force exerted by the spring is proportional to the difference between its current length and its natural length. The basic idea is to minimize the energy of the system by moving the nodes and changing the forces between them. Line lengths are changed and nodes are moved iteratively to minimize the total energy. At each iteration, the node with the highest energy gradient is displaced to make it zero. The iterations terminate when the nodes become stationary and the final layout is obtained.

Figure 5: Density in Committee Co-Membership Networks

The average density of relational tie connections in STEM department networks falls somewhere in between Graphs A and C. Table 1 reports 36% for friendship networks and 43% for committee co-membership networks.

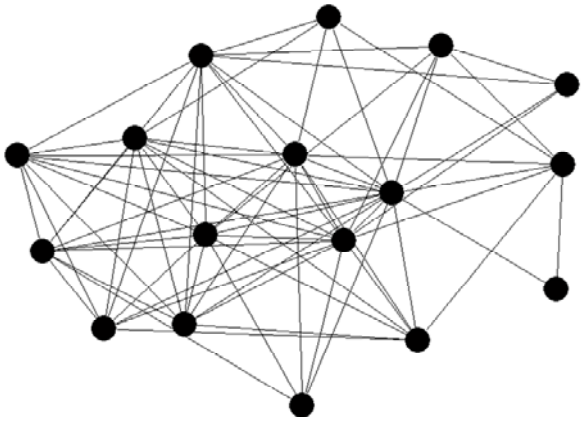
The graphs on this page map **committee co-membership networks** of faculty within four STEM departments.

The two graphs on the left show moderately dense networks for a medium (Graph A) and a small (Graph B) sized network.

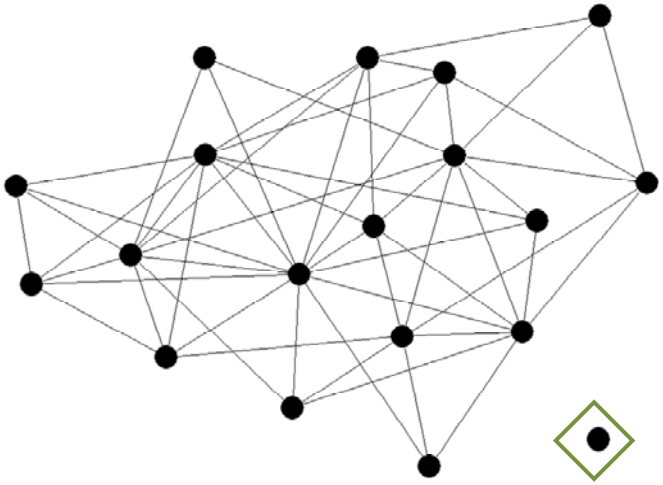
The two graphs on the right show departments with lower levels of density. Consistent with having lower levels of connectivity, Graph C has one isolate and Graph D has two isolates.

An **isolate** is a faculty member who has no relational tie connections to other faculty in their tenure home department. In the these graphs, the faculty member does not serve on committees with any other faculty in their primary department.

Graph A: density = 55%

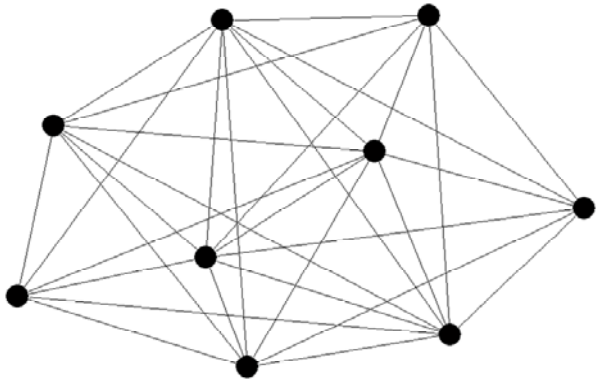


Graph C: density = 32%

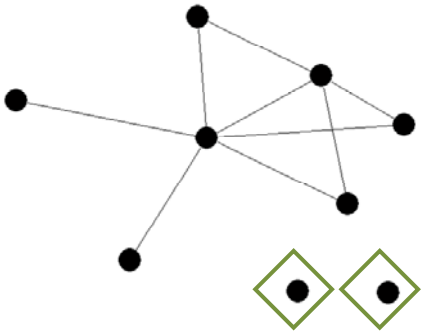


Isolate: an actor with no connections to other actors in the network

Graph B: density = 89%



Graph D: density = 25%



The average centralization of STEM department networks falls somewhere in between Graphs A and C. Table 1 reports .46 as the centralization average in research exchange networks and .42 in friendship networks.

The graphs on this page map the **friendship networks** of faculty within four STEM departments.

