Connecting the dots: Using social network analysis to map and facilitate scientific collaborations in research universities

Raffaele Vacca – Department of Sociology and Criminology & Law, University of Florida

Valerio Leone Sciabolazza – Department of Business and Economics, University of Naples Parthenope

Christopher McCarty – Department of Anthropology and Bureau of Economic & Business Research, University of Florida

Over the past several years a wide consensus has developed on the notion that many scientific discoveries are made in teams. A growing body of evidence shows that high-impact scientific work and groundbreaking inventions often originate in large and interdisciplinary teams. Academic institutions, government agencies and research centers in the public and private sector, now increasingly recognize that many of the problems we face today, from climate change to international migration to the translation of science into technology, are complex and need to be addressed by teams that span different disciplines and organizations. This realization has generated a new widespread emphasis on "team science", as well as new research fields, such as the "science of team science" and the "science of science", which study how team science happens and is sustained over time.

In medicine and the health sciences, *clinical and translational research* is one of the fields in which the importance of teams and interdisciplinarity has been most strongly recognized in recent years. As defined by the US National Institutes of Health (NIH), clinical and translational research has the goal of turning "observations in the laboratory, clinic and community into interventions that improve the health of individuals and the public — from diagnostics and therapeutics to medical procedures and behavioral changes". This is often characterized as the goal of getting scientific research "from bench to bedside". The breadth and complexity of the translational process involves a combination of research methods and substantive focuses from a large variety of fields, including the biomedical sciences, clinical research, social sciences, computer science, economics, and business administration. As a consequence, understanding how to promote, assemble and sustain multi- and inter-disciplinary teams is a top priority in clinical and translational science institutions. In a recent funding opportunity announcement for Clinical and Translational Science Awards (CTSAs), the NIH National Center for Advancing Translational Sciences urged applicants to describe how they would achieve the goals of "increased incentives for teamwork, facilitation of the assembly of multi-disciplinary translational teams, promotion of collaborative efforts, and increased knowledge and awareness of what works best in team science.".

In recent publications,[1] we have studied the problem of how to assemble and sustain interdisciplinary teams by drawing on the notion of *social network interventions* and exploring its application to team science. Social Network Analysis is a set of methods and theories that study social interactions, social relationships, and the way they affect individual and collective outcomes. A social network may represent friendships in a high school, professional collaborations at a research university, or sexual contacts in a population during the outbreak of an infectious epidemic. The collaborations among scientists in a team, as recorded by co-authored publications or research grants, form a social network too (Figure 1). These collaborations concatenate together to create broader network structures: Figure 2, for example, shows the whole social network of collaborations among scientists on publications and grants at the University of Florida in one particular year.

<< Figure 1 about here >>

<< Figure 2 about here >>

An important subfield in social network analysis is the implementation and study of network interventions: programs that use social network data and analysis to promote positive behavioral change in a population or to achieve desirable outcomes in an organization. Network interventions have traditionally been used in public health to block contagions or spread healthy behaviors such as contraceptive use or vaccination, and in organizational and business studies to improve the economic performance of organizations. In a novel type of application at the University of Florida Clinical and Translational Science Institute (UF CTSI), we have recently explored the use of network interventions to promote professional collaboration and increase scientific productivity at a research university.

Network interventions can be used to facilitate academic collaboration by creating new links in a university's network; and to do so in a way that enhances certain structural properties of that network, such as the creation of bridges that span "structural holes" in the university. A university collaboration network is similar to a brain: new connections create new ways the whole system thinks and operates. In traditional research funding programs, government or private funders issue requests for applications in which a set of research topics and goals is presented, and scientists are asked to choose their own collaborators and propose a project with them on those topics. In network intervention terms this is called *induction*. When induction happens, investigators tend to pick research partners in their professional comfort zone, reproducing existing connections in the network by working with previous or otherwise close collaborators (for example, with collaborators of their collaborators). Figure 3A shows the collaborations generated by a traditional, induction-based pilot funding program at the University of Florida: these collaborations mostly took place within the same department or within existing subgroups in the network. While these collaborations are natural and important for scientific progress, they rarely span structural holes and bridge distant, disconnected areas of a university network, combining ideas from different disciplines and scientific perspectives. However, spanning structural holes in social networks is known to produce new ideas and groundbreaking scientific innovation. A different type of network intervention, called *alteration*, can be conducted at a research university

1 Vacca, R., McCarty, C., Conlon, M., & Nelson, D. R. (2015). Designing a CTSA-Based Social Network Intervention to Foster Cross-Disciplinary Team Science. Clinical and Translational Science, 8(4), 281–289.
Leone Sciabolazza, V., Vacca, R., Okraku, T. K., & McCarty, C. (2017). Detecting and analyzing research communities in longitudinal scientific networks. PLOS ONE, 12(8), e0182516.
Leone Sciabolazza, V., Vacca, R., & McCarty, C. (Under review). Connecting the dots: Implementing and evaluating a network intervention to foster scientific collaboration and productivity. Social Networks.

to create new links that cross scientific comfort zones and span structural holes, something more similar to Figure 3B.

