

Interdisciplinary Papers Supported by Disciplinary Grants Garner Deep and Broad Scientific Impact

Keywords: Science of Science, Interdisciplinary Research, Grant-Paper Linkage, Research Impact, Measurement Framework

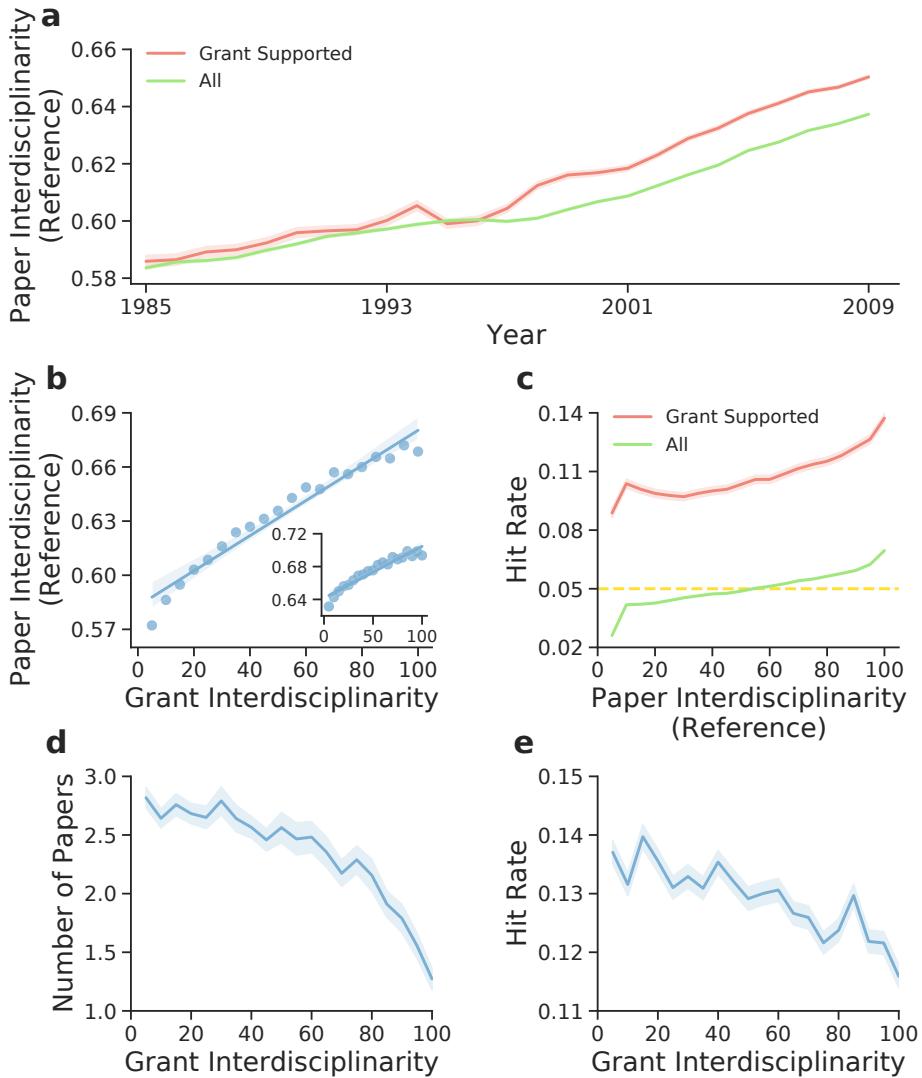
Extended Abstract

Interdisciplinary research has emerged as a hotbed for innovation and discoveries, representing a key pathway to address increasingly complex problems facing human society^{1–7}. The increasing dominance of grant-supported research in shaping scientific advances^{8–16}, combined with growing interests in funding interdisciplinary work^{2,7,14,17–20}, raises fundamental questions regarding the role of interdisciplinary grants in supporting high-impact interdisciplinary advances. Here we develop a general measurement framework to quantify the interdisciplinarity of both research grants and publications and apply it to 350,000 grants from 164 funding agencies across 26 countries as well as 1.3 million papers that acknowledged the support of these grants from 1985 to 2009. Our analysis uncovers two seemingly contradictory patterns. On the one hand, interdisciplinary grants tend to produce papers with higher interdisciplinarity, and highly interdisciplinary papers are associated with high impacts (**Figure 1**). Yet, on the other hand, compared with their disciplinary counterparts, interdisciplinary grants on average produce much fewer papers, and interdisciplinary papers that they support tend to have substantially reduced impact (**Figure 1**). We demonstrate that the key to resolving this discrepancy lies in the power of disciplinary grants in propelling high-impact interdisciplinary advances. Specifically, we find that highly interdisciplinary papers that are supported by deeply disciplinary grants garner disproportionately high impacts from both their core disciplines and broader fields (**Figure 2**). Further, the broad and deep impacts of disciplinary grants are not simply due to funding size, reception of ideas within disciplinary boundaries, or collaborative formats. Indeed, we find that when it comes to producing key interdisciplinary advances, disciplinary grants appear to do more with less and seem especially powerful when paired with other similarly disciplinary grants (**Figure 3**). Amidst the rapid rise of support for interdisciplinary work across the sciences, these results highlight the underexplored role of disciplinary grants in propelling crucial interdisciplinary advances, suggesting that interdisciplinary research is not only a risky endeavor but also requires deep disciplinary expertise and investments.

