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Is Science Able to Perform Under Pressure? Insights from COVID-19

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Is Science Able to Perform Under Pressure? Insights from COVID-19

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Abstract: *Although science has been an incredibly powerful and revolutionary force, it is not clear whether science is suited to performance under pressure; generally, science achieves best in its usual comfort zone of patience, caution, and slowness. But if science is organized knowledge and acts as a guiding force for making informed decisions, it is important to understand how science and scientists perform as a reliable and valuable institution in a global crisis such as COVID-19. This paper provides insights and reflections looking at aspects such as speed, transparency, trust, data sharing, scientists in the political arena, and the psychology of scientists; all of which are areas inviting more detailed investigation by future studies conducting systematic empirical studies.*

If national and international researchers can work together on a collaborative and coordinated research agenda, and include input from the population at risk, the global community has the best chance at being prepared for the next outbreak.

US National Academies of Sciences, Engineering, and Medicine (2014). Committee on Clinical Trials During the 2014–2015 Ebola Outbreak

If your brain is too busy, you won't hear or see well

Abraham Maslow (1969, p. 11)

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I would advise all in general that they would take into serious consideration that true and genuine ends of knowledge; that they seek it neither for pleasure, or contention, or contempt of others or for profit or fame, or for honour and promotion; or suchlike adulterate or inferior ends; but for the merit and emolument of life, and that they regulate and perfect the same in charity; for the desire of power was the fall of angels; the desire of knowledge the fall of men; but in charity there is no excess, neither men nor angels ever incurred danger by it.

Francis Bacon, The Great Instauration

"The time has come", the Walrus said,
"To talk of many things:
Of shoes – and ships – and sealing-wax-
Of cabbages – and kings-
And why the sea is boiling hot-
And whether pigs have wings."

Lewis Carrol, Alice

Introduction

Historically, science is an incredible powerful and revolutionary force, dispelling many of the unfounded traditional beliefs with often disastrous consequences; for example, witchcraft, illnesses attributed to sorcery or insanity due to possession by evil spirits, and the practice of human sacrifice (Russell 1985). Science is powerful because scientific progress and discovery build up over time in incremental steps (Simon 1996) and because it follows a clear set of grounded rules in which it operates (Gribbin 2002). Doubt, for example, is a powerful tool that guides science through the process of questioning, refining, and replacing (Nettle 2018). As Feynman (1999, p. 185) points out, science is "the result of the discovery that it is worthwhile rechecking by new direct experience, and not necessarily trusting the race experience from the past". Thus, science is organized knowledge (Medawar 1984). Most of the work is done by "normal scientists" who are "like those tiny marine animals building up a common coral reef (Maslow 1966, p. 2), and their diversity contributes to a healthy ecosystem. In that sense it is "knowledge hard won, in which we have much more confidence than we have in opinion, hearsay and belief" (Medawar 1984, p. 3).

But science has also been criticized for its detachment from the person-in-the-street. For example, Dunbar (1995) argues that science "has become a form of magic practiced by an élite priesthood whose members have been subjected to a long and arduous apprenticeship in secret arts and rites from which the layman is firmly excluded" (p. 7). Even fields – such as economics – with strong links to the 'outside world' have not been free of such criticism. Clower (1993, p. 23), a former editor of the prestigious economic journal *American Economic Review*, states that "[m]uch of economics is so far removed from anything that remotely resembles the real world that it is often difficult for economists to take their subject seriously". Mark Blaug (1997) made important contributions related to the history of economic thought and the methodology of economics, noting that "[m]odern economics is sick; economics has increasingly become an intellectual game played for its own sake and not for its practical consequences" (p. 3). Also several well-known economists and Nobel Prize recipients in economics have criticized their field for its lack of involvement in real life issues (for a discussion, see Chan et al. 2016). Shiller (2019) points out that [u]ltimately, the objective of forecasting is to intervene now to change future outcomes for society's benefit", (p. xv) yet we know that attempts at accurate forecasts of macroeconomic changes beyond a couple of quarters into the future quickly become worthless (p. xiv).

In addition, science tends to protect the methods, opinions, and innovations by those with inside access while barring outsiders; resulting in navel-gazing research questions of little import to society or even science as a whole (Frijters and Torgler 2019). Others criticize endless repetition of old ideas in social sciences (Alvesson et al. 2017). A division of labor promotes different ideas, instruments, and conclusions; nobody wants to listen to an orchestra with musicians who only play the bassoon or the oboe. Specialization is a result of prizing the production of knowledge (Stigler 1985), but an increasing *over*specialization or insularity makes scientists unintelligible to each other and the public, ensuring nobody can see the whole picture (Medawar 1984). Nobel laureate George Stigler (1985) points out in his *Memoirs of an Unregulated Economist* that "[u]niversities cater to more highly specialized human beings than most other callings in life. If X is a great mathematician, he will be more or less silently endured even though he dresses like a hobo, has the table manners of a chimpanzee, and also achieves new depts of incomprehensibility in teaching. His great strength is highly prized; his many faults are tolerated" (p. 31). He adds: "I should not exaggerate the virtuous single-mindedness of the university's search for scholarly ability. Because of personal characteristics or behavior a maverick type like Thorstein Veblen or Abba Lerner found it much harder to receive the recognition his scientific abilities deserve" (p. 31). The consilience of different fields and approaches to knowledge (Wilson 1998) aid in the understanding of real and human phenomena, particularly when exploring sudden and surprising shocks, changes, or crises

(Shiller 2019). Wilson (1998) sees the reduction of the gaps between branches of science as a way of increasing diversity and depth of knowledge, classifying the attempting to link sciences with humanities as the "greatest enterprise of the mind" (p. 8). Stigler (1985) also acknowledges that Adam Smith "in fact severely condemned the narrowness of vision and thought that he believed would result from excessive specialization" (p. 33), even as he gave us insights of the power of increased division of labor.