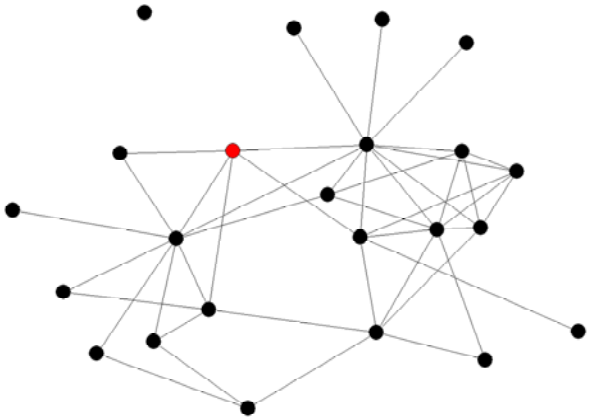
The two graphs on the left side show less centralized networks for a medium (Graph A) and a small (Graph B) sized network.

The two graphs on the right show (Graphs C & D) more centralized department networks.

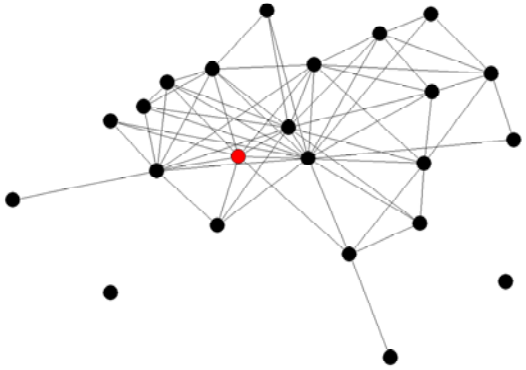
In all graphs, the **red colored dots** identify the chair of each department. On average, department chairs tend to be one of the most central actors in all types of department networks (research exchange, friendship and committee co-membership).

Figure 6: Centralization in Friendship Networks

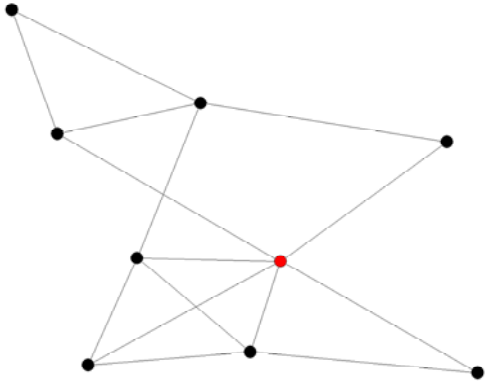
Graph A: centralization = .36



Graph C: centralization = .57



Graph B: centralization = .29



Graph D: centralization = .57

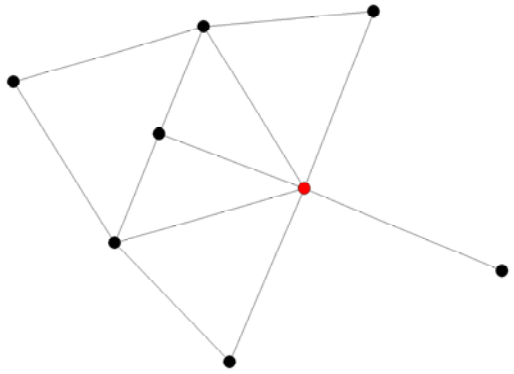


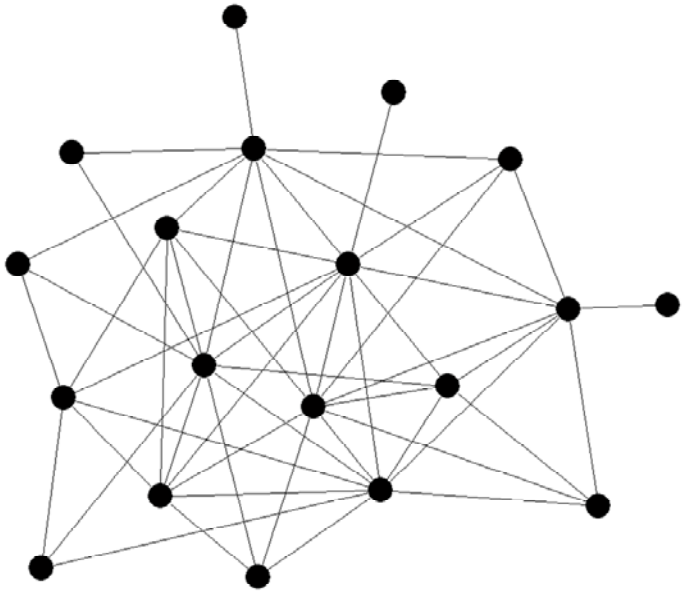
Figure 7: Clustering in Research Exchange Networks

Overall, department networks for research exchange, friendship and committee co-membership ties are highly clustered. The average clustering of STEM department networks falls in between Graphs A and B. Table 1 reports .65 as the average clustering coefficient for research and friendship networks and .66 for committee co-membership networks.

