Title: Big team science as a response to urgent societal developments

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**Abstract:** When responding to urgent societal developments – e.g., the rise of terrorism networks, global pandemics, and new disruptive technologies like AI – researchers often form collaborations that are ultra-large in size. The present work evaluates the impact of these big team science initiatives via an examination of a near-population of 2,150,491 scholarly articles published on terrorism, COVID-19, and ChatGPT. Results indicate that big team science is (a) an increasingly common response to urgent societal developments, that (b) is associated with increased impact on science, policy, and news, with (c) currently little-to-no concomitant delay in published insights. As we prepare responses to both existing and future urgent challenges, there is a pressing need to address existing barriers to mass collaboration in order to maximize the societal impact of science.

**Main Text:** The first quarter of the 21st century has presented society with numerous developments that have demanded quick and urgent action, including: (a) some of the deadliest terrorist attacks in modern history, (b) a global pandemic, and (c) the ongoing rise of transformative AI technologies. Such developments are often met with a vigorous response from various sectors of society – including scientists and the stakeholders they strive to impact. The present work focuses on these scientific responses, evaluating the role of a recent trend: big team science (*1*).

The present work focuses on research published by relatively small (1 – 4 co-authors) vs. big research teams (up to 100+ co-authors) during three significant societal events: one historical (the September 11, 2001 terrorism attacks), one recent (the COVID-19 pandemic), and one ongoing (the public release of the generative AI tool, ChatGPT). We examine a near-population of research on these topics via OpenAlex: an openly available catalogue of scientific articles (*2*). To index impact, we evaluate how often these articles are discussed in other scholarly publications, news outlets, and policy documents. For the latter two outcomes, we draw upon data from Altmetric: a proprietary service that tracks and measures online engagement with scholarly works. Last, we evaluate the speed at which researchers responded to these societal events by examining articles’ publication dates.

Results indicate that big team science is (a) an increasingly common response to urgent societal developments, that (b) is associated with increased impact on science, policy, and news, with (c) currently little-to-no concomitant delay in published insights. These results are described in fuller detail below.

**Researchers are increasingly responding to urgent societal developments with big team science**

Consistent with broader trends in science (*3*), big team science is an increasingly common response to urgent societal developments. As an example, we compare researchers’ response to the COVID-19 pandemic to an event that occurred nearly two decades prior: the September 11 terrorism attacks.

The September 11 attacks caused an estimated $10 billion in infrastructure damage, led to multi-decade military campaigns costing an estimated $4 trillion, and produced a multi-national flurry of policies designed to combat terrorism (*4*). The attacks also generated a sizeable response from scientists. Researchers have used the term ‘terrorism’ in 322,878 articles – 89.81% of which were published after the September 11 attacks. This research has been overwhelmingly published by relatively small teams. Approximately 93.66% of articles have fewer than 5 co-authors and 5.42% have between 5 and 9 co-authors. Less than 1% of articles on terrorism have 10 or more co-authors – and these historical big team efforts exhibited diminishing returns in terms of impact (*see SI*).

Nearly two decades later, collaborative infrastructure had evolved substantially when researchers began responding to another urgent development: the COVID-19 pandemic. COVID-19 claimed an estimated 15 million lives over a two year span (*5*), led to sweeping policy changes, and had an estimated $14 trillion economic toll in the U.S. alone (*6*). Compared to the September 11 attacks, researchers’ responses were substantially more collaborative. The proportion of published articles with fewer than 5 co-authors decreased by 27.28% (now 66.38%), the proportion of articles with 5 to 9 co-authors increased four-fold (now 23.96%), and the proportion of articles with 10 or more co-authors increased eight-fold (now 8.71%).

Part of the shift towards larger collaborations on COVID-19 was a 37-author Phrase 3 clinical trial describing the mRNA-1273 vaccine (*7*). As we review in the next section, the unusually high impact of this big team effort is not an exception – but rather part of a generalizable trend in research on COVID-19.