The term science (scientia) is derived from Latin term 'scire' which means to know, and while the pursuit of knowledge and understanding is noble in and of itself, it raises an important question: What do we want from science? Specifically, what is it that we and our societies want science to provide. For science to benefit humankind, it needs to have social function, i.e. some benefit outside of itself. John D. Bernal (1938), for example, argued that science should contribute to satisfy the material needs of ordinary human life and that it should be centrally controlled by the state to maximize its utility (benefit), other such as John R. Baker who favored the more liberal free-science approach in the spirit of Bacon who emphasized that "the advancement of knowledge by scientific research has a value as an end in itself" (Baker cited in McGucken 1978, p. 46). This was echoed in Thomas Henry Huxley's (1887) reception of Darwin's newly published *Origin of Species*: "The known is finite, the unknown infinite; intellectually we stand on an islet in the midst of an illimitable ocean of inexplicability. Our business in every generation is to reclaim a little more land, to add something to the extent and the solidity of our possessions" (Darwin 1896, p. 557). For none of us are clairvoyant enough to know what science will become useful and shape the future and which will be left on a shelf and forgotten by all but the author. A perfect example of this was the creation of Boole's (1847) *Mathematical Analysis of Logic*, where argued with philosophy that logic should be in the preview of mathematics, not philosophy. Little did he or anyone else understand that his exercises in mathematical logic, which were completely useless (impractical) at the time, was to become the foundation of all modern computing and technology.

Thus, the question arises over whether such detachment from reality and the subsequent issues it raises may affect how scientists manage the demands for fast, efficient, and flexible knowledge generation in a crisis. If science is *organized knowledge*, science should also be functional in a crisis, a situation where feeding back into the decision-making process becomes essential. In other words, is science as an institution able to perform under pressure? A global crisis such as the current COVID-19 pandemic is therefore an interesting situation to analyze and reflect upon; scientists are challenged in a key part of their science, namely their judgment around what to observe and to which phenomena or information should they pay attention (Feynman 1999, p. 173). Science, one would expect, would be able to provide valuable information and knowledge that can guide policy decisions in times of crisis. Good science must be versatile and adaptable while maintaining caution and skepticism (Maslow 1969). A pandemic moves scientists away from their usual comfort zone of being primarily patient, cautious, and slow (Maslow 1969). The "art of not making mistakes" is challenged. On the other hand, it also naturally attracts scientists to important problems, rather than remaining stuck in method-centered endeavors that are technically elegant but potentially less useful to society. We therefore aim to provide insights on the capacity and adaptability of science during the COVID-19 crisis.

COVID-19 Crisis

The Curses and Challenges of Speed

Snowden (2019) notes that historically, "major epidemics caught authorities unprepared, leading to confusion, chaos, and improvisation" (p. 77). The urgency of a crisis and its pressing concerns automatically makes the public and the government impatient to find solutions. From a clinical perspective, for example, conducting trials of novel interventions during pandemic emergencies such as COVID-19 becomes increasingly important for the success in identifying potential vaccines or therapies and controlling the spread of an infectious disease (Dean et al. 2020).

Lessons from Past and Current Experiences

Lessons from the testing of Ebola treatments indicate that research responses were implemented late, despite rapid protocol approval by ethics committees and the devising of transparent and pragmatic protocols. However, bureaucratic and logistical barriers slowed down the clinical trial phase (Lang 2015); for example, difficulties in deploying staff and delays over contracts were identified as key elements for the slowdown. Consequently, it was clear that the world needed to "be 'research ready' for the next outbreak" (Lang 2015, p. 30). Lang (2015) suggested the assembly of an on-call global task force of around 100-200 clinical-trial staff, available for everyday studies and trained for outbreak research. Contractual agreements between parties with stakes in clinical trials are predictably required, something that can be addressed ahead of time using contract templates. Lang (2015) also recommended a neutral, independent body that sets research priorities during an epidemic. Lang suggested the WHO, but criticized the agency for lacking the necessary funds, mandate and support. Similarly, Keusch et al. (2017) suggested international coordination and cooperation for the next outbreak. In developing countries, the limited local experience with clinical research and poor capacity for timely scientific and ethical review or negotiation of research contracts combined with differing views of trial designs and reactions slowed down the process (Keusch et al. 2017). In addition, volunteers may be fearful, vulnerable, stigmatized and confused about goals, benefits, and risk of trial. Thus, a relationship of mutual trust relationship between researchers and participants is required, otherwise misunderstandings and resistance become the norm (Keusch et al. 2017, p. 2456). The *US National Academies of Sciences, Engineering and Medicine* evaluated the clinical trials on Ebola in a special report, providing recommendations on how to improve the likelihood that important new information on therapeutics and vaccines are obtained in future epidemics. The key points of the report related to the development of sustainable health systems and research capacities in low-income countries; facilitation of data collection and sharing; facilitation of rapid ethics reviews and legal agreements; ensuring capacity-strengthening efforts that benefit the local population; incorporation of research into national health systems; prioritizing communication of engagement in research, and response and fund training; and research into community and coordinated international efforts (p. 2456). The report also emphasizes the importance of maintaining ethical standards: "The high mortality of Ebola and the uncertainty about how the epidemic would progress produced a sense of urgency to quickly identify effective therapeutics or vaccines. Despite this sense of urgency, research during an epidemic is still subject to the same core scientific and ethical requirements that govern all research on human subjects" (p. 33). In addition, the report also recommended a *Coalition of International Stakeholders* including representation from governments, WHO, academia, the private sector, humanitarian response organizations, and the countries and communities at risk (Keusch et al. 2017, p. 2457). To avoid being a "toothless tiger" the report recommended that such a coalition should secure financial resources to lead the effort and should have the responsibility and resources to convene a fast response. The World Health Organization has developed guidance and tools into how to frame collaborations and exchanges. At the request of member states, it has developed a Blueprint for accelerating research and development in epidemics or health emergencies to address situations with no or insufficient preventive and curative solutions[1]. London and Kimmelman (2020) strongly criticize the attitude towards research exceptionalism during the COVID-19 crisis. To balance scientific rigor against the danger of speed they urge following the five conditions of informativeness and social value of research proposed by Zarin et al. (2019): "(1) the study hypothesis must address an important and unresolved scientific, medical, or policy question; (2) the study must be designed to provide meaningful evidence related to this question; (3) the study must be demonstrably feasible (e.g., it must have a realistic plan for recruiting sufficient participants); (4) the study must be conducted and analyzed in a scientifically valid manner; and (5) the study must report methods and results accurately, completely, and promptly. Trials that do not meet all of these conditions are very likely to be uninformative" (p. 813). In general, the number of studies on COVID-19 until May 01 has already reached very high numbers (Table 1) compared to previous pandemics (see, e.g., SARS 2002-2003 figures). Not surprisingly, a large share of currently published articles on COVID-19 are in the fields of medicine, immunology and microbiology, or biochemistry, genetics and molecular biology (see also Table A1).