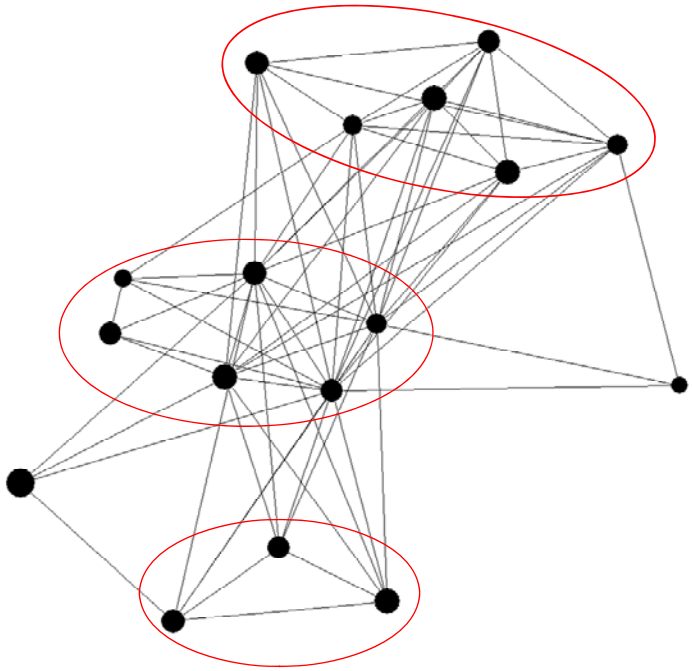
The graphs on this page map the **research exchange** networks within two STEM departments.

Graph A shows moderate clustering and Graph B shows high clustering. The **three red circles** overlaying Graph B highlight the three primary subgroups within this department.

Graph A: clustering = .49



Graph B: clustering = .77



In sum, department network structures tend to show high levels of clustering and moderate levels of density and centralization. The next section of this report explores how measures of department network structure associate with climate.

<u>Research Question #2:</u> How is department network structure associated with climate?

We explored the association between department network structure measures and three measures of academic climate:

- *Department Satisfaction*: a five-item index that sums the answers to survey questions asking faculty to report on their satisfaction with various aspects of their departments climate, such as collegiality and the value other faculty place on their work.
- *Organizational Commitment*: a dichotomous measure where 1 indicates an intention to stay at UNL and 0 no indication of an intention to stay at UNL – this measure excluded faculty who intend to leave because they are approaching retirement
- *Tenure and Promotion Process Clarity*: a five-item index that sums the answers to survey questions asking faculty to identify the degree of clarity in various aspects of the tenure and promotion process within their department, such as the body of scholarship that is evaluated and the performance expectations for scholarship.

We focus on associations with network centralization and clustering, as network density did not predict academic climate. We further focus on these associations for research exchange and friendship networks, as network measures for committee co-membership networks also did not predict academic climate.

Findings for the association between Department Network Structure and Academic Climate

Table 2 shows the bivariate associations between department network structure and academic climate. Several trends are evident in this table. First, centralization in research exchange or friendship networks is associated with more positive perceptions of academic climate (see Figures 8 & 9). Second, clustering in research networks is associated with *only one* climate measure. Departments with high clustering in research exchange networks report more department satisfaction (see Figure 10). Third, clustering in friendship networks is associated with *less* positive climate perceptions in three out of the four measures. Departments with high clustering in friendship networks report lower organizational commitment (see Figure 11) and less clarity in the tenure and promotion processes.

Table 2: Correlations for a Department's Network Structure with Acadmic Climate

	Department Mean Score on Climate Measure			
Department Network Structure	Department Satisfaction	Organizational Commitment	Tenure Process Clarity	Promotion Process Clarity
Centralization	*r*	*r*	*r*	*r*
Research Network	.40	.31	.41	.58
Friendship Network	.49	.37	.31	.46
Clustering				
Research Network	.37	-.14	.02	.02
Friendship Network	-.06	-.41	-.30	-.30

N= 19 Departments

The scatter plots shown in Figures 8 to 11 visually display the associations between network structure and academic climate. These graphs plot a department's network score for the relational tie (horizontal axis) by the department's average for the measure of academic climate (vertical axis). Each graph overlays a trendline across these points and reports the correlation coefficient from Table 2.

