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How the COVID-19 pandemic has changed research?

Hassan Karimi-Maleh[1] · Elena Niculina Dragoi[2] · Eric Lichtfouse[3,4]

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> Adversity and challenges are life's way of creating strength. Adversity creates challenge, and challenge creates change, and change is absolutely necessary for growth. If there is no change and challenge, there can be no growth and development.
>
> Willie Jolley

The coronavirus disease pandemic (COVID-19) started in 2019 and induced long-lasting effects on many aspects of life. Every one of us felt how the quiet existence was transformed into a chaotic state full of uncertainties, doubts, and fear for one's safety. This led to many societal changes, some influenced by objective facts and events, others by human risk perception and behavior modifications. Although risk perception tends to be biased and the responses of individuals to the perceived threat are very different, jumping from lack of precautions and a false feeling of security to unnecessary scares and stigmatization of risks groups will impact human activities in all areas for many years to come (Brug et al. 2009). Here, we review the positive and negative outcomes of the pandemic on academia and scientific enterprises.

✉ Elena Niculina Dragoi
elena-niculina.dragoi@academic.tuiasi.ro

Hassan Karimi-Maleh
hassan@uestc.edu.cn

Eric Lichtfouse
eric.lichtfouse@gmail.com

[1] School of Resources and Environment, University of Electronic Science and Technology of China, Xiyuan Ave, P.O. Box 611731, Chengdu, People's Republic of China

[2] Cristofor Simionescu Faculty of Chemical Engineering and Environmental Protection, Gheorghe Asachi Technical University, Bld. D Mangeron No. 73, 700050 Iasi, Romania

[3] Aix Marseille Univ, CNRS, IRD, INRAE, CEREGE, Aix-en-Provence, France

[4] State Key Laboratory of Multiphase Flow in Power Engineering, Xian Jiaotong University, Xian 710049, Shaanxi, People's Republic of China

Research disruption

The government's drastic measures, especially in the early days of the pandemic, led to the closure of many laboratories. The discontinuation of experiments caused the loss of data and, in turn, shrank financial and material resources. In addition, the potential for scientific innovation was significantly hampered by travel restrictions, and by less face-to-face meetings, conferences, and workshops (Subramanya et al. 2020). Although few argue the importance of precautions to slow the spread of diseases, the pandemic policies significantly disrupted both professional and personal lives. The adverse effects of the pandemic on academia and scientific enterprises resulted from the closure of laboratories, the reduction of avenues for conducting research in a collaborative and direct manner, and the limitation of direct dissemination of results to peers. These major issues prompted changes in research time allocation, publication behavior, and funding in a domino fall-like way.

Impact on publication

Publishing is essential for researchers because, whatever criticisms are currently raised against the use of publication metrics, an academic career is closely correlated to the quality and frequency of publications. During the first COVID year of 2020, the average self-reported number of publication metrics for the USA and Europe was slightly lower than in 2019 (Gao et al. 2021). However, this perceived reduction is not general, and publication number varied with country, institution, and discipline. For example, medical-based publications showed a 6.5-fold increase, while non-medical publications decreased by 10–12% (Riccaboni and Verginer 2022). In the engineering field, for the School of Resources and Environment of the University of Electronic Science and Technology of China, a Scopus search indicates a slight reduction of publication number in 2020, of 163, compared to 165 in 2019, while in 2021, the number raised to 243. The same search procedure applied to the Cristofor Simionescu Faculty of Chemical Engineering and Environmental

Protection from Gheorghe Asachi Technical University shows a rise from 36 articles in 2019 to 63 articles in 2020 and 73 articles in 2021.

