Evaluation of Centers and Institutes: Developing a Framework from Complex Systems and Team Science

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How do we evaluate research centers & institutes?

- Gap between research infrastructure goals of large scale centers and institutes and traditional evaluation efforts and reporting requirements.
- Funding shift from individual to collaboratives; evaluation shift?
- Science of team science (SciTS) and complex systems approaches to research provide direction for evaluation methods and outcomes/indictors that address the evaluation needs of C&I.

Evidence for Team Science Trends

- Research papers are increasingly authored by teams (Lauer, 2018; Wuchty et al., 2007)
- Team authored publications are 6.3 times as likely as single author publications to be cited at least 1000 times (Wuchty et al, 2007; Larivière et al., 2015)
- Teams 38% more likely than individuals to generate novel ideas or resources that are adopted by others (Fortunato et al., 2018)
- Team size (Fortunato et al., 2018; Larivière et al., 2015; Wu et al., 2017)
  - Small teams are more likely to generate new ideas; large teams more likely to develop existing ideas
  - Team size increases on average 17% per decade

Trends in Supporting Centers & Institutes

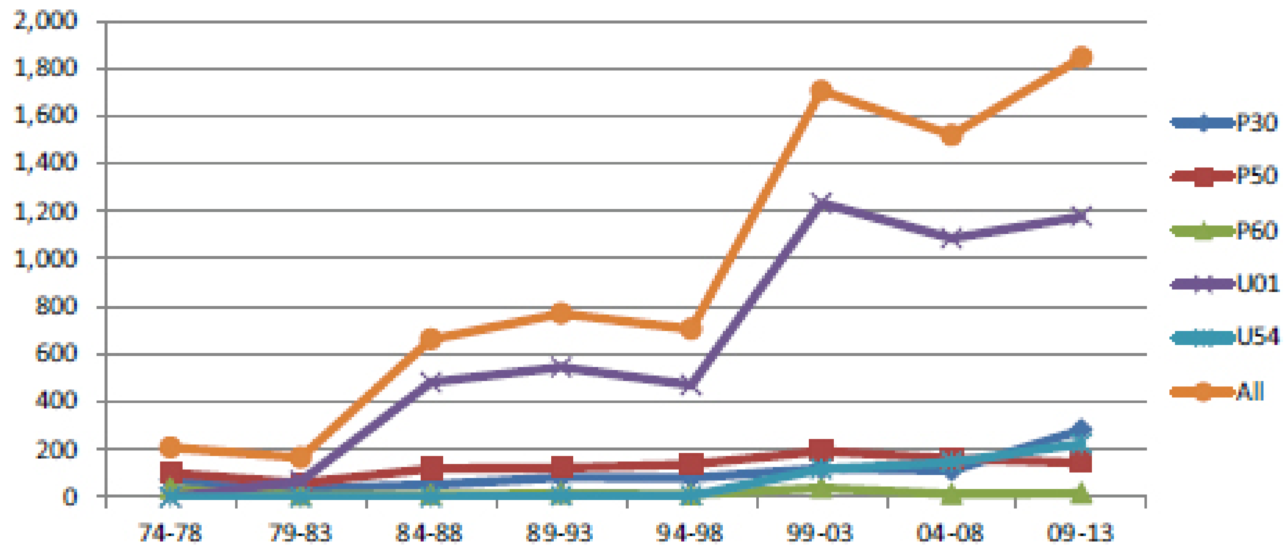
Funding Growth

- Advent of center grants in late 1970s-early 1980s for NIH, NSF, US Department of Energy, etc.
- Consistent increase in funding for centers and institutes across agencies
  - E.g., in 2011, NSF invested $298 million across 7 center programs
- Funding investments into the Science of Team Science (SciTS) to find out how to effectively and efficiently develop team science (Borner et al., 2010)

Examples of Funding Mechanisms

- National Institutes of Health
  - IDeA Programs
  - CTSA
- National Science Foundation
  - EPSCOR
  - Science of Learning Centers
- Institute of Education Sciences
  - Education and Development Centers
- Department of Defense
  - MINERVA

Number of commonly awarded National Institutes of Health Center/Network Grants by mechanism over time.