<< Figure 3 about here >>

Our intervention program at the UF CTSI began by mapping the UF scientific collaboration network based on publication co-authorship and co-participation in research grants. This network was used to identify research communities at the University of Florida, and then to conduct alteration by adding "missing links" that would connect researchers in specific locations of these communities. In a first iteration of the program, we applied different structural criteria to identify dyads and triads of unconnected researchers, whose collaboration would have enhanced desirable network properties of individuals or groups. We then launched an online survey that introduced the unconnected, potential collaborators to each other via their webpages. Team science requires not just connecting people in teams, but also understanding when and how these teams work.

Both environmental and individual factors may facilitate or hinder team effectiveness. To explore these factors, our survey investigated the potential collaborators' attitudes and views toward working with each other, and potential barriers and incentives to starting a collaboration.

In a second iteration of the program, the network was used to detect the different research communities that exist at the University of Florida. In a randomized trial design, we then paired comparable treatment and control research communities. In treatment communities we identified pairs of unconnected scientists whose new collaboration would maximally enhance the "cohesion" of their community according to specific network measures. These pairs were then offered an incentive (professional development funding) to actually start a collaboration by submitting a pilot research proposal to the UF CTSI. The resulting proposals were peer-reviewed and three of them were funded by the UF CTSI for $25,000 each.

Studies of science and research policy increasingly register a tension between the societal need to support novel and interdisciplinary combinations of ideas to address complex problems, on the one hand; and the need of individual scientists to collaborate with professionally close and familiar colleagues, on the other hand. In addition, while innovative solutions to problems often emerge from the combination of **interdisciplinary** approaches, **intradisciplinary** focus is also necessary to maintain disciplines to cross. How to reconcile these tensions remains an open issue and a central challenge for the future development of science. The experimental network intervention conducted at the University of Florida will hopefully suggest new ways to address these problems and to design more effective research policy at the university, national, and international level.

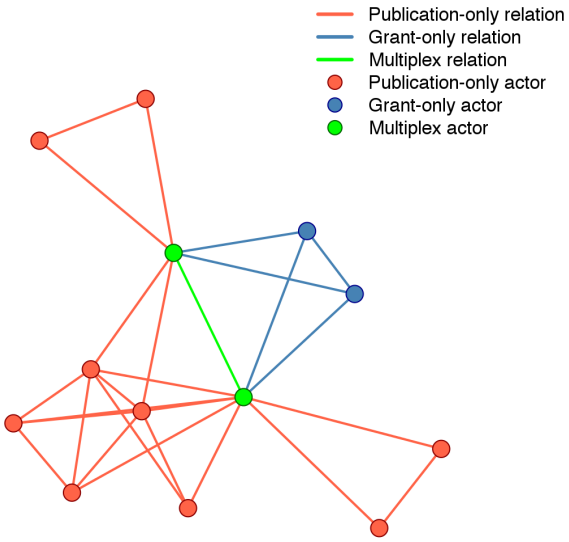

Figure 1. Collaborations between scientists on publications and grants can be represented as a social network. In this network visualization, dots (nodes) are scientists, and lines (edges) are collaborations between scientists on the same publications or grants in a given year.

