The influence of group size and heterogeneity on the productivity of research teams

Jonathon Cummings
Duke University

Sara Kiesler, Reza Zadeh, and
Aruna Balakrishnan
Carnegie Mellon University

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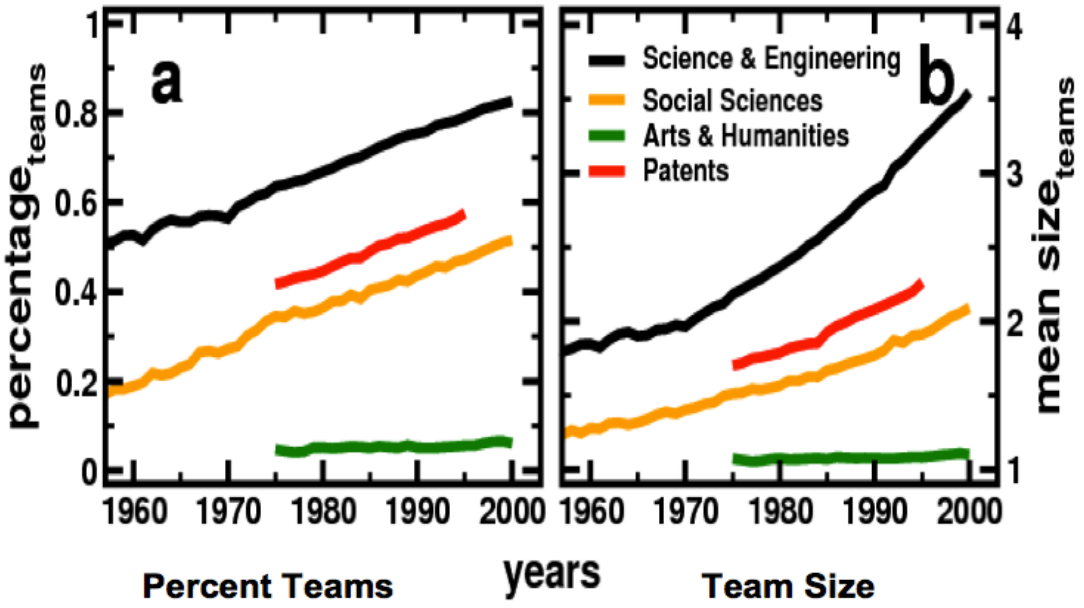
Scientific Collaboration

- Working together of researchers to achieve the common goal of producing new scientific knowledge (Katz & Martin, 1997)

- NSF ITR Examples
  - "Project ZebraNet" (position-aware power-aware wireless computing for wildlife tracking) facilitated remote tracking of wildlife over large distances by biologists
  - "Simulation-Based Medical Planning for Cardiovascular Disease" constructed computational models for physicians to predict differential changes in blood flow
  - "Integrating Smart Sensing, Data Mining, Pervasive Networking, and Community Computing" developed tools for security personnel to monitor and respond to disasters

Changing Landscape in Science

- Interdisciplinary research teams have become more prevalent (Metzger & Zare, 1999)
- Multi-institution research teams have become more prevalent (Corley, Boardman, & Bozeman, 2006)
- Research teams increasingly dominate the production of knowledge (Wuchty, Jones, & Uzzi, 2007)



Research Question

- How are group heterogeneity (multiple disciplines or multiple institutions) and group size related to research team productivity?

Team Heterogeneity and Size

- Heterogeneity (Mannix & Neale, 2005; Williams & O'Reilly, 1998)
  - Interdisciplinary - disciplinary differences in language and norms about the research process (e.g., Palmer, 1999)
  - Multi-institution - geographic dispersion and cultural differences across institutions (e.g., Herbsleb, Mockus, Finholt, & Grinter, 2000; Olson & Olson, 2000)

- Size (Steiner, 1972)
  - more members provide more resources available to meet task demands (e.g., publishing more papers)

Group Identification

- People define themselves in terms of their meaningful social groups; they tend to view in-group members more favorably than out-group members (Abrams & Hogg, 1990; Brewer, 1991; Tajfel & Turner, 1986)
- Group heterogeneity creates barriers to identification with the group as a whole because members do not feel psychologically connected to those who are different (O'Reilly, Caldwell, & Barnett, 1989; Tsui, Egan, & O'Reilly, 1992)