Figure 8: Centralization in Friendship Networks on Promotion Process Clarity

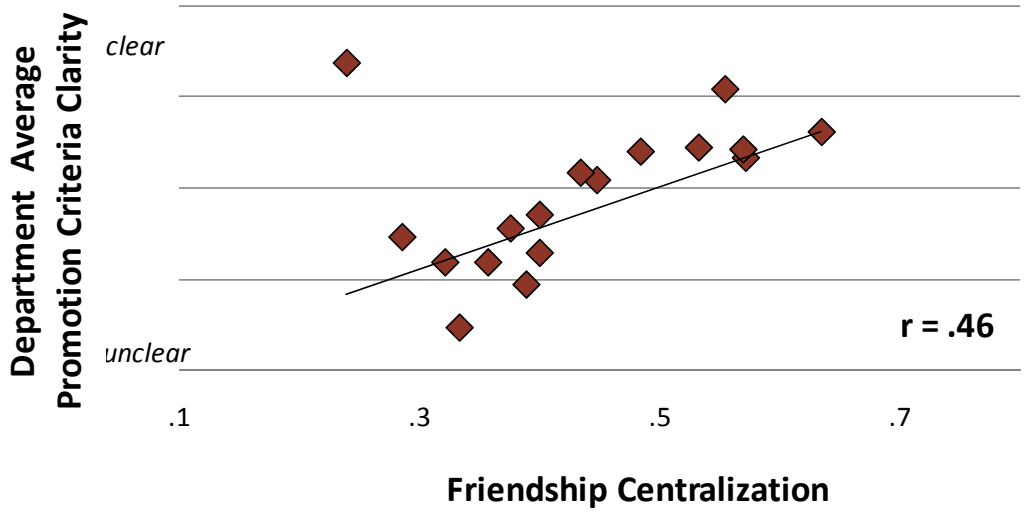
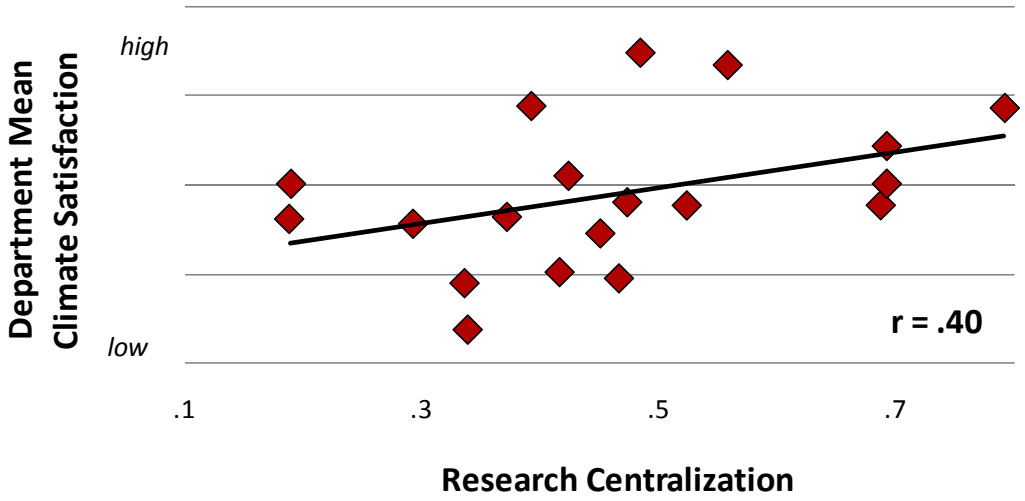


Figure 9: Centralization in Research Networks on Department Climate Satisfaction



Centralization and Climate: Clearly, having one or a few highly prominent faculty members within a department (i.e., high levels of network centralization) is associated with more positive academic climates. As reported earlier, department chairs are likely to be one of the most central actors in department networks.