P30 = Center Core Grants
P50 = Specialized Center
P60 = Comprehensive Center
U01 = Research Project Cooperative Agreement
U54 = Specialized Center Cooperative Agreement
SOURCE: Unpublished data provided by the National Institutes of Health.

Figure Source: National Research Council. 2015. *Enhancing the Effectiveness of Team Science*. Washington, DC: The National Academies Press. https://doi.org/10.17226/19007.

Challenges for Evaluation of C&I

- Typical approaches applied in evaluation of C&I
  - Focus on the individual as the sole or primary unit of analyses
  - Measure time in terms of individual expectations for success and career trajectory
  - Apply statistical methods that may not account for clustering or nesting
- Common characteristics of Centers and Institutes
  - Specialized and context bound
  - Relatively small sample or nested samples
  - Goals are often multilevel (e.g, infrastructure, human capital)
  - Interest in outcomes at different units of analyses

Centers & Institutes are Complex Systems

- Centers and institutes are complex systems (Borner et al., 2010). They are characterized by behavior that is:
  - Complex – behavior at macro levels of the system that is not reducible and adaptive (Gell-Mann & Lloyd, 1996; Mitchell, 2009).
  - Dynamic – microprocesses amongst systems components that change over time (Koopmans, 2015)
  - Emergent - dynamic microinteractions of system components give rise to novel macrosystem behavior (Holland, 2006)
- Range in complexity based on tasks, goals, size, proximity, and diversity (Fiore, 2015)

SciTS Perspective on Evaluation

- Evaluation Approaches must be multi-level and mixed-methods to adequately represent the ecology of team science (Fiore, 2015)
  - Macro-level: teams at the population level with a focus on growth and patterns of collaboration
  - Meso-level: focus on the group level including interaction patterns amogst group members
  - Micro-level: focus on individuals within teams
- Methods and approaches are required that support dynamic relationships in the team, specifically relationships amongst scientists and knowledge over time bound by context and discipline (Borner et al. 2010)

Team Science Objectives to Guide the Evaluation of C&I

1. Collaborative scholarly productivity
   - Does the relational structure of the collaborative display evidence of self-organization?
2. Planned and emergent research infrastructure
   - Does collaboration generated by the C&I lead to scientific advancement?
3. Shared vision and culture of research
   - Is there evidence that members of the collaborative have adopted similar values and goals around research?
4. Mentoring and advancement of scientists
   - Are funded investigators forming productive relationships with other scholars and senior personnel that lead to scholarly productivity?
5. Leveraging of resources to promote growth
   - How are grant resources being used to develop productive collaborative partnerships among members to promote research infrastructure, scholarly productivity, shared vision, and advancement of investigators?

Methods and Analyses

- Methods
  - Primarily mixed-methods
- Data Sources
  - Survey census data
  - Surveys and interviews (e.g., mentorship, work engagement)
  - Bibliometric and productivity data
- Analytic Approaches
  - Content analyses
  - Descriptive stats and pre-post comparisons
  - Social Network Analyses

Social Network Approaches in Evaluation

- The underlying structure of a collaborative group is a network (Mitchell, 2009). Actors within a network can interact in dynamic ways, and the outcomes are often emergent shared goals and products (Hilpert & Marchand, 2017).
- Analysis of Teams using Social Network Analysis
  - Document information flow
  - Brokers of information
  - Bottle necks in communication
  - Formation of subgroups

Questions that Complement Traditional Evaluation

- Big Question about Collaborative Impact
  - How do these network structures develop, spread, and exceed the initial boundaries of the founding collaborative group?
- Examples of Specific Network Questions
  - Who forms ties with whom? (collaboration patterns)
  - How large is a collaboration network and are there smaller teams within the C or I? Who links the network with other networks?
  - How dense is the network?
  - What are the characteristics of close collaborators?
  - How does production change over time?
  - How does the network grow over time?
  - Who brokers relationships in a network (e.g., mentors)?