Table 1: Number of Studies Exploring Different Pandemics until May 01, 2020

Field	Ebola	SARS (2002-2003)	SARS (since 2002)	Covid19
Medicine	3747	719	5369	2057
Immunology and Microbiology	1568	38	1840	243
Biochemistry, Genetics and Molecular Biology	1280	151	2911	202
Social Sciences	562	15	523	100
Pharmacology, Toxicology and Pharmaceutics	436	66	1399	93
Environmental Science	291	23	772	92
Health Professions	121	6	114	64
Nursing	223	27	176	60
Neuroscience	70	7	152	53
Engineering	148	54	585	40
Computer Science	119	10	277	37
Agricultural and Biological Sciences	688	88	2133	36
Multidisciplinary	431	34	388	35
Psychology	34		72	32
Mathematics	197	21	264	24
Dentistry	2	2	17	21
Business, Management and Accounting	78	40	204	21

[1] https://www.who.int/blueprint/about/r_d_blueprint_plan_of_action.pdf

Chemistry	189	47	1102	15
Energy	2		46	15
Chemical Engineering	79	20	243	14
Materials Science	68	32	239	13
Physics and Astronomy	78	24	344	13
Economics, Econometrics and Finance	43	7	65	11
Arts and Humanities	107	1	87	9
Decision Sciences	21	3	42	6
Veterinary	128	4	100	5
Earth and Planetary Sciences	30	21	475	1
Undefined	1		15	

Note: Scopus contribution based on a search conducted May 1, 2020.

Partnerships between Government Agencies and Scientists

A crisis such as a global pandemic demands close interactions between scientists, government agencies, and politicians. However, building and maintaining this relationship has been challenging in the past. Medawar (1984), for example, criticizes that "politicians tend to have a low opinion and an unaccountably resentful attitude toward science and scientists" (p. 19). Similarly, scientists are critical when it comes to politicians, the former accusing the latter of being subject to an action bias[2] (Ioannidis 2020). An extreme negative example is Trump, who abruptly fired a senior US government doctor, Rick Bright from his position as the director of the US health department's Biomedical Advanced Research and Development Authority and as Deputy Assistant Secretary for Preparedness and Response. Bright stated that the dismissal was due to his refusal to embrace hydroxychloroquine, a malaria drug promoted by Trump without scientific evidence[3]. He further stated that he was pressured to direct money toward that drug by those with political connections, but if we are to "combat this deadly virus, science – not politics or cronyism – has to lead the way"[4]. M. Granger Morgan – a Carnegie Mellon University engineer, policy professor, and advisor to past administrations – was asked what kind of grade he would give Trump. Morgan quickly answered that Trump receives an F, criticizing how presidents often put politics before science[5]. Steven Chu – the Nobelist who

[2] For more details on action bias see, e.g., Patt and Zeckhauser (2000).
[3] See, e.g., https://www.nytimes.com/2020/04/22/us/politics/rick-bright-trump-hydroxychloroquine-coronavirus.html or https://www.theguardian.com/world/2020/apr/22/rick-bright-trump-hydroxychloroquine-coronavirus
[4] https://www.nytimes.com/2020/04/22/us/politics/rick-bright-trump-hydroxychloroquine-coronavirus.html. For an interview of *Science* with Anthony Fauci, see https://www.sciencemag.org/news/2020/03/i-m-going-keep-pushing-anthony-fauci-tries-make-white-house-listen-facts-pandemic
[5] https://www.haaretz.com/science-and-health/disinfectant-coronavirus-riff-is-latest-of-many-trump-science-clashes-1.8799575

was energy secretary under Obama – criticized Trump's recent statement regarding disinfectants: "When he starts to air things like that (injection), it's definitely a danger to the public because some people might actually do that. This isn't science. This is something else" [6]. Lack of an honest portrayal of partial knowledge can lead to dilettantism and quackery and the failure to humbly listen – without presupposing, classifying, or approving or disapproving, or dueling with what has been said – and that can reduce credibility[7]. In his book *Epidemics and Society,* Snowden (2019) concludes that "[p]lague regulations also cast a long shadow over political history. They marked a vast extension of state power into spheres of human life that had never before been subject to authority. One reason for the temptation in later periods to resort to plague regulations was precisely that they provided justification for the extension of power, whether invoked against plague or, later, against cholera and other diseases... With the unanswerable argument of a public health emergency, this extension of power was welcomed by the church and by powerful political and medical voices. The campaign against plague marked a moment in the emergence of absolutism, and more generally, it promoted an accretion of the power and legitimation of the modern state" (pp. 81-82). The parliament in Hungary gave Prime Minister Viktor Orbán, for example, the right to rule indefinitely by decree. Dr Balazs Rekassy, a former manager of a state health clinic criticized that Orbán is trying to strengthen his power to create a long-term political advantage[8]. In a podcast with Sam Harris (Making Sense), the historian Yuval Noah Harari expressed his worries about the political situation in Israel[9], stressing that even at the beginning of the crisis, Israel's unelected prime minister used the situation as an excuse to try to shut down the elected parliament and rule de facto with emergency decrees. He received enough pushback to reopen the parliament to maintain a democratic balance.

The politicization of scientific methods can be dangerous. Science is not some magic bullet that can slay the monsters that haunt us, nor can it solve all the world ills with a wave of its microscopes. It can, however, inform and provide a range of options and solutions to problems, which might be feasible and predict what the outcomes of them *might* be. In general science does not directly answer questions of what ethics, morality, fairness or social acceptability *should be* - the social sciences sometimes report on what they currently *are*. The

[6] https://www.haaretz.com/science-and-health/disinfectant-coronavirus-riff-is-latest-of-many-trump-science-clashes-1.8799575
[7] It is no surprise that Trump's behaviour is a constant topic of ridicule from comedians hosting daily shows, such Jimmy Kimmel or Stephen Colbert.
[8] https://www.nytimes.com/2020/04/05/world/europe/victor-orban-coronavirus.html
[9] https://samharris.org/podcasts/201-may-1-2020/