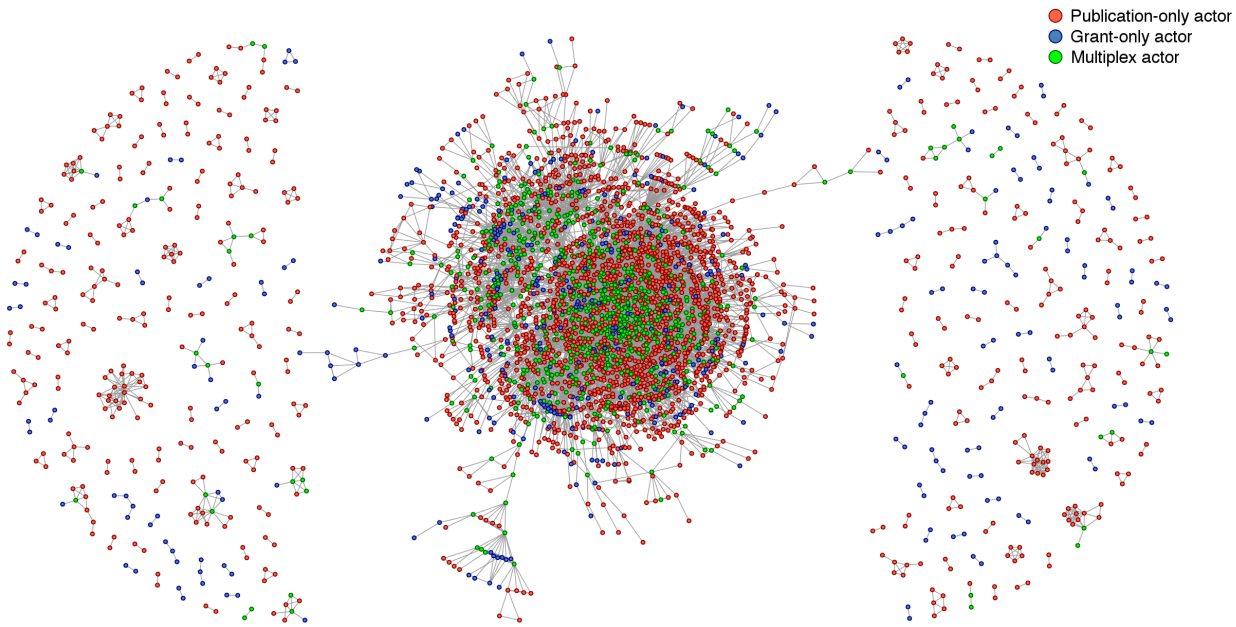

Figure 2. The whole network of collaborations on publications and grants among University of Florida scientists in a year.

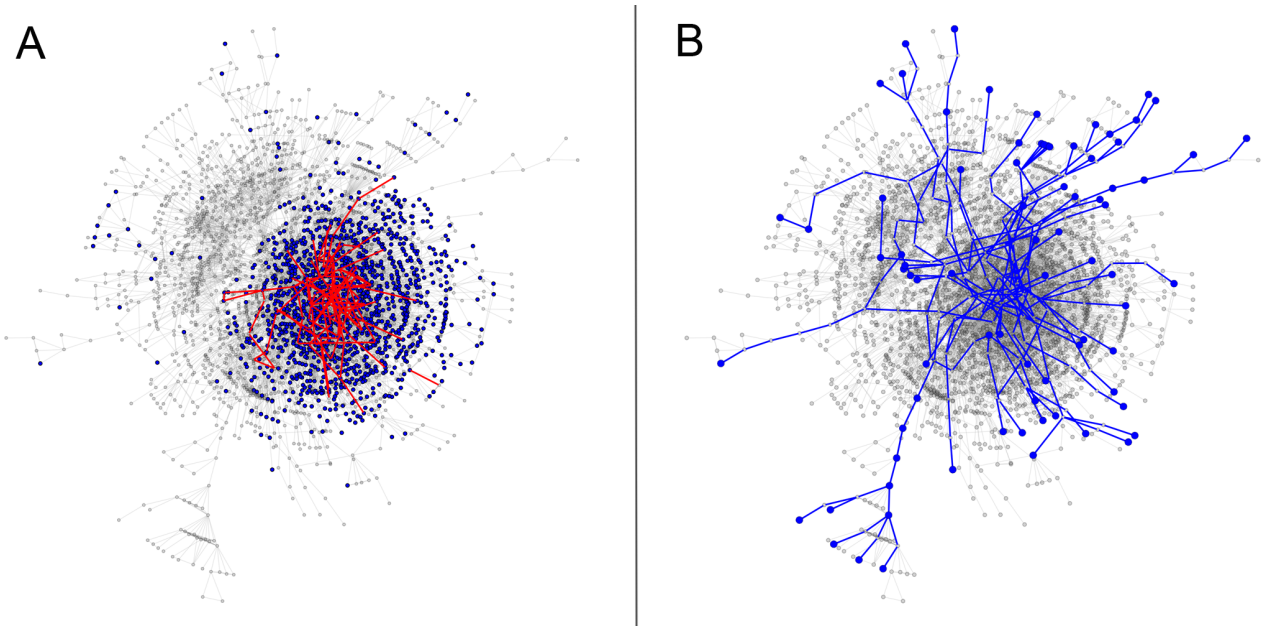

Figure 3. Research funding via induction (A) versus alteration (B). Panel A shows collaborations activated by a traditional, induction-based funding program: red paths are the shortest network paths between scientists whose collaboration was funded by the traditional program (blue nodes are scientists in health science departments). Panel B shows potential collaborations targeted by alteration: the blue paths are the shortest network paths between scientists targeted by one of the UF CTSI alteration programs.