Welch, Feeney & Siciliano, 2016

Example Questions & Methods

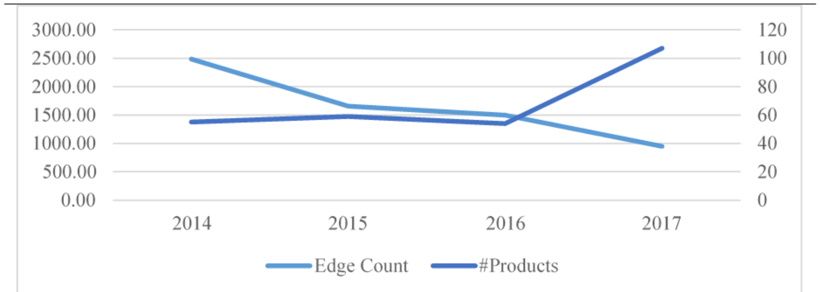
- Questions
  - How do COBRE relevant author relationships change as the Center matures?
  - How do Center self-organize around cores and projects?
- Methods
  - Data collected from CVs annually with a focus on publications and presentations – 12 key personnel
  - Data collected from annual collaborative engagement survey focused on the nature of collaboration – all members

Scholarly Products

Table 1

Descriptive publication network characteristics by CNTN year

	2014	2015	2016	2017
Edge Count	2485.00	1655.00	1497.00	949.00
Transitivity	0.60	0.59	0.70	0.59
Density	0.01	0.01	0.01	0.00
#Connected Nodes	290/43%	260/40%	193/29%	196/30%
#Products	55	59	54	107



Note: Data from 2014 serves as a baseline year, before the CNTN was funded. Node count = 672 for all years. Primary axis scale = Edge Count. Secondary axis scale = Products. Products include publications, presentations, and abstracts.