**When responding to the COVID-19 pandemic, bigger teams had more impact on science, the news, and policy – with little-to-no speed tradeoff**

To evaluate the impact of big teams during the COVID-19 pandemic, we first consider the relatively small team efforts typically seen in science (Fig. 1). In research on COVID-19, articles published by teams of 1 - 4 co-authors (*N* = 1,240,191) were mentioned, on average, in 5.51 scholarly works (*SD* = 41.35), 1.53 news outlets (*SD* = 15.55), and 0.10 policy documents (*SD* = 0.80). Comparatively, articles with 10 – 19 co-authors (*N* = 143,539) were mentioned 3.28 times more in scholarly works (*M* = 18.07, *SD* = 125.11), 2.68 times more in news outlets (*M* = 4.11, *SD* = 37.21), and 1.80 times more in policy documents (*M* = 0.18, *SD* = 1.34). As an even more extreme comparison, consider COVID-19 articles with 100 or more co-authors (*N* = 1,635). Compared to small team efforts, these ultra-large collaborations were mentioned 17.06 times more in scholarly works (*M* = 93.98, *SD* = 381.37), 21.94 times more in news outlets (*M* = 33.64, *SD* = 139.23), and 9.63 times more in policy documents (*M* = 0.99, *SD* = 4.97).

Of note, big teams did not usually encounter significant time delays (Fig. 1). In fact, they often published scientific insights *quicker* than their small team counterparts. On average, small teams of 1 - 4 co-authors published their insights 780.15 days after the World Health Organization declared a pandemic on March 11, 2020. Larger teams of 10 – 19 co-authors published at a similar speed (*M* = 783.65 days) – and the quickest insights tended to come from teams of 40 – 49 co-authors (*M* = 716.55 days). Some exceptions exist, of course. For example, compared to small teams of 1 – 4 co-authors, the largest teams of 100+ co-authors were indeed slower (*M* = 834.75 days). However, one might argue that the cost of their 54-day delay is offset by the benefits of their 17-fold increase in scientific citations, 22-fold increase in news mentions, and 10-fold increase in references in policy documents.

**Looking forward: How are scientists collaboratively tackling the emergence of transformative AI technologies?**

Almost two years after developing vaccines to combat the COVID-19 virus, scientists encountered yet another urgent global development: the public release of the AI chatbot, ChatGPT. Although certainly not the only technology on the market, ChatGPT is often considered one of the most influential – receiving credit for accelerating an AI boom whose economic, social, and environmental impacts are rapidly evolving but still unknown (*8*). Furthermore, the phrase “ChatGPT” is virtually nonexistent in the scientific literature before the product’s release (November, 2022). Like research on terrorism and COVID-19, this provides a unique methodological opportunity to evaluate scientists’ response time.

The first few years of published research on ChatGPT (*N* = 35,940) provide preliminary insights into how researchers are responding to this new urgent development. Similar to the COVID-19 pandemic, researchers’ responses signal a shift towards big teams – with 4.45% of published articles having 10 or more co-authors. There are too few papers to reliably evaluate the impact of their largest collaborative responses; articles with 40-49 authors (*N* = 19), 60-69 authors (*N* = 6), and 80-89 authors (*N* = 1) are still rare (*see SI*). Nonetheless, the pattern observed in collaborations up to those sizes suggest that history may very well repeat itself: big teams will have an outsized impact on the development and understanding of emerging AI technology.

Once again, we first consider the norm: papers published by smaller teams of 1 – 4 co-authors (*N* = 26,324; 73.24%). In research on ChatGPT, these relatively small teams have received an average 4.66 mentions in other scholarly work (*SD* = 27.05) 1.48 mentions in the news (*SD* = 17.96) and 0.03 mentions in policy documents (*SD* = 0.43). Comparatively, the 1,392 articles with 10 - 19 co-authors have received 2.70 times more mentions in scholarly works (*M* = 12.58, *SD* = 69.79), 2.21 times more mentions in news (*M* = 3.27, *SD* = 28.53), and a similar number of mentions in policy documents (*M* = 0.03, *SD* = 0.30). The 106 articles with 20 – 29 co-authors have fared even better, receiving 7.99 times more mentions in scholarly works (*M* = 37.27, *SD* = 169.64), 1.32 times more mentions in news (*M* = 1.96, *SD* = 5.51), and 3.99 times more mentions in policy documents (*M* = 0.13, *SD* = 0.60). Once again, these larger collaborations are achieving increased impact with minimal speed tradeoffs. On average, small teams of 1 – 4 co-authors published their insights 5.72 days quicker than teams of 5 – 9, 19.20 days quicker than teams of 10 – 19, and 19.13 days slower than teams of 30 – 39 co-authors.