Figure 10: Clustering in Research Networks on Department Climate Satisfaction

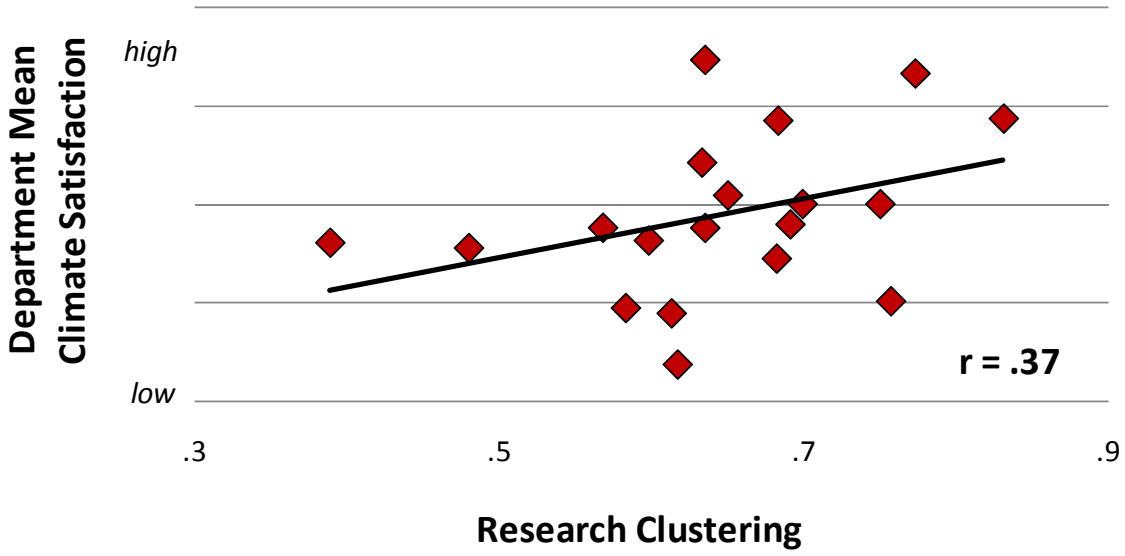
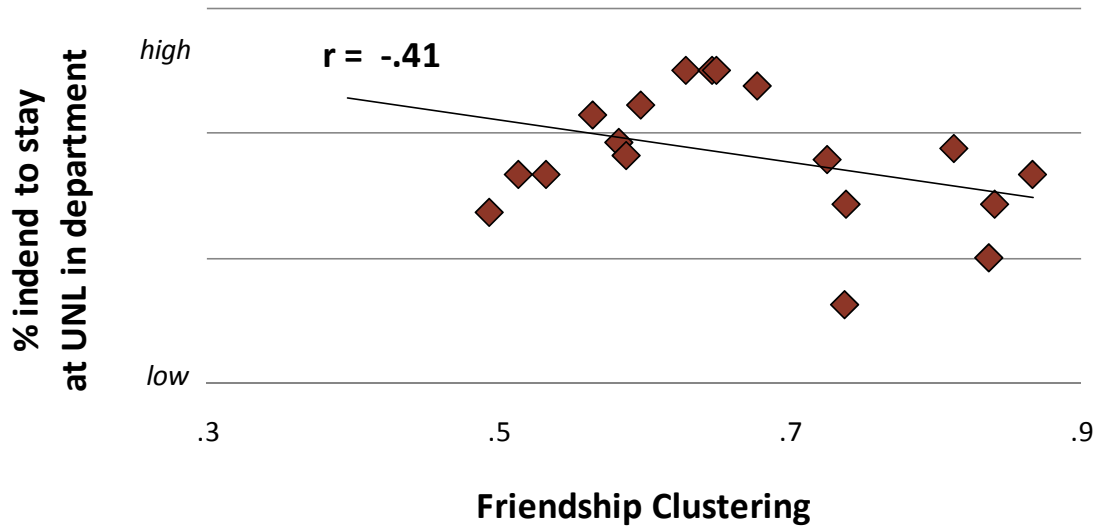


Figure 11: Clustering in Friendship Networks on Organizational Commitment



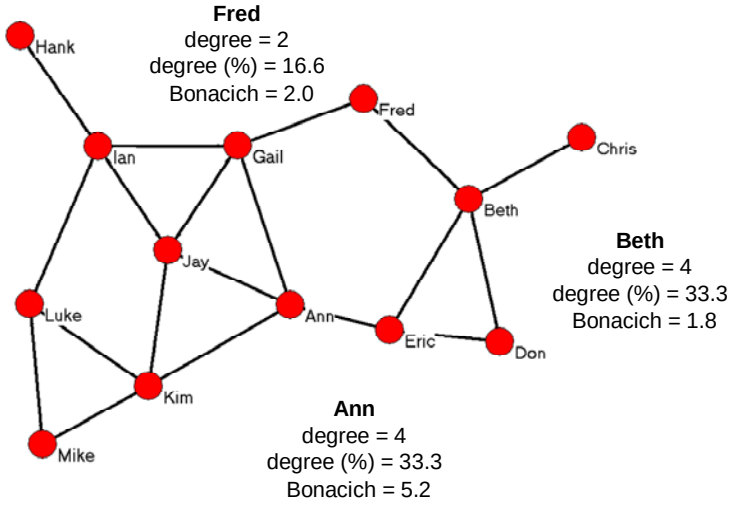
Clustering and Climate: Whether or not network clustering is good for climate depends on the relational tie under investigation. High clustering in friendship networks shows a clear pattern of *less* positive climate perceptions. In contrast, high clustering within research exchange networks is positively associated with one measure of climate. Thus, research clusters within departments may be beneficial as long as friendship cliques are not also forming within the research clusters.

<u>Research Question #3:</u> Do faculty network positions vary by race and gender?

Here we examine variation in actor network positions by race and gender. We focus on one measure of an actor's network position: *centrality*. Network measures of actor centrality identify the most prominent or central actors within a network. The flip side of central actors are the least central or most peripheral actors within the network. The actual meaning of an actor's centrality score will depend on the relational tie network used to calculate it. Within friendship networks, for example, central faculty should have more access to informal departmental knowledge, such as promotion and tenure requirements. Within research exchange networks, central faculty should have the most research support (e.g., collaborators and/or colleagues who review manuscripts, help with research protocols, etc.). It is important to consider multiple relational ties as gender and race differences in actor centrality scores may be more likely to occur within informal (e.g., friendship) networks than formal ones (e.g., committees).