References

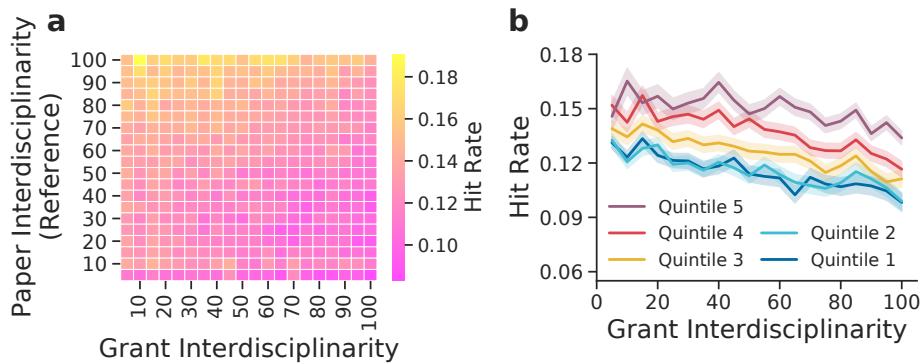
1. Bromham, L., Dinnage, R. & Hua, X. Interdisciplinary research has consistently lower funding success. *Nature* **534**, 684–687 (2016).
2. Rylance, R. Grant giving: Global funders to focus on interdisciplinarity. *Nature* vol. 525 313–315 (2015).
3. Ledford, H. How to solve the world’s biggest problems. *Nature* vol. 525 308–311 (2015).
4. Szell, M., Ma, Y. & Sinatra, R. A Nobel opportunity for interdisciplinarity. *Nature Physics* vol. 14 1075–1078 (2018).
5. National Academy of Sciences, National Academy of Engineering, and I. of M. of the N. A. *Facilitating Interdisciplinary Research. Facilitating Interdisciplinary Research* (Washington, DC: The National Academies Press, 2005). doi:10.17226/11153.

6. Rhoten, D. & Parker, A. Risks and rewards of an interdisciplinary research path. *Science* vol. 306 2046 (2004).
7. Van Noorden, R. Interdisciplinary research by the numbers. *Nature* vol. 525 306–307 (2015).
8. Price, D. J. D. S. Little Science, Big Science. *Little Sci. Big Sci.* (1963) doi:10.7312/PRIC91844/HTML.
9. Stephan, P. *How Economics Shapes Science. How Economics Shapes Science* (Harvard University Press, 2012). doi:10.4159/harvard.9780674062757.
10. Lane, J. Assessing the impact of science funding. *Science* vol. 324 1273–1275 (2009).
11. Ma, A., Mondragón, R. J. & Latora, V. Anatomy of funded research in science. *Proc. Natl. Acad. Sci. U. S. A.* **112**, 14760–14765 (2015).
12. Wang, J., Lee, Y. N. & Walsh, J. P. Funding model and creativity in science: Competitive versus block funding and status contingency effects. *Res. Policy* **47**, 1070–1083 (2018).
13. Yan, E., Wu, C. & Song, M. The funding factor: a cross-disciplinary examination of the association between research funding and citation impact. *Scientometrics* **115**, 369–384 (2018).
14. Lyall, C., Bruce, A., Marsden, W. & Meagher, L. The role of funding agencies in creating interdisciplinary knowledge. *Sci. Public Policy* **40**, 62–71 (2013).
15. King, D. A. The scientific impact of nations. *Nature* vol. 430 311–316 (2004).
16. Fleming, L., Greene, H., Li, G., Marx, M. & Yao, D. Government-funded research increasingly fuels innovation. *Science* vol. 364 1139–1141 (2019).
17. Bloch, C. & Sørensen, M. P. The size of research funding: Trends and implications. *Sci. Public Policy* **42**, 30–43 (2015).
18. Bozeman, B. & Boardman, P. C. Managing the New Multipurpose, Multidiscipline University Research Centers: *Transform. Organ. Ser. - IBM Cent.* (2003). Leahy, E., Beckman, C. M. & Stanko, T. L. Prominent but Less Productive: The Impact of Interdisciplinarity on Scientists' Research. *Adm. Sci. Q.* **62**, 105–139 (2017).
20. Gates, A. J., Ke, Q., Varol, O. & Barabási, A. L. Nature's reach: narrow work has broad impact. *Nature* vol. 575 32–34 (2019).



