Quiet Brainstorming: Expecting the Unexpected

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The COVID-19 lockdown has given us time to reconsider some of the approaches we use for generating research ideas. We propose a set of three critical “E” processes—extract, expose, and evaluate—for an individual researcher to replicate team brainstorming.

Imagine a group of brains in a room... Well, to be specific, people with brains that are churning with ideas. The group convenes, sharing ideas and research results, identifying new connections and organizations, and eventually deriving something completely fresh and exciting! We call this brainstorming. Team brainstorming is most effective when people from different backgrounds and interests are allowed to interact with one another in an uninhibited manner. United by the goal of bringing new ideas to life, participants share spontaneous, unexpected and even provocative thoughts, allowing their combined imaginations to flow freely. Novel creative ideas flow from logically connected individual elements that initially appear unstructured and unrelated but after careful examination reveal their underlaying deeper meaning and connections.

A Vacuum Makes Way for Novelty…

The COVID-19 lockdown from March to June has given us time to reconsider some of the approaches we have used for research. We decided to challenge ourselves by setting up a virtual environment using Microsoft Teams to create a communication hub, connect lab members, and share documents easily. It is a particularly daunting task for an experimental group.

Many video conferences later, we sent out a questionnaire to analyze which methods we typically use to generate creative ideas. It is not surprising that inspiration from literature, both inside and outside of our field, was the most common method. The second most reported method was, as might be expected, the famed “Eureka!” moment. We also noticed a significant difference between peoples’ individual ideas versus team brainstorming—for ideas generated alone, the product is usually structured in a very similar way to the inspiration, and thus it is very derivative.

Can the Work of a Team Translate to a Lone Scientist?

The combined brainpower of a team makes it possible to thoroughly explore the connections between various concepts and to generate original ideas more efficiently than if this process were undertaken by a single individual. The question is this: how can we produce a similar effect from brainstorming, even when we work alone and quietly? Moreover, can this method be described scientifically?

We propose that it is possible for an individual to replicate team brainstorming by using three critical “E” processes: (1) extract unexpected, diverse, and reliable information; (2) expose unusual but logically sound connections; and (3) evaluate the new possibilities that evolve from the connections. For (3), the new possibilities can and should involve the latest techniques and scientific advances. They could include a shortcut that connects the terminals of the connections or similar connections but with the altered direction of the logic flow.

The most critical portion of generating new ideas—asking an original question—is usually not part of solving the problem. The extract and expose processes could help us reveal these types of questions, whereas the evaluation process helps formulate the initial hypothesis for later experimentation. We have envisioned two approaches to virtual brainstorming by using the three “E” processes.

The Power of “E”…

Article databases are an ideal platform for virtual brainstorming. In a typical brainstorming session, one person can agree or disagree with another person’s viewpoints, which often creates an extended network of ideas and conflicts that go back and forth (Figure 1A). In a literature search, we can produce a very similar effect by looking into the details of the citation network. When articles are cited and referenced, we naturally generate a flow of logic and consensus around which scientific ideas should propagate. Bibliographic tools such as the Web of Science and Scopus let us easily navigate this network.

To demonstrate this approach, let us choose an article, “a,” that contains an initial idea of interest (Figure 1B). It does not matter whether an article presents a method, an application, or a theory. After defining our starting point, we will check its references, such as article “c,” for the basis of research, and we will also access later studies, such as article “b,” which reference the article of interest, “a.” These retrograde and anterograde searches

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yield the ideas that inspired or were inspired by the central study. This point is where we extract unexpected, diverse, and reliable information, like what we experience during brainstorming. The distance in the space of ideas between articles in this network can vary greatly, and even if we look no further than this group, we can derive a substantial amount of useful information.

However, we can do more. We can move to article “b” and check its references and the articles that cite article “b” (Figure 1B). Now, you could find a path from “c” to “d,” following the chronological direction of citations. However, this yields very structured and expected connections, and we hope to expose the unusual but logically sound connections. How might we achieve that?