role of science is to advise not to rule or decree - that is the role for decision makers (democratically elected or not). Politicians have seen the power that science backed evidence can have on public opinion, and its ability to sway or win over an argument. Unfortunately, “what politicians want is not evidence-based policy rather but policy-based evidence” (Henderson, 2012, p.70). If science is abused for political gain and not society’s benefit by, for example, cherry picking evidence that supports their beliefs (or pet policy) rather than examining all the evidence to create a functional policy has often been observed, the general public may also lose trust in science as many are not used to scientific terminology or methods applied to make science testable, repeatable and falsifiable (Popper 1992). Feynman (1998), for example, argues that we are not living in an unscientific age: “Sometimes when history looks back at this age they will see that it was a most dramatic and remarkable age, the transformation from not knowing much about the world to knowing a great deal more than was known before. But if you mean that this is an age of science in the sense that in art, in literature, and in people’s attitudes and understandings, and so forth science plays a large part, I don’t think it is a scientific age at all” (p. 63). Richard Dawkins, for example, provides a wonderful discussion on scientific terminology: “Confusion of a different kind is introduced by those who agree to abandon “theory of evolution” but try to replace it by “law of evolution.” It is far from clear that evolution is a law in the sense of Newton’s Laws or Kepler’s Laws or Boyle’s Law or Snell’s Law. These are mathematical relationships, generalisations about the real world that are found to hold true when measurements are made. Evolution is not a law in that sense (although particular generalisations such as Dollo’s Law and Cope’s Law have been somewhat dubiously introduced into the corpus of Darwinian theory). Moreover, “Law of Evolution” conjures up unfortunate associations with grandiose overgeneralisations linking biological evolution, cultural evolution, linguistic evolution, economic evolution and evolution of the universe. So please, don’t make matters worse by turning evolution into a law”[10]. The political abuse of science and the lack of scientific training in the political class can result in large scale policy failures as evident in the March 2010 eruption of Eyjafjallajökull volcano in Iceland (Henderson, 2012). As soon as the eruption was detected an instant no-fly zone was declared across Europe, as volcanic ash can melt and destroy jet engines, but no one tested of examined the levels of ash in the atmosphere (which was much lower than any previous examination). Fairly quickly the industry tested the ash levels and revised the safety threshold for ash in the air and flights resumed - but not before immense economic damage had been done. The

[10] https://www.richarddawkins.net/2015/11/is-it-a-theory-is-it-a-law-no-its-a-fact /

government response to the threat was to impose a blunt and heavy-handed knee-jerk reaction to safety that effectively cost the airline industry an estimated £2.2 billion. “We have been left with the impression that while science is used effectively to aid the response to emergencies, government attitude to scientific advice is that it is something to reach for once in emergency habits, not a key factor for consideration from the start of the planning process,” the select committee concluded (quoted in Henderson, 2012, p.87). This is not dissimilar in nature to the automatic lockdown measures seen as a response to COVID-19.

Scientists in general, struggle with politicians’ lack of patience, and understanding for sound and credible assumptions behind the models and data when supporting policy choices. In a global crisis, in particular, it is challenging to strike a scientific balance between simplicity and concision, or total comprehensiveness and inclusiveness. Political pressure may lead to biases, such as wishful extrapolations driven by untenable assumptions. As Manski (2013, p. 27) stresses, “[w]hen researchers overreach, they not only give away their own credibility, but they diminish public trust in science more generally” (p. 27). Such damages can be particularly severe in a time of crisis. There is some ignorance or even “innocence” of handling human choices in situations that arise so infrequently which produces planning and dilemma problems. Thus, partnerships between government agencies can be challenged during a crisis due to impractical and condensed time frames on alliances that otherwise require substantial efforts, investment, and adjustments when establishing an effective framework (Doe-Anderson et al. 2016). Social science research struggles with unobservability of counterfactual outcomes in a crisis, and the lack of time or willingness to conduct systematically randomized field experiments hamper causal insights. Pandemics are extremely challenging to investigate from an empirical point of view due the complex nature of social interactions. Thus, the risk of unequivocal policy recommendations increases. It is understandable that concerned citizens as well as civil servants, journalists, and politicians have limited understanding of the prediction methods necessary to assess immediate dangers within a crisis. Derivation of reliable insights during a pandemic requires a never-ending interplay of theoretical abstraction and real data on lived experiences. The denial of doubt, confusion, or the lack of versality may affect the quality (or even the existence) of such an interplay. Although different studies might be coherent internally, studies conducted at the beginning of a crisis are subject to fragile foundations of weak data which undermine its findings. In addition, crises demand a higher level of certitude and lower tolerance for ambiguity about the consequences of alternative decisions; a problem for science as policy predictions are often fragile (Manski 2013). Maslow (1969) considers the ability to admit ignorance as a defining characteristic of an empirical or scientific attitude (p. 71). Even in normal times, we seldom find policy reports that chronicle, for example, *interval predictions* of policy outcomes. Manski (2007) cites President Lyndon B. Johnson's response to an economist report offering a range for forecast values: "Ranges are for cattle. Give me a number" (p. 8). Ioannidis (2020) discusses the implications of an action bias: "adoption of measures in one institution, jurisdiction or country creates pressure for taking similar measures elsewhere under fear of being accused of negligence. Moreover, many countries pass legislation that allocates major resources and funding to the coronavirus response. This is justified, but the exact allocation priorities can become irrational" (p. 2).

On the other hand, a pandemic can change scientific norms. Many scientists avoid being subjected to imprecise, undefined, or even non-manageable problems. But a crisis may encourage acceptance and embrace of the mentality 'what needs doing, is worth doing even though *not* very well'. The first effort to research a new problem is often inelegant, imprecise, and crude (Maslow 1969, p. 14). Such efforts help others understand what needs improving to advance knowledge in the area. In addition, if scholars are able and willing to reveal their experienced uncertainty and ambiguity, faster feedback can be provided on how to improve knowledge. As Maslow states, "[S]omebody has to be the first one through the mine fields" (p. 14).

The dangers of a contest over priority

Just like any other institution, science is subject to several pathologies driven by the reward system; pathologies that are often a mere expression of human nature. As Merton (1973) emphasizes, "[o]ur religion, our moral fabric, our very basis of life are centered around the idea of reward" (p. 321). The contest over priority is a key one, already discussed in great detail by sociologists such as Merton (1973). Major scholars in the history of science have been subject to hostile battles over priorities, revealing the supreme value of originality as a mechanism of advancing science. Newton, for example, fought battles with Robert Hook over priority in optics and celestial mechanics or Leibniz over the invention of calculus (Merton, p. 287). Not even brotherly love can prevent such feuds as evident in the repeatedly bitter attacks between Jacob and Johannes Bernoulli (p. 313). According to Merton, even the sensitive and modest Faraday was wounded by the claims of others to several of his key discoveries (p. 288). In addition, like other professions, science attracts ego-centered people who are hungry for fame

(p. 290) or recognition (p. 293) as symbols of having done one's job well. Merton quotes Darwin who once emphasized that his "love of natural science … has been much aided by the ambition to be esteemed by my fellow naturalists" (p. 293).