For each relational tie (friendship, research exchange and committee co-membership), we compare two measures of actor centrality. The local centrality measure, *degree centrality*, captures the number of direct connections a faculty member has to other faculty in their department (i.e., their personal network size). In the standardized form, it ranges from 0 to 1 identifying the percentage possible ties in a network that are actual ties. The global centrality measure, *Bonacich Centrality*, captures an actor's reach across the entire department by taking into account the number of connections held by a faculty member's direct ties. It is important to explore both local and global centrality, as personal network size does not necessarily capture the degree of social capital available to an actor. In Figure 12, Ann and Beth both have a personal network size of 4. Ann's connections, however, are to well-connected actors (e.g., Gail, Jay and Kim all have four ties). In contrast, Beth is connected to actors with much smaller personal networks (except for Eric, all direct ties have only two ties). In theory, Ann should have greater social capital than Beth, even though they have similar personal network size.

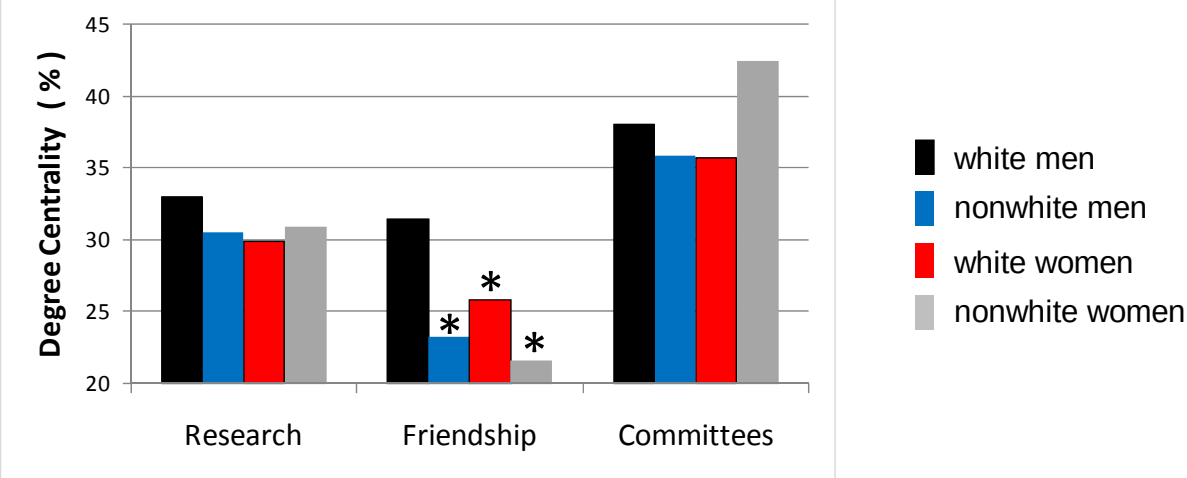
Figure 12: An Example Network to Illustrated Local and Global Actor Centrality



Findings for variation in actor centrality by race and gender

We conducted a series of linear regression analyses with a four-category gender by race variable predicting actor centrality scores - all models control for academic area and faculty rank. The predicted mean actor centrality score for each group (white men, nonwhite men, white women, and nonwhite women) based on the regression results are given in Bar Charts 1and 2.

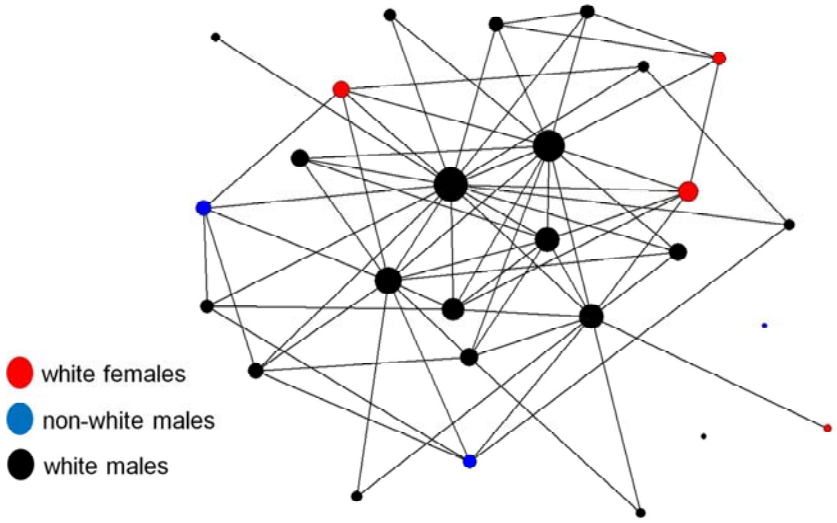
Bar Char 1: Variation in Local Actor Centrality by Race and Gender



∗ significant mean difference from white men (p<.10)