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2 **Figure 1 | The impacts of interdisciplinary grants.** **a**, Paper interdisciplinarity has been rising
 3 steadily from 1985-2009, and the increase of interdisciplinarity is more pronounced when we
 4 considered papers with grant support. **b**, Paper interdisciplinarity, as measured through paper
 5 references, increases as a function of the interdisciplinarity of supporting grants. Inset shows similar
 6 results when we consider paper interdisciplinarity based on citations. **c**, Papers with high
 7 interdisciplinary inspirations (i.e., reference-based paper interdisciplinarity) have a higher chance to
 8 be hit papers (dashed line as the baseline). This relationship also holds for grant supported papers.
 9 The number of papers resulting from a grant (**d**) and the propensity to produce hit papers (**e**)
 10 systematically decrease as grant interdisciplinarity increases.



11

12 **Figure 2 | The impact of interdisciplinary papers as a function of grant interdisciplinarity.** a,
13 Interdisciplinary papers from more disciplinary grants tend to be associated with higher impact. b,
14 While the baseline average of impacts increases with paper's interdisciplinarity (from Quintile 1 to
15 Quintile 5), interdisciplinarity grants have an overall reduced probability to produce impactful
16 papers when controlling for papers with the same level of interdisciplinarity (based on references).

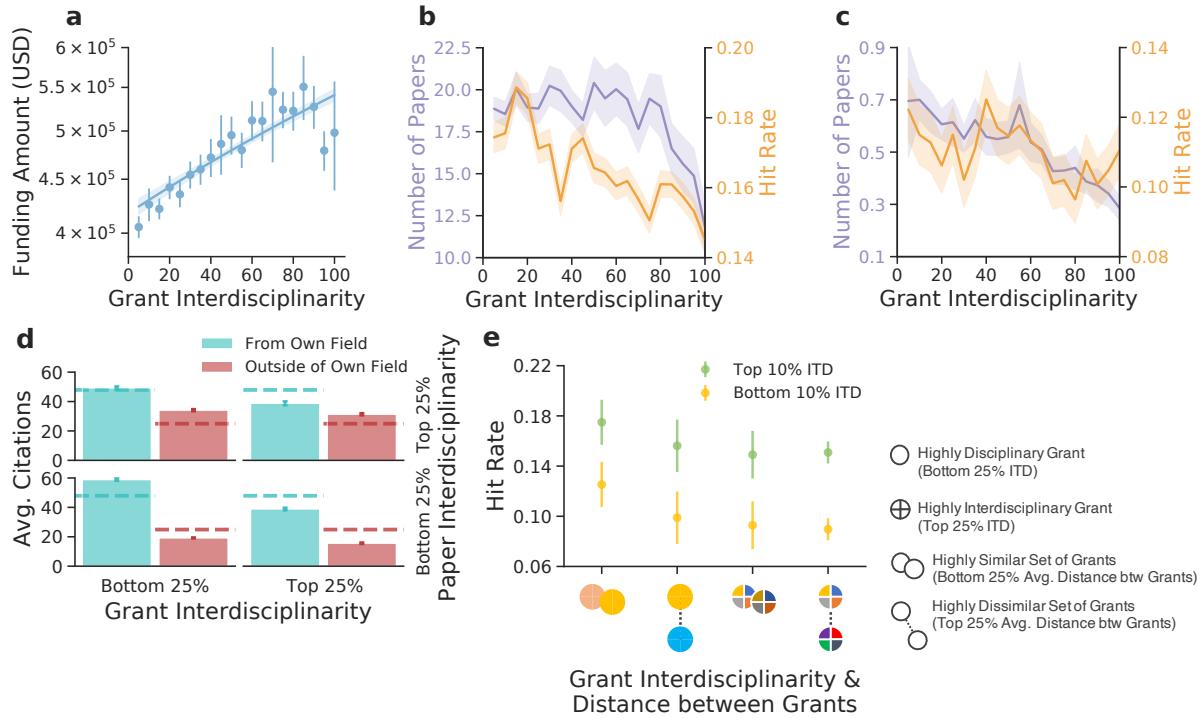


Figure 3 | Disciplinary grants and high-impact interdisciplinary papers. **a**, Interdisciplinary grants tend to feature larger funding amounts. **b**, Considering only grants with large funding amounts (top 10%, *Mean* = 3.5M USD), we observe a sharp decline in both productivity (purple) and impact (orange) as a function of grant interdisciplinarity. **c** shows a similar pattern of diminishing return when we focus on grants with median funding amounts (middle 10%, *Mean* = 744K USD). **d**, Interdisciplinary papers supported by disciplinary grants (top left) tend to have similar or higher number of citations than baselines (dashed lines) both from inside and outside of their own fields. Other papers attract more citations than the random baseline either from their own field (disciplinary papers supported by interdisciplinary grants; bottom left), outside their own field (interdisciplinary papers supported by interdisciplinary grants; top right) or neither (disciplinary papers supported by interdisciplinary grants; bottom right). In **e**, we consider sets of the top and bottom 10% interdisciplinary papers based on their references that were supported by multiple grants. We calculate the distance between grants and further divide the groups of publications in sets of highly (dis)similar pairs of (inter)disciplinary grants. We find that high-impact interdisciplinary papers tend to acknowledge the support of closely related, disciplinary grants.