Less experimental time

A strong impact of the discipline field on research time was observed. For instance, research time declined by 30–40% versus pre-pandemic levels in research heavily relying on physical laboratories and experiments such as biological sciences and chemical engineering (Myers et al. 2020). This reduction is not only due to the lack of on-site access but also to staff shortage and supply-chain issues for materials, spare parts, and protective equipment (Sohrabi et al. 2021). As the measures relaxed and more protective equipment became available, laboratory work improved slowly to return to a 'new normal' functioning where the measures and the management of the protective equipment are still essential (Yang et al. 2022; Ufnalska and Lichtfouse 2021; Gorrasi et al. 2021). Nevertheless, the self-reported working hours decreased by 11%, and the reduction of time allocated to research was about 24% (Myers et al. 2020). Consequently, most tasks were performed at home, sometimes in unsuitable conditions, with spouses and kids wandering around. The work at home focused more on data analysis, manuscript, and proposal writing.

Research advancement was slowed down, particularly for early-stage career scientists, due to reduced laboratory access, less direct teamwork, and meeting cancelation. The delay or cancellation of research opportunities and the impaired ability to collect and analyze data led to a decreased ability to work. According to a survey in the UK, 50% of responders reported being very stressed, and 75% were apprehensive about their future plans (Byrom 2020). This survey also revealed that only 12% of final-year doctoral students had an option to extend their studies, which put additional pressure on an already at-risk group.

Fund redirection

The pandemic also reduced the number of projects. For example, in the USA and Europe, the number of respondents claiming that they had no new project increased from 9% in 2019 to 27% in 2020 (Gao et al. 2021). Research topics were also strongly modified by redirecting funds toward COVID issues, with many classical clinical trials being temporarily stopped in vulnerable, low-income countries (Subramanya et al. 2020). Specifically, in July 2020, about 1200 clinical trials were suspended because clinical scientists had no or reduced access to healthcare research infrastructures (Riccaboni and Verginer 2022). Moreover, drastic budget cuts also occurred in other areas, such as cancer research. For instance, 45 million pounds were cut in the UK, inducing a substantial decline in fellowships and research programs for hundreds of scientists (Burki 2021). Here, early-career scientists are at risk because institutions are not hiring new personnel.

The redeployment of private and public funds to COVID-related concerns has substantially increased the number of investigations in this field. For instance, in May 2020, shortly after the pandemic outbreak, 1,221 COVID studies were declared in the international clinical trial registry (Bramstedt 2020). Nevertheless, research misconduct increased rapidly as an unwanted consequence of the rapid pace imposed by the pandemic and available funds. Indeed, 33 articles were already considered unsuitable in May 2020 (Bramstedt 2020). Ironically, the overflow of funds is as much a curse as the lack of funds, as it uncovers new problems and exacerbates existing issues. Crowdfunding, a popular fund-raising means commonly used by the public, was explored by academia for the first time during the pandemic. However, researchers did not favor this approach due to the somewhat different rules that must be applied and the limited amount of money compared with the standard sources (Sultan et al. 2022).

Inequality

The personal living conditions of scientists have also dropped research efficiency. Indeed, the balance between work and free time has been utterly disrupted during the pandemic. Moreover, researchers who did not fit the classical profile of the ideal academic career—the traditional man with his traditional wife—have been under additional pressure in the context of unrealistic expectations for tenure or promotion (King and Frederickson 2021). In addition, female academics had difficulty balancing the expected primary role of caregiver with the role of the scientist, leading to an overall reduction in female publications compared with men (Alam et al. 2021). For example, in the first ten weeks of lockdown, the academic productivity of women dropped 13.2% compared to that of male academics in the USA. This productivity gap occurred in various countries and was more pronounced for assistant professors and top-ranked institutions (Cui et al. 2022). In several academic journals, the reduction in the proportion of published articles by women was confirmed in the summer of 2020 (Pereira 2021). Analyzing tweets, similar trends were observed in social media (Kim and Patterson 2022).

Elitism discrimination, a form of inequality, was exacerbated by the pandemic. In this context, elitism discrimination indicates the cases where results or scientists from less prestigious institutions are considered of lower quality.

One example is the discrepancy between the number of vaccines approved by the European Medicines Agency versus the World Health Organization, where some vaccines were considered inadequate for the former. This has led to confusion, skepticism, and an increased sense of injustice (Sikimić 2022).