It is natural that scientists in all domains are eager and impatient to contribute their efforts to our understanding of and coping with the global pandemic. Thus, excessive concerns with success in scientific work can lead to some negative effects in a time of a crisis such as COVID-19; effects that can deteriorate some academic standards. The competition for journal publication may encourage scientists to announce their results quickly, although over time the scrutiny of science will provide some readjustments of what is perceived as relevant: "The large majority of scientists, like the large majority of artists, writers, doctors, bankers and bookkeepers, have little prospect of great and decisive originality. For most of us artisans of research, getting things into print becomes a symbolic equivalent to making a scientific discovery" (Merton 1973, p. 316). Ioannidis (2020) has flagged the dangers of exaggerated information and non-evidence-based measures. He provides examples of articles in the *New England Journal of Medicine* and the *Lancet*, indicating that even top journals are not free of sensationalism. He also criticizes that "peer review may malfunction when there is little evidence and strong opinions. Opinion-based peer review may even solidify a literature of spurious statements" (p. 1). Furthermore, Ioannidis (2020) is critical of how the circulation of exaggerated estimates can even come from otherwise excellent scientists, listing pandemic estimates around cases of fatalities and exponential community spread as examples. He also criticizes adoption of extreme measures with unknown effectiveness, stressing the lack of evidence for the most aggressive measures. He cites a review study that found for past events insufficient evidence on entry port screening and social distancing (Jefferson et al. 2011). He also refers to the potential harms of impulsive actions such as panic buying of face masks that result in shortages among medical personnel. In addition, contrary to many economists, he pointed out very early the risks of misallocation of resources and economic and social distribution. For example, "if only part of resources mobilized to implement extreme measures for COVID-19 had been invested towards enhancing influenza vaccination uptake, tens of thousands of influenza deaths might have been averted" (p. 1). He is also concerned that "some political decisions may be confounded with alternative motives. Lockdowns weaponized by suppressive regimes can create a precedent for easy adoption in the future" (p. 3), a point also raised by other scholars, referring, for example, to the situation in Hungary (Eichenberger et al. 2020). Dean et al. (2020) suggest the need to "balance the importance of publishing the results of all completed clinical trials against the potential adverse consequences if published results do not provide reliable answers to the questions that the trials were designed to address" (pp. 1366-1367).

Trust in Scientists

Trust is science can help society as it informs politicians, legitimizing political decisions (Bogner and Torgersen 2005 in Huber, et al. 2019), and allows for individuals to form opinions about important political issues (Huber et al. 2019). Evidence indicates that as complexity increases individuals rely more on trusted representation (Stadelmann and Torgler 2013). Trust in science may help in guaranteeing preparedness and response-ability (Balog-Wag and McComas 2020) and can influence compliance with prevention guidelines (Plohl and Musil 2020, Balog-Way and McComas 2020). A UK poll indicated that trust in scientists has grown as fake coronavirus news increased[11]. Additionally, research in science is reliant on a public willingness to participate in research studies and on public funding (Medical Research Council 2016). Therefore, if society does not have trust in science, it can become problematic. Definitions put forward on trust such by Rousseau et al. (1998), outlines trust to be a psychological state, "comprising the intention to accept vulnerability based upon positive expectations of the intentions or behaviour of another" (p. 395), and Gambetta (1988) describing trust as "the probability that [someone] will perform an action that is beneficial or at least not detrimental to us is high enough for us to consider engaging in some form of cooperation with [them]" (p. 217). In other words, these definitions indicate that trust can be considered to be reliant on the good will of others, although Mayer et al. (1995) have identified trust in others to comprise of factors such as expertise, integrity, and benevolence. Regardless, the concept of trustworthiness in scientists is a debated topic. In a British sample from a European Commission (2013) survey, 52% of participants agreed with the statement "information they hear about science is generally true", with 40% of those participants further stating that they had no reason to doubt the scientists. With reference to the assumed competence of scientists, 66% of participants agreed to the statement "university scientists are qualified to give explanations about the impact of scientific and technological developments on society", while in contrast, only 35% of participants felt scientists working for private

[11] https://www.theguardian.com/world/2020/may/05/trust-in-scientists-grows-as-fake-coronavirus-news-rises-uk-poll-finds

companies were qualified. An American sample from a more recent survey found that participants trust in scientists more than business leaders and elected officials (Pew Research Center 2019). Results found 86% of participants to have, at minimum, "a fair amount" of confidence that scientists act in the interest of the public. However, researchers have found trust in certain topics, such as climate change, indicate a lower trust than that in general science (Hamilton et al. 2015). Pew Research Center (2015) studies have found adults to be skeptical towards climate change, with only 50% of participants, in an American sample, agreeing climate change occurs as a result of human activity. While in another American survey (Nationwide POLE survey) following the 2015 outbreak of Zika virus, participants were asked if they trust information from agencies such as the Centres for Disease Control, with 73% responding "they trusted science agencies for information about the Zika virus" (Hamilton and Safford 2020).

It appears that the relationship between science and religion is again breaking down to levels not seen perhaps since the persecution of Galileo by the Catholic Church in 1633. Where the Church proclaimed "We pronounce, judge, and declare, that you, the said Galileo … have rendered yourself vehemently suspected by this Holy Office of heresy, that is, of having believed and held the doctrine (which is false and contrary to the Holy and Divine Scriptures) that the sun is the center of the world, and that it does not move from east to west, and that the earth does move, and is not the center of the world".[12] What is driving this new divide seems to be a regression to a significant lower level of general education and a lack of understanding of what science is. To many of the undereducated in our modern society science is viewed as witchcraft (Brackett 1942) and technology becomes indistinguishable from magic (Clarke 1973). Religion and pseudo-science are on the rise, along with a substantial increase in fundamentalist anti-science thought and belief in scientific conspiracy. From *Flat Earth* societies, *Anti-Vaccination* movements, and a plethora of *Space Fraud* societies (basically anything to do with Space and NASA is deemed to be *fake news)*.[13] As Feynman (1998) stresses, the "problem is *not* what is possible. That's not the problem. The problem is what is probable, what is happening. It does no good to demonstrate again and again that you can't disprove that this could be a flying saucer. We have to guess ahead of time whether we have to

[12] Quote sourced from https://www.history.com/this-day-in-history/galileo-is-convicted-of-heresy

[13] For example, 5G cell towers cause radiation (or maybe COVID-10); high altitude aircraft are generating `chem-trails' polluting the world; the CERN supercollider is attempting to open a gate to the underworld (Hell) to bring forth the apocalypse.

worry about the Martian invasion. We have to make a judgment about whether it is a flying saucer, whether it's reasonable, whether it's likely" (p. 77).