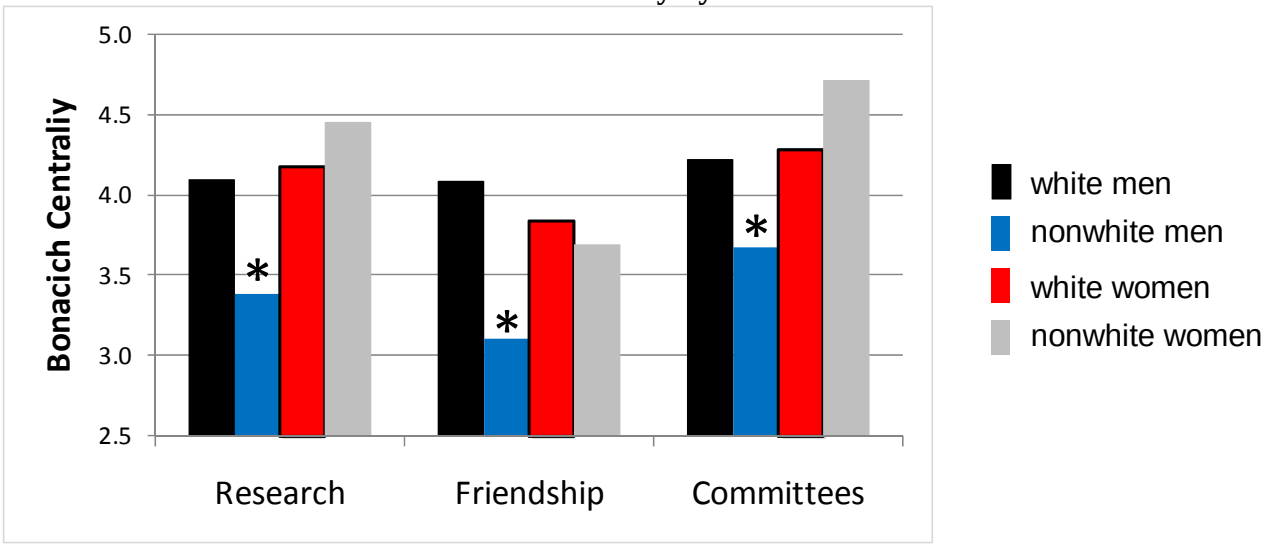
Women and nonwhite men have fewer direct faculty connections (i.e., lower degree centrality) in friendship networks compared to white men. The network map in Figure 13 clearly illustrates this trend for one department in the study. Degree centrality, however, did not vary by gender or race within more formal network ties: research exchange and committee co-membership.

Figure 13: Actor Centrality within a Friendship Network by Race and Gender



node size is proportional to the degree centrality

Bar Char 2: Variation in Global Actor Centrality by Race and Gender

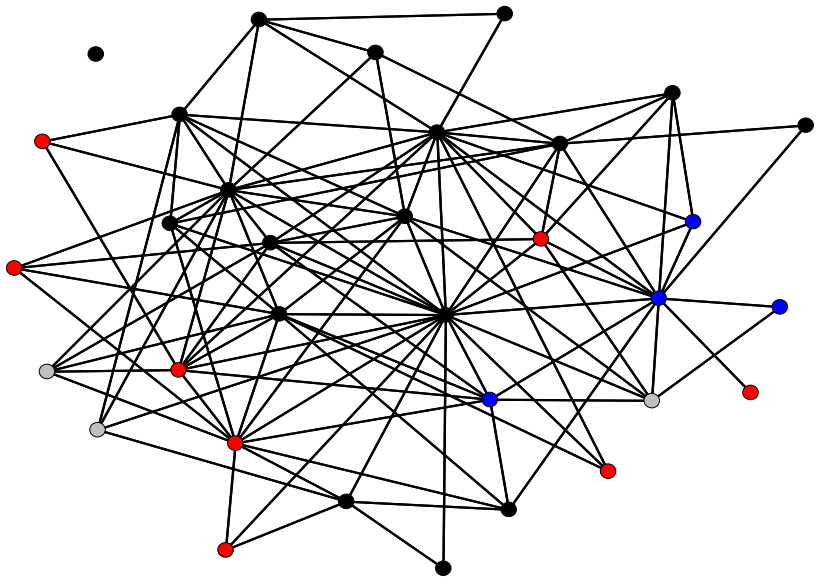


* significant mean difference from white men (p<.10)

In contrast to local centrality, the above bar chart shows that women were not more likely to be globally peripheral actors (i.e., no significant differences in Bonacich centrality) in any networks compared to white men. Thus, women are likely to have connections to the most prominent actors in the department (in most cases the chair). Nonwhite men had lower Bonacich centrality in all department networks (friendship, research exchange, and committee co-membership) compared to white men and women. Thus, nonwhite men are the most globally peripheral actors in all types of network. This occurs because the direct ties held by nonwhite men tended to be to other peripheral faculty members in the department.