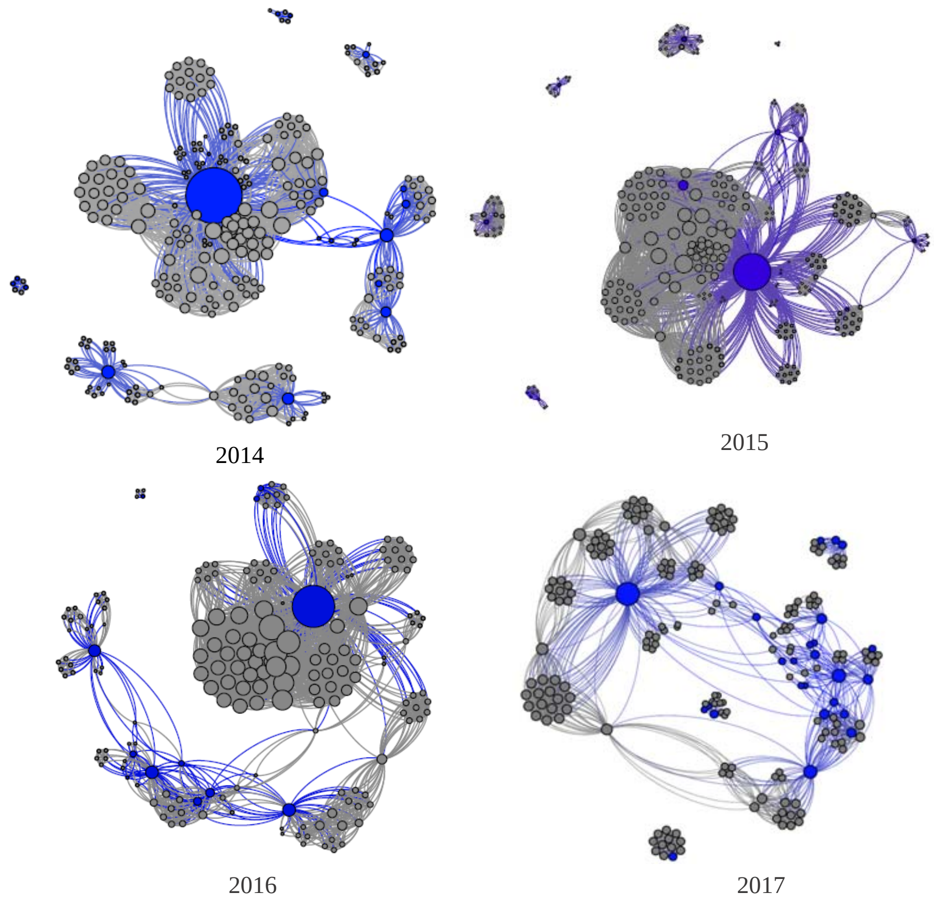


Figure 1. *CNTN member publication network layouts for all study years.*
Note. Isolated nodes were removed from the analysis and visualizations. Blue nodes = CNTN authors; Gray nodes = non-CNTN authors.
Modularity (2014 = .609; 2015 = .748; 2016 = .573; 2017 = .738)
Average Degree (2014 = 34.6; 2015 = 24.7; 2016 = 31.0; 2017 = 19.35);
Connected Components (2014 = 6; 2015 = 5; 2016 = 2; 2017 = 4)

Marchand, G.C, Hilpert, J.C., †Bragg, K.M., & Cummings, J. (2018). Network-based assessment of collaborative research in neuroscience. *Alzheimer's and Dementia: Translational Research & Clinical Interventions.* https://doi.org/10.1016/j.trci.2018.08.006

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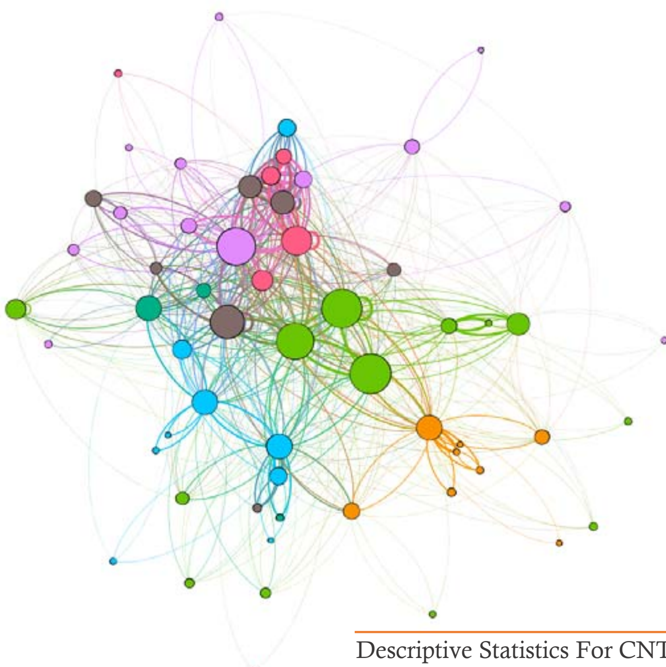
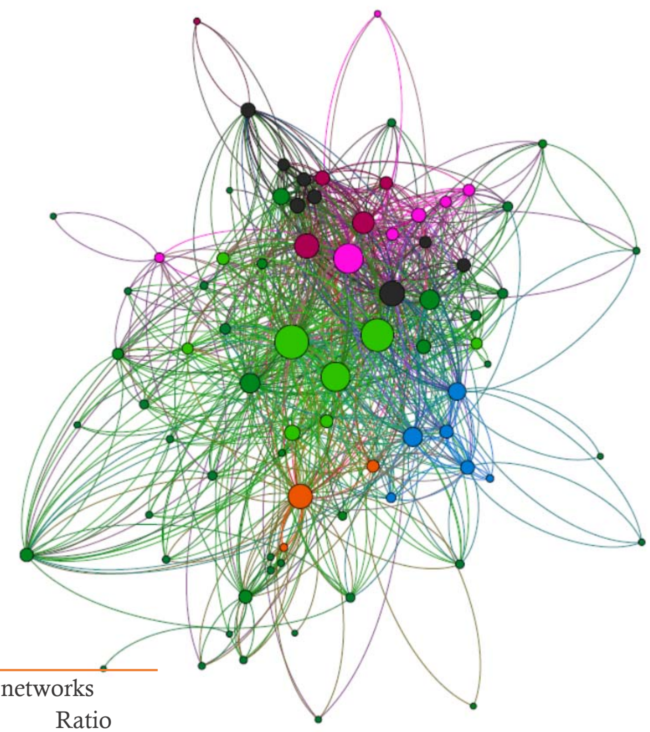
Project 1
Administrative Core
Data Core
Project 3
Clinical Core
Project 2
Not assigned