In 2020 science and religion has once again come to a significant fork in the road with the emergence of the coronavirus (COVID-19) pandemic, some are happy to have science and religion co-exist without any conflict. For example, Tsamakis (2020) cites a cartoon in his *British Medical Journal* rapid response article circulating in the Greek social media depicting a scientist looking through his microscope, while religious leaders are standing next to him in profound anxiety. One of them cries out: "please son, please hurry, we need to tell the flock that our prayers have been heard". However, we also have the religious extremists who want no part in the heretical science, atheist types and refuse to adopt measures designed to help stop the spread of the pandemic. Some religious leaders continued to conduct religious services in packed out churches, claiming that "god will save them as they are religious people". The anti-science or pseudo-science beliefs were famously described by Richard Feynman as 'cargo-cult' science (Feynman 1974, so named after the Papua New Guinean tribes who observed that during the Second World War American planes brought valuable cargo such as clothing, food and medicine). However, after the war and when the planes stopped coming the tribes started building imitation landing strips which they believed would summon the planes to return with their precious cargo. Many of the modern anti-science hoaxers and non-believers are truly 'cargo-cultists' they use technology everyday (computers, phones, TV etc.) and understand its value but have absolutely no idea how it works. Unfortunately, they are unable (or unwilling) to extend this to vaccinations, or scientific ideology that can actually save lives. Is it any great surprise that we see (armed) protests against the pandemic health measures in the United States, especially in the so-called Bible Belt and the South where religion has much more sway than science and education. In most US states there are religious exemptions to social distancing rules,[14] clear evidence that here religion *Trump*'s the science of COVID-19.

Psychology of Scientists

Pandemics lack the kind of empirical knowledge around decisional processes that we prefer. Emerging hard facts about the actual world are therefore often harder to apply in a systematic

[14] https://www.pewresearch.org/fact-tank/2020/04/27/most-states-have-religious-exemptions-to-covid-19-social-distancing-rules/

and rigorous way, using theory or available tools of thought and exploration. For example, media coverage during pandemics is often overreaching, which challenges the demands inherent to the seriousness and informative nature of a policy analysis. Impulsivity or arbitrary whimsicality and emotionality are more likely to emerge in a pandemic, and scientists are not free of such emotions. A conversation provided by Kong and Chan (2020) in *Science* offers a window into the emotional turmoil personally faced by scientists during COVID-19. As Ben-Haim (2018) stresses, "[n]othing is as ancient as the feeling that some things are beyond our control" (p. 27). Being directly subject to and absorbed with potential risks trigger emotional responses that may affect a scientist's judgement. Scientists are no longer passive spectators like a viewer of a movie. Their suggestions can have direct and rapid impact on their lives and the lives of their beloved ones; thus ambiguity and uncertainty may trigger feelings or dislikes akin to skating on thin ice. One cannot assume that scientists are always cool, sober, or stern despite being usually skilled, competent, professional, knowledgeable, and learned. It is questionable to assume that science is free of human values (: "our orthodox conception of science as mechanistic and a human seems to me one local part-manifestation or expression of the larger, more inclusive world view of mechanization and dehumanizing" (Maslow 1969). Science does not exist in an intellectual vacuum, thus pressures to be rational, sensible, logical, analytic, precise may even backfire. It is natural that scientists respond to fear with cognitive impulses that could affect their scientific evaluation. As Maslow (1969) points out, "being a full human being is difficult, frightening, and problematic… Thus knowledge includes the defenses against itself, the repressions, the sugar-coatings, the inattentions, the forgettings… any methodology for getting at this truth must include some form of what psychologists call "analysis of the resistance," a way of dissolving fear of the truth about oneself, thus permitting one to perceive himself head on, naked – a scary thing to do" (p. 17). It is unclear as to how much anxiety and how much anxiety-free interests are involved during a crisis but is clear that scientists are subject to a mixture of both. Mastering one's own anxieties around coping with problems is challenging and humans have the tendency to avoid any anxiety-producing confrontation with problems. It is understandable that feelings of safety become an important cognitive element, a way of coping with the pandemic, and also a method of dealing with both anxiety-avoiding and anxiety-controlling mechanisms. Although scientists love knowledge and seek it, they may also fear it. Justin Wolfers – an economist at the University of Michigan – was quoted by a *New York Times* article declaring that "[i]t's useful to adopt the cost-benefit frame, but the moment you do that, the outcomes are so overwhelming that you don't need to fill in the details to know what to do", adding that the only case in which the benefits outweigh the costs is when “the epidemiologists are lying to us about people dying”[15]. In general, scientists may not be free of an optimal sin problem (March 1978) when trying to find solutions. Standard notions of intelligent choices are based on strict morality which means that values and actions are to be consistent. But it is more consistent with our behavior that we do things, or that we need to do things that unfortunately deviate from our values. As March (1978) points out, “saints are a luxury to be encouraged only in small numbers” (p. 603). In the following, we will therefore discuss some of the narratives used by economists to deal with the pandemic. Showing some of the narratives may help to understand beliefs, assumptions, values, thought processes and the psychology of scientists in general.

Scientists, including academics are also not free of the institutional or career pressures that plague every other person in the working world, scientists are usually highly trained (many with 20+ years of education) working in a narrow environment where skills are not easily transferred to another career (van Dalen 2019). Added to this has been the erosion of the ideals of academic freedom and integrity, where once academic and scientists were asked to speak without fear or favour on issues they were expert – now such freedoms only exist on toothless document that are no longer supported by the institutions and university that wrote them. Now governments threaten to regulate freedoms and the withdrawal of funding to ward off evidence and comments that do not support the narrative they wish to paint. Internally there is an ongoing and extreme pressure to ‘publish or perish’ i.e. those that do not publish regularly and in high ranked journals … perish. Such a system has the problem of disregarding other scholarly contributions (Frey 2009) and can lead to boring and irrelevant papers and even to intellectual prostitution (Frey 2003). This is a tight rope to walk, be productive and publish often in high ranked journals, but don’t say anything or do research that may be perceived as controversial or unpopular, make sure you are more successful than your colleagues so when the funding cut happen you are not the first to feel the axe. In short, scientists like academics regularly fear for their jobs.