Swimming Upstream Reveals Hidden Connections…

We can begin with the paper that cites article “a” (i.e., paper “e”), and end with an article that is one of the references for article “b” (i.e., paper “f”). Going backward against the stream, we identify ideas that are not directly connected (Figure 1C). But given the hidden connections, and their relative neighborhood in the literature space, we can call “e”–“f” an unusual, but potentially logical, connection. Finally, we can investigate if there is a refined path from “e” to “f,” or could these concepts be combined to generate new ideas? Importantly, we should consider how the latest scientific and technical advances might help us formulate connections that might not have been available when the original articles were published. Frequently, the answer is “yes,” and after we perform a careful evaluation, we can create a plan for a new and original study. Of course, we don’t have to stop on the first branches in this network, but we can explore further for even more unexpected links between articles. This approach represents one way (Figure 1C) in which the three “E” processes can help us generate a new idea or a new hypothesis.

Although literature research provides a significant amount of information regarding ideas and concepts, it might not offer sufficient hands-on experiences or connections to our field of study. During in-person brainstorming, the team members involved can easily share research experiences (where they know all the hidden and “tricky” parts and have this knowledge readily available)—something that is not possible when isolated. To expand our research and make it innovative, even when alone, we are proposing a second method of exploring the network of scientific ideas.

Changing the Lens…

The typical workflow of a scientific investigation begins with the initial observations (Figure 2A), which are usually surprising. Then, we state the hypothesis and use a set of experiments to test and revise them. The ultimate goal is to have a law or theory that can be broadly applied to many different situations. However, because we cannot collect new data during the laboratory...
lockdown, the only two elements currently available for analysis are the initial observation and the initial hypothesis. Although we continuously strive to be open-minded in our initial interpretations, our thoughts are often biased or focused only on a particular set of directions (“α,” Figure 2A). This limitation makes some observations dormant or “failed,” because we are not accustomed to looking outside the lens of our immediate attention. However, we can change the lens of our scientific focus, such that we could identify new opportunities (“β,” Figure 2A) by revisiting some of the previous observations and extracting the unexpected, diverse, and relevant information. In this case, however, we are seeking to expose the unusual but logically sound connections, so that we can ask ourselves original questions and make them a starting point to evaluate a new hypothesis.

**Peer Wisdom…**

In the first method, we expose the unusual connections by looking at the citation network. In the second method, as things become more “personalized,” we can instead look to our peers. For example, the Tian group works partially in the bioelectronics field, and some of our initial observations, such as the discovery of the atomic gold over silicon nanowire surfaces1–3 (α), have contributed to our established niche of photoelectrochemical modulation of neurons2,4,5 (α0, in the orange circle, Figure 2B). Let’s say we have a respected peer, who currently works at least partially in a similar field (β0, in the blue circle, Figure 2B). We can trace his or her career achievements and identify several earlier established research areas (β1, β2, and β3), such as the neuromorphic computing (β2). Then we could expose a set of connections that link a different initial observation from our group, such as the mineralization of inorganic clusters over subcellular structures (β), with this neuromorphic computing area (β2)—this is unusual but, again, might be logically sound. Now, the following questions emerge: how can we go from β to β2, and what is the connection? We can now evaluate the commonalities and differences between the previous approaches, how they developed, and similarly propagate our ideas by using current scientific and technological advances (Figure 2C). This approach allows us to identify the missing connections and build upon our peers’ achievements while advancing the field in a new direction.

**The Interplay of Opposites Yields Something New…**

“Expected” yet “unexpected,” the conflicts that are intrinsic to our methods would stimulate new idea generation.
Do we claim to have found the perfect creative method? Not at all. Developing innovative ideas requires intuition, imagination, curiosity, and experience—our ability to identify correct scientific problems and ask the right questions demands constant improvement. Navigating the vast amount of literature and experimental results might be a daunting task, but with a systematic approach, we might generate many new ideas that lead to other breakthroughs. We hope that readers will find our methods useful, giving them a new look at the connections within the landscape of scientific ideas and helping them visualize a multitude of exciting new directions.

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