Group Heterogeneity Moderates Group Size

- Weakened group identification can raise motivation and coordination costs for larger groups (Mueller, 2012; Wheelan, 2009)
  - Motivation costs include social loafing; members of larger groups perform less than their share of the work (Latane, Williams, & Harkins, 1979)
  - Coordination costs include managing the flow of work as well as sustaining members' attention and cooperation (Chompalov, Genuth, & Shrum, 2002; Malone, 1987)

Hypotheses

- Productivity in larger (vs. smaller) research teams should decrease with more disciplines represented

- Productivity in larger (vs. smaller) research teams should decrease with more institutions represented

ITR Study of Research Groups

N=549 funded projects in the Information Technology Research (ITR) program at NSF

- Program grew from US $90M in 2000 to US $295M in 2004
- Typical project was funded 3-5 years ($500,000-$1M/year), had five Principal Investigators (PIs), represented two disciplines and two universities
- Interview/observation data gathered from 2-day PI meeting
- Survey on coordination costs and outcomes completed by 885 PIs (at least one per project, 68% response rate) in 2005*

*Cummings, J. N., & Kiesler, S. (2007). Coordination costs and project outcomes in multi-university collaborations. *Research Policy*, 36(10), 1620-1634.

ITR Follow-Up (5-9 Years Later)

PI publications mined from NSF Final Reports, Google Scholar, and Web of Science

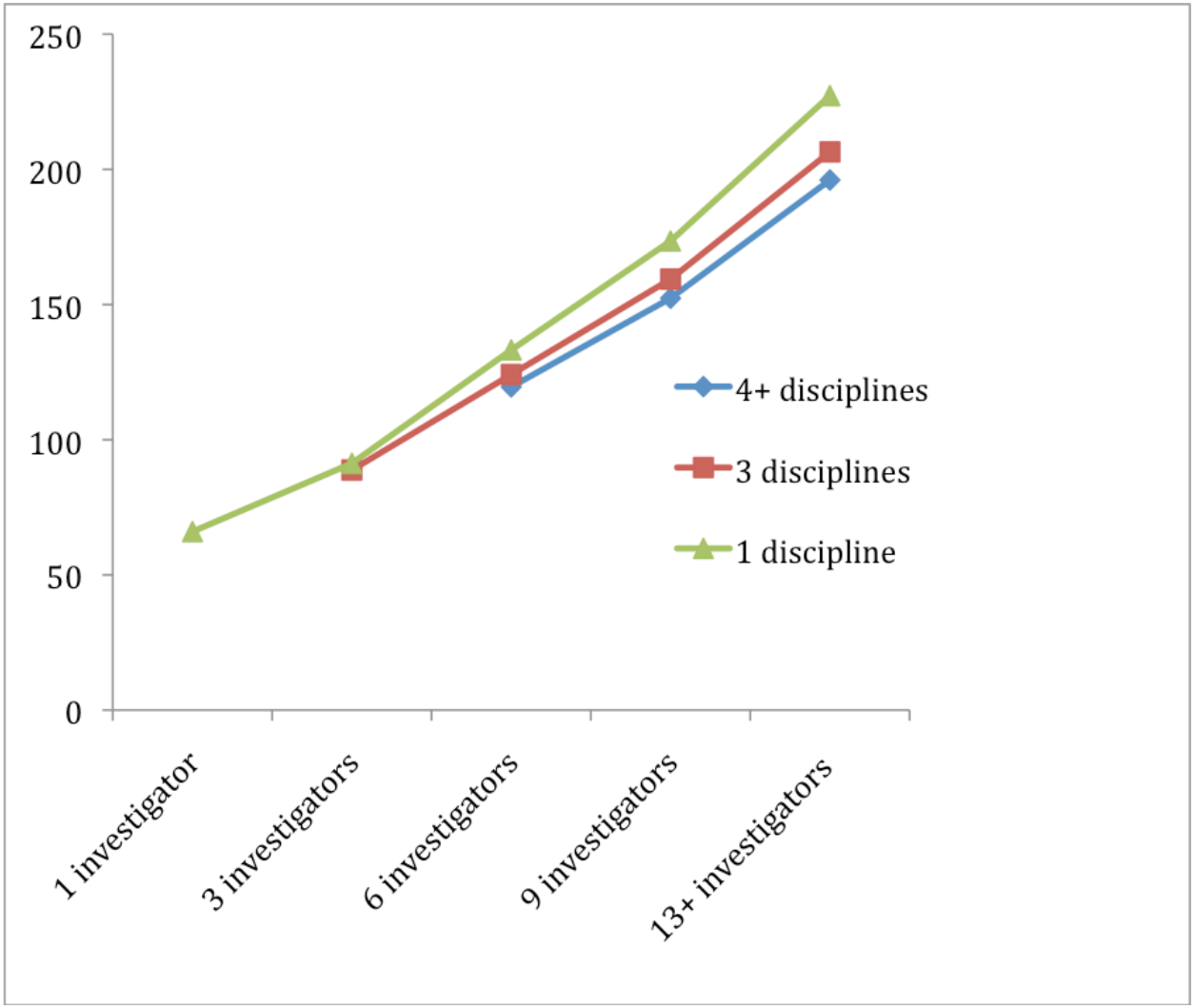
- Created group-level measure of productivity for each ITR project to assess number of (unique) publications (as listed in NSF Final Reports)
- Also created a control variable for publications prior to ITR project (as documented in Google Scholar and Web of Science)