In a recent open letter petitioning the Prime Minister and Members of the National Cabinet not to sacrifice health for the economy[16] signed by 265 Australian economists, it was not surprising that a large number of the signatories were Go8[17] university scholars, in

[15] https://www.nytimes.com/2020/03/24/business/economy/coronavirus-economy.html
[16] https://theconversation.com/open-letter-from-265-australian-economists-dont-sacrifice-health-for-the-economy-136686
[17] https://go8.edu.au/about/the-go8

particular from the University of Melbourne (including the Melbourne Institute).[18] Among them were recipients of prestigious Australian awards and recognitions, and overseas scholars from universities such as University of Oxford, University of Chicago, University of Toronto, or University of Michigan. The short letter criticizes that the trade-off between the public health and economic aspects are a false distinction, stating that one "cannot have a functioning economy unless we first comprehensively address the public health crisis". The letter also stresses that "We recognise the measures taken to date have come at a cost to economic activity and jobs, but believe these are far outweighed by the lives saved and the avoided economic damage due to an unmitigated contagion". The core initiators also argue in a complementary article published in The Conversation (Hamilton et al. 2020) that "[w]e believe a callous indifference to life is morally objectionable, and that it would be a mistake to expect a premature loosening of restrictions to be beneficial to the economy and jobs, given the rapid rate of contagion"[19].

Oddly, both documents showed very little evidence of the normal tools or lines of thought that an economist would generally employ in their work (either articles or textbooks), and both provided very limited economic insights or rationale. From the discipline known as the 'dismal science' they chose to make *emotional* pleas unsupported by the usual plethora of evaluations or economic justifications. The narrative they used (Shiller 2019) relied on minimizing a loss function, but it was unclear whether it also maximized social welfare, while other economists request a cost-benefit analysis (Eichenberger et al. 2020). A *New York Times* article quotes Walter Scheidel, an economic historian at Stanford who asks "Why is nobody putting some numbers on the economic costs of a monthlong or a yearlong shutdown against the lives saved? The whole discipline is well equipped for it. But there is some reluctance for people to stick their neck out."[20] The same *New York Times* article also quotes Casey Mulligan, a University of Chicago economist who acted as chief economist in Trump's Council of Economic Advisers with the following: "We put a lot of weight on saving lives. But it's not the only consideration. That's why we don't shut down the economy every flu season. They're ignoring the costs of what they're doing. They also have very little clue how many lives they're saving". Another economist, Kip Viscusi, argued in that article that "[m]aking people poorer

[18] For example, University of Melbourne: 66; Monash University: 28; University of Sydney: 24; University of Queensland: 16, ANU: 15.
[19] https://theconversation.com/open-letter-from-265-australian-economists-dont-sacrifice-health-for-the-economy-136686
[20] https://www.nytimes.com/2020/03/24/business/economy/coronavirus-economy.html

has health consequences as well" and that jobless people sometimes commit suicide, and poor people are more likely to die if they become sick, estimating that every loss of $100 million in income from the economy causes one additional death.

One of the few Australian economists willing to 'stick their neck out' was Gigi Foster, a professor from the University of New South Wales who had the temerity to openly discuss on national television (ABC)[21] what real economist deal with every day, i.e. the trade-offs. Specifically, she discussed the lives that would have been lost or sacrificed because of the lockdown,[22] not caused by the pandemic but by the actual lockdown, and for she was heavily criticized[23] by people purporting to be economists. Abul Rizvi, at the Australian National University even tweeted that "Gigi Foster makes me ashamed to be an economist[24]" even Joshua Gans (2020) argues in his recent book *Economics in the Age of COVID-19*, that "pandemics are not the time where trade-offs at the margin are appropriate" emphasizing the need to "balance the needs of the economy with the needs of public health" by combining epidemiological models with economic analysis[25]. However, other economists have made comments consistent with economic thought, emphasizing the statistical lives that may be lost in the future because of the decisions we have already made. "These are the people that will die in years to come because the roads they drive on didn't get repaired because of lack of funds because of the pandemic. These are the people that will die without proper health care because the health sector will have less funds as there is less to go around. These are the people that will die because their doctors, policemen, farmers, and everyone else is somewhat less competent because of the lower education due to the panic we now have. They will be the ones dying from diseases that sewage works would have prevented, but those sewage works were delayed. They will be the millions dying in civil wars as this economic meltdown pushes their social systems over the brink" (Frijters, 2020)[26]. Snowden (2019) concludes his chapter on SARS and Ebola with the observation that "[a]n economic system that neglects what economists euphemistically call "negative externalities" will ultimately exact a heavy cost in terms of public health. Chief among these externalities are the negative effects of certain models of development on the relationship between human beings and their natural and societal environments" (p. 505). Knowledge can be feared and potentially avoided or distorted. But a

[21] https://www.abc.net.au/qanda/2020-20-04/12141184
[22] See, around 12 minutes after the start of the presentation.
[23] https://au.news.yahoo.com/coronavirus-economist-slammed-horrible-lockdown-idea-013505468.html
[24] https://twitter.com/RizviAbul/status/1252203583954546691
[25] https://economics-in-the-age-of-covid-19.pubpub.org/pub/2yyquj1y/release/4
[26] http://clubtroppo.com.au/2020/03/18/has-the-coronavirus-panic-cost-us-at-least-10-million-lives-already/

certain level of abstraction is still necessary during a crisis to avoid what Maslow (1969) calls "total insanity and if we wish to live in the world" (p. 75) while still having "their footing in the experiential reality with which all knowledge and all science begins" (p. 101).