Network Growth

2017



2018



Descriptive Statistics For CNTN collaborative networks

Core	2017	2018	Ratio
Nodes	59.00	79.00	1.34
Edge Count	680.00	990.00	1.46
Dyad Count	3422.00	6162.00	1.80

Note. Ratio shows increase in CNTN network size.

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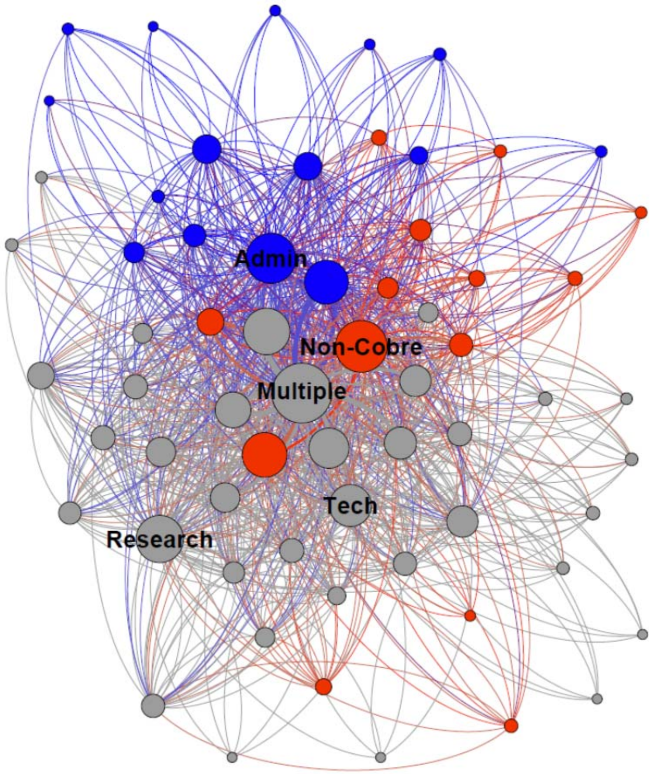
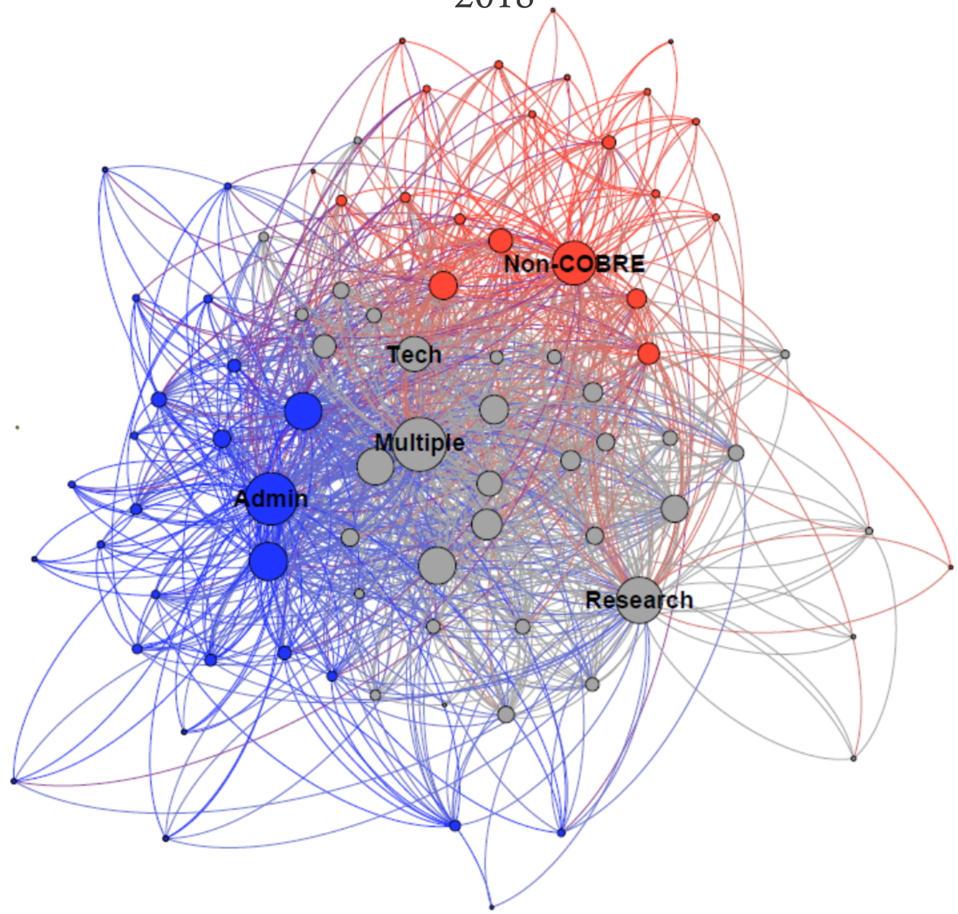
2017