Hierarchical regression models of the effect of research group size and group heterogeneity (multiple disciplines or institutions) on group productivity

Predictor	Dependent Variable 1: Log NSF Final Report Publications		
	Step 1	Step 2	Step 3
Controls*			
Publications prior to project (log)	**.33*** **	**.17*** **	**.12*** **
Project funding (log)	**.20*** **	**.16*** **	**.16*** **
Main Effects			
Number investigators (1 – 13+)		**.27*** **	**.37*** **
Number of disciplines (1 – 4+)		.02	.00
Number of institutions (1 – 7+)		-.07	-.04
Two-Way Interactions			
Number investigators x number disciplines			**-.11***
Number investigators x number institutions			**-.10***

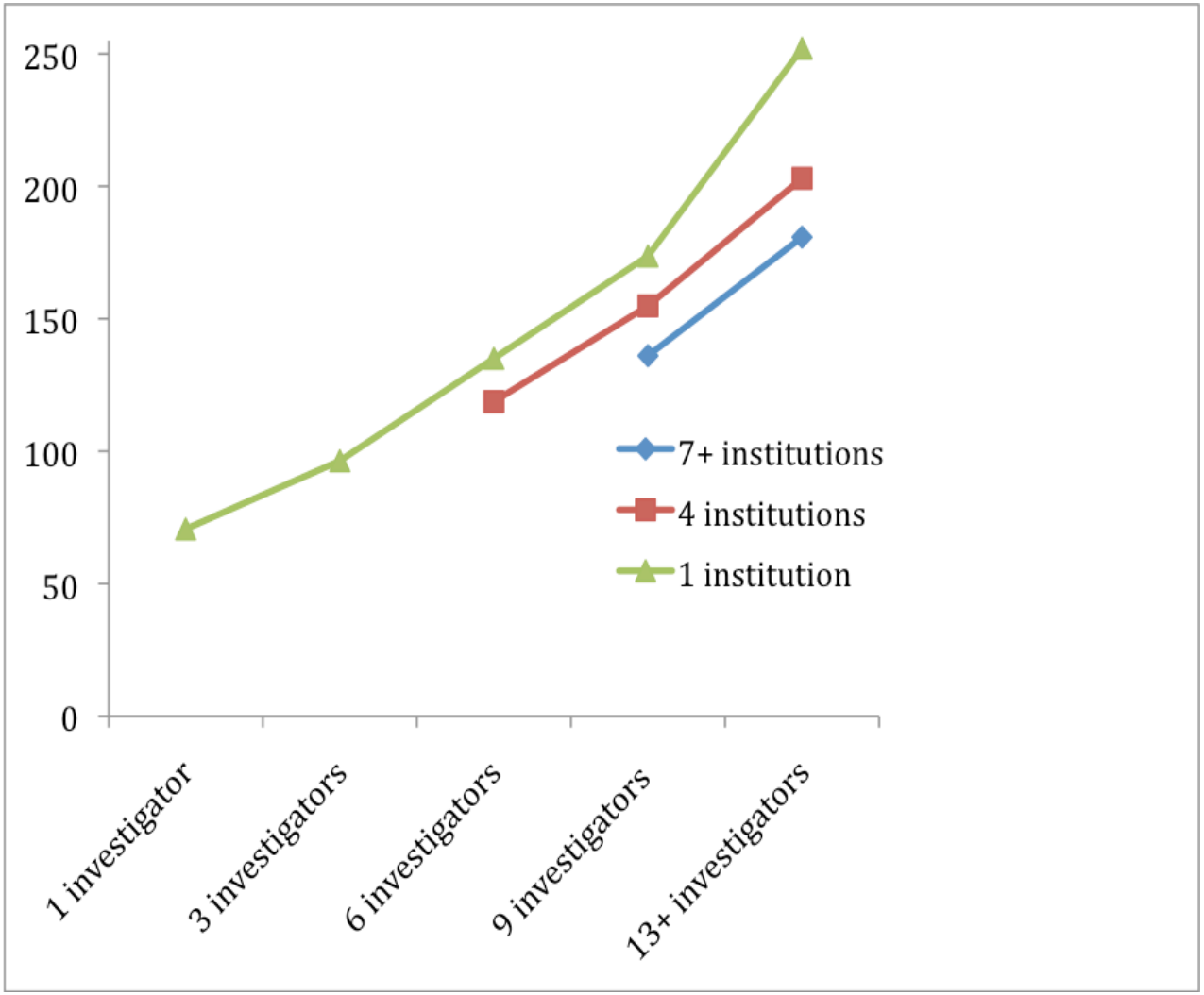
Not all controls included in slide. Standardized coefficients. N = 549.