Supplemental analyses further revealed that nonwhite men were more likely to have ties to other nonwhite men more often than what we would expect due to chance. Thus, nonwhite men may be forming subgroups within research, friendship and committee networks that often include other nonwhite men. Furthermore, these subgroups groups are likely to be more peripheral in the overall network structure of the department network. This pattern of tie formation is illustrated in Figure 14. Nonwhite men (blue dots) are all grouped in the same area of the network and one locally central nonwhite male connects all other nonwhite males. One nonwhite woman (grey dot) also figures prominently in this subgroup. Furthermore, this sub-grouping of actors is not well embedded in the network overall. The primary racial minority group at UNL is Asian, and the vast majority of nonwhite men at UNL are Asian.

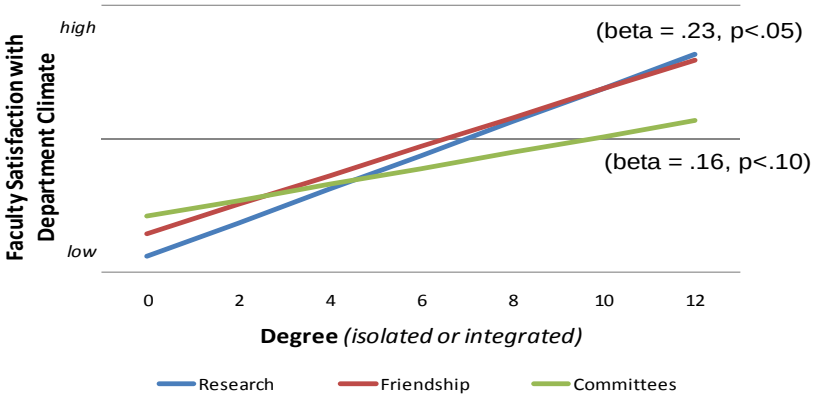
Figure 14: Friendship network by race and gender



Research Question #4: How is a faculty member's network position associated with climate?

The last research question explores the effect of actor centrality on department satisfaction and organizational commitment. We conducted a series of linear regression analyses with actor centrality scores predicting climate– all models control for gender, race, rank and discipline. Line Graphs 1 and 2 visually display those results and report standardized regression coefficients.

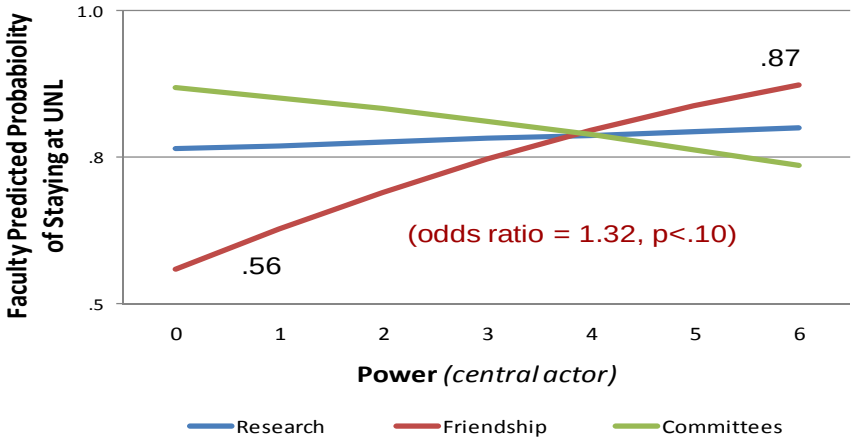
Line Graph 1: The effect of actor centrality on satisfaction with department climate



Faculty with larger research and friendship networks report more satisfaction with department climates than faculty with smaller networks (red and blue lines in Graph #1). Actor centrality in committee co-membership networks showed a similar trend, but the effect is not as strong (green line in Line Graph #1). The same results hold when we use a global measure of actor centrality. In other words, faculty with ties to central actors also report more positive department climates.

Only actor centrality in department *friendship networks* significantly predicts organizational commitment. Faculty with friendship ties to well-connected faculty (i.e., central actors) are more likely to remain at UNL (red line in Graph#2). The predicted probability of intending to staying at the UNL is .85 for globally central actors and .56 for globally peripheral actors. The same results hold when we use a local measure of actor centrality. Faculty with larger sized friendship networks are more likely to intend to stay at UNL than faculty with small friendship networks.

Line Graph 2: The effect of actor centrality on organizational commitment



Research Dissemination

Manuscript under review

Falci, Christina, Julia McQuillan, Megumi Watanabe and Mary-Anne Holmes. "Disconnected in the Ivory Tower: An Exploratory Study of Gender and Race Differences in STEM Faculty Networks." Initial submission under review at *Social Problems*.

Invited Talks

Falci, Christina. "Research and Social Networks of STEM Faculty: Differences by Gender and Race" Syracuse University, Syracuse, NY, April 2011.

Falci, Christina and Megumi Watanabe. "Network Diversity, Climate and Productivity by Gender and Race" NSF-ADVANCE PI Meeting, Alexandria, VA November 2010.

Falci, Christina. "The Effects of a Faculty Member's Location within Department Research, Friendship and Committee Networks on Climate Perceptions." Pacific Sociological Association Annual Meeting, Oakland, CA April 2010.

Conference Presentation

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