2018



Betweenness Values For CNTN cores

Core	2017	2018	Ratio
Research	258.59	993.38	3.84
Admin	330.20	1153.33	3.49
Non-COBRE	346.92	835.05	2.41
Multiple	637.38	1152.24	1.81
Tech	191.92	294.19	1.53

Note. Ratio shows increase in CNTN core centrality to network.

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Evaluation Impacts: The Bigger Picture

- What is the role of infrastructure in human capital development for effective team science?
  - How are **research support networks** and **research production networks** associated?
  - How "portable" are research support networks?
  - How can transitioning scientists most quickly and productively access these networks?
- Are **individuals with shared or different characteristics** more likely to form productive collaborations within the context of a C or I?
  - Skills, Attitudes, Demographics, Location
  - Who brokers connections and how can these be fostered? (not always obvious)

Team and Relevant Projects

CREA Team

- Dr. Tiberio Garza, Associate Director
- Dr. Kristine Bragg – postdoctoral associate
- Monica Johnson – research associate
- Elizabeth Hofschulte – graduate assistant
- Christie Gardner – graduate assistant

C&I Projects

- *Mountain West IDeA Clinical and Translational Research Infrastructure Network (CTR-IN), Years 6-10,* National Institute of General Medical Sciences , PI: Dr. Parvesh Kumar #1U54GM104944
- *Center for Biomedical Research Excellence (COBRE), Center for Neurodegeneration and Translational Neuroscience (CNTN),* National Institute of General Medical Sciences, PI: Dr. Jeffrey Cummings, Cleveland Clinic Luo Ruvo Center for Brain Health , P20GM109025
- *Personalized Medicine Center of Biomedical Research Excellence,* National Institute of General Medical Sciences, PI: Dr. Martin Schiller, #1P20GM121325-01A1
- *Center for Childhood Obesity Prevention ,* National Institute of General Medical Sciences, PI: Dr. Judith Weber, # P20GM109096

Thank you!

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