Online adaptation

To mitigate research issues arising from the pandemic, research institutions strongly reinforced techniques allowing online work and collaboration by video-conferencing. For example, new portals for sharing scientific data, such as the European COVID-19 Data Portal, emerged, and conferences and workshops were held online (Korbel and Stegle 2020). Social media were also found to facilitate the dissemination of information. However, curating data effectively and extracting meaningful information from social media remains a challenge.

Despite shutdowns, electronic communications systems allowed researchers to participate in various collaborative endeavors (Korbel and Stegle 2020). Due to its effectiveness, electronic communication was initially targeted at COVID research and then rapidly transferred to most research disciplines. Sometimes, work unfinished in the lab was enhanced by exchanging information with theoretical researchers, improving the quality of published articles. In other words, online work allows more time to think compared with experimental work, where scientists, in particular students, tend to jump rapidly from one experiment to another without taking the time to explore the meaning of their results in depth.

Figure 1 depicts the main changes induced by the pandemic in 2020. Before the pandemic, collaboration was done face-to-face with information shared within local groups. At that time, computers were mainly used to improve presentation. Although online tools were already available, e.g., for online teaching and research discussions, they were rarely used by universities. Moreover, data storage database processing was done mainly in local servers and computers. During the pandemic, we observed sharp and rapid changes such as an intense development of online tools for meetings, teaching, cloud storing, data sharing, and social media. As a result, platforms such as Zoom, Google Meet, or Microsoft Teams registered an unprecedented rise in the number of users and services provided. This allowed a tighter connection between people in different areas and demonstrated that even the most change-resistant institutions could adopt new technologies when needed.

The conference format underwent significant changes during the pandemic. Due to the various restrictions, most topical conferences were suspended or transformed into online meetings. On-site laboratory and project meetings

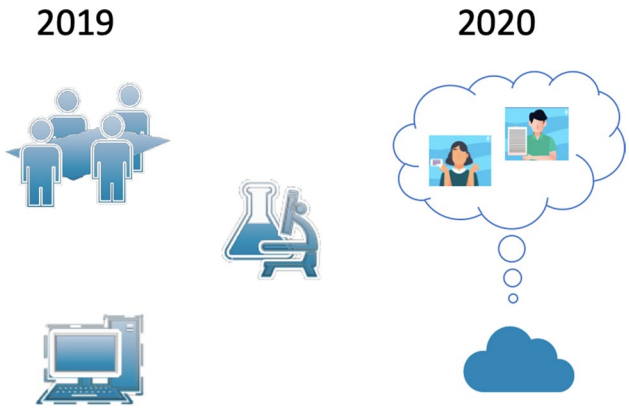

Fig. 1 Research before the pandemic in 2019 involved mainly local meetings, teaching, experiments, computers, and servers. The pandemic in 2020 has fostered remote meetings, distant teaching, international collaboration, and the use of cloud services

were rapidly converted into online sessions. Indeed, these types of gatherings are essential for learning, dissemination, and creating collaboration. Virtual meetings presented advantages such as easy accessibility to many individuals located anywhere, and reduced meeting organization and participant accommodation costs (Reinhard et al. 2021). These meetings have fostered international collaboration. Moreover, virtual conferences display a much lower environmental price (Donlon 2021). Virtual conferences also save much traveling time. These benefits make virtual meetings attractive to young scientists and underfunded academics from developing countries. Social media tools allow for the improvement of the attractiveness of these events. For example, backchannels on Twitter enhance immersion and communication, live streams increase awareness, and video recordings and archiving perpetuate information availability (Atkinson 2009). However, a virtual conference environment does not provide the same level of social networking, camaraderie, and connection that an in-person conference can offer (Reinhard et al. 2021). Nevertheless, virtual conferencing must not be dismissed, and a mixed format of both online and in-person meetings is promising for future research.

Overall, although the COVID pandemic induced adverse effects on many societal aspects, the lockdowns stimulated a rapid adaptation of research with the development of online practices that will undoubtedly improve research.

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