Predicted number of publications as a function of research group size and heterogeneity as measured by number of disciplines of the investigators



Shown are slopes for low and high heterogeneity (low $t = 5.23$, $p < .0001$, $d = .45$; high $t = .64$, n.s.) The slope in the middle is shown for purposes of illustration: Above 3 disciplines ($t = 2.79$, $p < .01$, $d = .24$), the slopes are not statistically significant.

Predicted number of publications as a function of research group size and group heterogeneity as measured by number of institutions involved in the research



Shown are slopes for low and high heterogeneity (low $t = 4.88$, $p < .0001$, $d = .42$; high $t = .12$, n.s.) The slope in the middle is shown for purposes of illustration. Above 4 institutions ($t = 2.5$, $p = .01$, $d = .22$), the slopes are not statistically significant.

Overcoming Heterogeneity in Large Groups*

- "One of the advantages [was that] I was PI. And I have worked in this cross-disciplinary space for a long time. And so basically people knew I wouldn't tolerate any hiding in your discipline. So it was like if you're not part of this cultural change to meld together across these things then we don't need you on the project."

- "An awful lot of the work is learning to understand each others' vocabulary. . . I don't know a lot about her field and vice versa. . , It helped that [in my lab] I had a junior faculty member [in the other field] working on the project as well and so he could act as the translator between the two of us."

*Sample quotes from interviews conducted with 55 ITR project members

Summary

- Science policy emphasizes the desirability of research teams that can integrate diverse perspectives and expertise into new knowledge, methods, and products
- Though larger groups were more productive than smaller groups, their marginal productivity declined as their heterogeneity increased
- Both number of disciplines and number of institutions contributed to the decrease in marginal productivity for larger research groups

Unanswered Questions

- But what about research integration? To what extent did research integration actually occur across disciplinary and/or institutional boundaries? What are the antecedents and consequences of research integration?

- And what about other outcomes not necessarily related to group-level productivity, such as students getting jobs and junior faculty getting promoted? Are there other tradeoffs for having multiple disciplines and/or multiple institutions represented on the project?

- What are the even longer-term impacts of distributed, interdisciplinary projects such as continued collaboration by PIs and subsequent grant success?

More information about prior research…

Cummings, J. N., & Kiesler, S. (2005). Collaborative research across disciplinary and organizational boundaries. *Social Studies of Science*, 35(5), 703-722.

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Cummings, J. N., & Kiesler, S. (2008). Who collaborates successfully? Prior experience reduces collaboration barriers in distributed interdisciplinary research. *Proc. of CSCW '08* (p. 437-446). NY: ACM Press.

Cummings, J. N., Kiesler, S., Zadeh, R., & Balakrishnan, A. (in press). Group heterogeneity increases the risks of large group size: A longitudinal study of research group productivity. *Psychological Science*.