If you want creativity, keep the team small

Jeanne Brett and Dashun Wang

Kellogg School of Management, Northwestern University, Evanston, IL 60208, USA.

Published in *Scientific American*, 2020

An almost universal trend in science today is the growth and prominence of large teams and the receding presence of small teams and solitary researchers (1). To be sure some innovation activities require massive teams, such as complex physics experiments—like the Nobel-winning LIGO experiment that detected gravitational waves (and validated Einstein's theory of relativity), which required over 1000 researchers. Although the motivation for larger teams goes beyond science and beyond scale (1), research in social psychology, on the other hand, has documented extensively the benefits of small teams, with small teams outperforming large teams on criteria ranging from efficiency to creativity and innovation (2, 3). To understand the implications of the shift toward large, complex teams is of fundamental importance for science and scientists, as teams, especially large teams, are increasingly viewed as core engines of breakthrough ideas and innovations (4).

Large teams have emerged for many reasons. The problems many scientific teams are addressing are complex requiring integration of diverse expertise (5, 6). The internet makes it easier to communicate and coordinate among members of larger and dispersed teams (7, 8). Furthermore, in science, products of larger teams tend to garner more citations than those of smaller teams (1). And there is evidence showing that NSF is more likely to fund larger than smaller teams, even though they were equally qualified (9), suggesting additional impetus for larger teams.

However, recent research shows that the dominance of larger over smaller teams comes at a cost to innovation and creativity (10). Wang and colleagues analyzed over 65 million papers, patents, and software products produced between 1954-2014, to study the implications of team size on productivity. They used an established measure of disruption (11) to assess how much a given work destabilizes its field by creating new directions of inquiry versus builds on existing ideas and designs to address existing problems. They found that relative to larger teams, smaller teams' work was more "disruptive". In other words, large teams solve problems; small teams generate new problems to solve. They found that as team size increased from 1 to 50 members, level of disruptiveness plummeted. Moreover, they found that team size itself, rather than confounding factors, such as differences in topic or type of research design, explained the differences. To be sure, large teams contribute materially to science and other creative fields by developing established ideas. But, in a world where large teams flourish as small teams diminish, these results suggest that, at the extreme as science is taken over by large teams, ultimately large teams may run out of problems to solve.

These "Big Data" results fit in nicely with decades of social psychology research, which has documented the diminishing returns of team size on all types of team productivity (2, 3), from Ringlemann's study of adding people on each side of a tug of war (12, 13) to multiple studies of brainstorming (14). Whether the task is physical or intellectual, the output per capita decreases as team size increases. A team needs the requisite capabilities to address the complexity of its task; however, as teams' tasks become more complex and teams become larger, *process losses* - problems of coordination of information and motivation accumulate exponentially and interact to reduce team productivity (15).

Two major information-coordination challenges that larger teams have to overcome are the *common knowledge effect* and *getting the floor*. As teams increase in size, team members' redundancy increases. Despite the fact that large teams should have greater access to non-redundant information than small teams, the *common knowledge effect* occurs – team members talk about what everyone already knows instead of the unique information known by just one member (16). And yet, that unique information could potentially be combined with the unique information known by one other member for creative solutions. *Getting the floor* also becomes more difficult as team size increases. The pattern of direct communication in larger teams looks like a Poisson distribution: one, sometimes two members, do the lion's share of the talking (17). For example, early attempts to address the information-coordination problems in groups include Simmel's study of the dynamics of triads (18) and Morino's sociograms of relationships within a refugee camp outside Vienna in 1916 (19), which formed the basis for the field of network analysis in contemporary sociology.

The motivational challenges as team size increases are myriad: *relational loss*, loss of *social cohesion*, and *social loafing,* among others. *Relational loss* is the perception of team members that they are working with little support from other team members (20). Members of larger teams also feel less cohesive – united, connected, interrelated than members of smaller teams (21). They tend to be less satisfied with the team and less likely to cooperate with each other (22). At the same time, they are more likely to conform to group norms, such as *social loafing* (23), the tendency of individual group members to contribute less than they would working in a smaller group or alone. It can escalate in large teams as team members view others as *free riding* and reduce their contributions so as not to be viewed as a sucker. Free riding occurs as teams increase in size because of *diffusion of responsibility,* which can be a particular problem when goals and responsibilities are not clear. As a whole, larger teams can lack the *developmental maturity* of their smaller counterparts (24). Throughout the lifetime of the group, larger teams tend to look to leaders for direction and motivation, whereas smaller teams frequently progress to periods of intense productivity fueled by trust-based relationships, structure, and consensus. It is no wonder that larger teams are building on *existing* ideas to solve complex problems but smaller teams are identifying *disruptive* new ideas that need solving.

Since it seems neither likely nor necessary for the march toward larger teams to be turned back, the challenge becomes how to make large teams or parts of them into small teams. New research in multi-team systems (MTS) may offer useful lessons. A multi-team system is a large team that is system of smaller teams organized with a structural network, which is usually, but not necessarily hierarchical. Teams within a multi-team system share at least one common goal and are interdependent with respect to inputs, process, or outcomes (25). Effectiveness in these MTS structures requires team members to balance the demands of their own component team, while also allocating resources to the interdependent needs of the higher-order multi-team system (26). As research begins to identify the best practices with respect to leadership (27) and team identity (28) that facilitate team performance, it will help us understand how to structure teams—both large and small—that are best positioned for innovation.

In sum, science needs both disruptive innovations and ideas, and the theoretical and practical solutions to them. Large teams remain as an indispensable engine for problem solving. But, we must also recognize the key role of small teams, which have been shown not only to disrupt fields more than their larger cousins, but also to be associated with greater productivity, better communications, and a deeper sense of relational unity, all of which could contribute to strong individual and collective performance.

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