**Outstanding issues: Facilitating, understanding, and balancing big team efforts in science**

The tendency for bigger teams in science to produce higher impact work during urgent societal developments is at odds with another finding: such collaborations are relatively unusual. Fortunately, previous investigations have provided multiple clues as to why this gap exists. For example, researchers have noted that collaborative efforts are undervalued in academic evaluations, difficult to fund, and challenging to reconcile with existing publication norms (*9*). Furthermore, researchers are not usually trained on how to most effectively contribute to team-based science (*10*) – e.g., how to handle the disagreements that are sometimes inevitable in large groups (*9*). Addressing these barriers requires changing the way that scientists are trained, evaluated, funded, and promoted. This change is itself an urgent priority – one we should work to address before we’re faced with our next major societal development.

The tendency for bigger teams in science to produce higher impact work also raises questions about what mechanisms drive their success. One possibility, of course, is that big teams exhibit collective intelligence – e.g., combine their expertise to select better ideas and/or conduct higher-quality investigations. Consistent with this idea, past research has shown that crowdsourcing the perspectives of scientists can be leveraged to predict the replicability of published findings (*11*) and the number of citations that a manuscript will receive (*12*). However, it is also possible that the impact of big teams is exaggerated by social biases, such as increases in self-promotion and/or bandwagon effects. Future research can begin to disentangle these effects, for instance, via blind evaluations of research conducted by large vs. small teams.

Last, efforts to facilitate and understand big team science should also seek to identify their ideal balance. Although the efficacy of the mRNA-1273 vaccine was described by a large team, many key discoveries related to mRNA were made by small teams – including the Nobel prize winning work of Karikó, Buckstein, Ni, and Weissman (*13*). The best approach to addressing urgent global developments likely isn’t to focus exclusively on big team or small team efforts – but rather to find a better balance between their unique benefits.

**Concluding remarks**

In summary, the present work highlights the growing role of big team science as a response to urgent societal developments. The analysis of research following the September 11 attacks, COVID-19 pandemic, and release of transformative AI technologies like ChatGPT reveals a trend: during urgent societal developments, researchers are increasingly coming together en masse to produce timely and high-impact insights. Indeed, an influential paper describing GPT-4 was co-authored by a team of over 200 authors (*14*) – as was a paper describing an influential competitor, DeepSeek (*15*). Despite the impact of ultra-large collaborations, they remain relatively uncommon due to barriers related to funding, training, evaluation, and publication norms. As we prepare for future urgent challenges, we must adapt our existing frameworks to not just accommodate but also encourage scientists to leverage the power of mass collaboration to maximize societal impact.

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Supplementary Materials

Materials and Methods

Supplementary Text

Figs. S1 to S4

Tables. S1 to S4

**Fig. 1.** **Impact and response speed of research conducted on COVID-19 and ChatGPT.** In researchers’ responses to COVID-19 and ChatGPT, articles published by bigger teams have received higher average mentions in scholarly articles (pink), news outputs (blue), and policy documents (orange). Bigger teams have also exhibited little-to-no difference in response speed (green), showing small improvements in response time in some cases and small decreases in response time in other cases. In the graph below, dots indicate average percentiles. Solid dark lines represent relationships estimated via generalized additive models, and colored bands represent 95% confidence intervals. For select outcomes, dotted lines highlight raw differences between the smallest and largest collaborations studied.

A graph of different colored lines

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