The Power of Collective Initiatives

In 1837 William Whewell received he Royal Medal at the Annual Meeting of the Royal Society of London for his contribution to the understanding of ocean tides in project called "great tide experiment" that relied on almost a million observations collected by thousands of ordinary people living in coastal towns (Cooper 2016). Volunteers at 650 tidal stations measured tides around the clock at exactly the same points in time for two weeks in June 1835. Collection initiatives such as open source platforms have gained in important in recent years. For example, the *Human Connectome Project* compiles neural data and a graphical interface to navigate the data, and the Genome Aggregation Database aims to aggregate and harmonize exome and genome sequencing data. Further remarkable collaborations are the Earth Microbiome Project[27], systematically attempting to characterize microbial life on the planet and its functional diversity with participation of more than 500 investigators, and the Long Term Ecological Research Network[28] being carried out across Australia to understand the impacts of disturbances in the Australian ecosystem. The success and sustainability of such initiatives depend on the willingness of researchers to share data, a practice that has been intensively debated in science. A relatively recent survey suggests that the acceptance and willingness to engage in sharing data has increased but barriers to data sharing persist (Tenopir et al. 2015). A core barrier is, for example, the right to make the data public. Global scientific bodies such as the European Commission, the Global Research Council, or the US Office of Science and Technology are more active in designing policies that increase public access to research (Gewin 2016). A large number of organizations, societies, publishing houses, and journals have affirmed their commitment to the 2016 Statement on Data Sharing in Public Health Emergencies[29] that allow the World Health Organization (WHO) to get rapid access to findings that may help inform a global response to COVID-19[30]. The WHO has, for example, created ZikaOpen[31], a platform that tries to facilitate data-sharing.

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[27] https://earthmicrobiome.org/
[28] https://www.ltern.org.au/
[29] https://wellcome.ac.uk/coronavirus-covid-19/open-data
[30] https://wellcome.ac.uk/coronavirus-covid-19/open-data
[31] https://www.who.int/bulletin/online_first/zika_open/en/

A crisis such as a pandemic offers the opportunity to pursue a common goal, reducing uncertainty and enabling caregivers, health systems, and policy-makers with the knowledge to address individual and public health (London and Kimmelman 2020). Interesting data sharing initiatives have emerged during COVID-19. For example, Nextstrain[32], an open-source project tries to harness the scientific and public health potential pathogen genome data, including visualization tools to aid epidemiological understanding and improving the outbreak response. Dashboards such as Singapore's COVID-19 UpCode SG allowed residents to see known infection cases[33]. The COVID-10 Dashboard by the Center for Systems Science and Engineering (CSSE) at John Hopkins University is a widely cited source of information.[34] The trade-off faced by such dashboards is the goal of guaranteeing accurate data representation while taking people's concerns and fears into consideration (Patel 2020)[35]. A key concern is whether such dashboards violate privacy of those infected; for example, Singapore's Ministry of Health official dashboard provides detailed information of each hospitalized case including age, sex, approximate residence, workplace, and places visited (Patel 2020). In addition, various scientific "consortia of intelligences" have emerged during the COVID-19 crisis. For example, various international surveys have been conducted or are currently in progress. A good example is the International Survey on Coronavirus[36] involving an international team of researchers from 12 different institutions collecting data from 113,362 individuals around the world and making the data accessible to the public and researchers (see osf.io/3sn2k/). As a platform that supports research and enables collaboration, OSF has a collection of coronavirus studies, some of which also provide free access to data (see **https://osf.io/collections/coronavirus/discover).** Searching in Github[37] for the term COVID returns about 48,000 repositories; GitHub's dedicated COVID-19 page alone has 3,159 public repositories (https://github.com/topics/covid-19). Using the same search terms on Scopus indicate that around 73% of the articles are open access compared to only 56% of the documents that are generally published open access (see Martín-Martín et al. 2018 for the period 2009-2014) as various journals made their COVID-19 papers freely accessible for the purposes of knowledge transfer.

[32] https://nextstrain.org/ and https://nextstrain.org/ncov
[33] https://co.vid19.sg/singapore/
[34] https://www.arcgis.com/apps/opsdashboard/index.html#/bda7594740fd40299423467b48e9ecf6
[35] https://www.technologyreview.com/2020/03/06/905436/best-worst-coronavirus-dashboards/
[36] https://covid19-survey.org/
[37] https://github.com/search?q=covid

While there is much to be gained through international collaboration, the sharing of data and ideas - there always lies the potential for unintended group think, i.e. so much focus is devoted to a single line of thought that other competing points of view are drowned out. However, group thinking only becomes a problem if the chosen research path is ultimately unsuccessful and all the time and resources were tied up into a single stream. For example, string theory has tied up physics for decades as being the primary focus of world research, for while it is mathematically attractive it has been untestable and remains an unproved conjecture … now what if it is wrong? Physics would be set back decades, with millions of dollars of funding and countless hours of research time and thought ending with no other viable alternatives currently being explored. Smolin (2006) stresses that the strong focus on string theory "hurts science, because it chokes off the investigation of alternative directions, some of them very promising" (p. xxii) stressing that science requires "a delicate balance between conformity and variety" (p. xxii). But this narrow thinking problem can extend well beyond the limits of a single field, as we see in the research output that were published after the SARS and Ebola outbreaks the emergent focus is mostly limited to the medical impacts (accounting for over 75%). What is clearly missing from this work is how the pandemics impacts on the rest of our lives – our economies, businesses, social structures and societies in general. Have we been so conditioned that as scientists we believe that pandemics are only of value for medical research to the exclusion of the rest of our society? If we consistently under value, underfund and ultimately underpower all other streams of science, when it comes to pandemics we should not be surprised that solutions and advice only come a limited number of sourced – as underpowered science will result in underpowered solutions in emergencies (when we need them most).

Concluding Remarks

Science has experienced rapid progress since we humans swallowed what Eiseley (1961) terms a magic pill: the pill of science. Not long after the plague and the Great Fire of London in September 1666, the House of Commons Committee inquired into the causes of those misfortunes and concluded that it must be attributed to Divine displeasure; however, this raised the question of who was the source of vexation. Perhaps not surprisingly, and possibly conveniently, Hobbes, the author of Leviathan, was blamed by the Committee for such displeasure. The Committee decided that Hobbes' works had most displeased the Lord, initiating a decree that no work of his should be published in England (Russell 1985, p. 4). Great statesmen of science such as Francis Bacon helped to bring about the invention of invention: the experimental method offering that unique soil in which science could flourish (Eiseley 1961). Bertrand Russell (1985) reminds us that – despite Aristotle's knowledge and insights – it never occurred to him to verify his statement that women have fewer teeth than men by examining his wives' mouth, despite being twice married.

Scientists would agree that policy choices should be driven by research findings or the tools of thought and exploration applied by scientists. Science – as any social institution – is faced with forces that are defensive, conserving, ordering or stabilizing (Maslow 1969). In this paper we discussed insights regarding just how fit science is to deal with global crisis. In such circumstances, the health and functionality of science and academia are revealed, with the crisis providing insights into whether methods need to be revised (or created) and how heuristic frameworks need to be adjusted. COVID-19 is a fascinating case study of how human aspects such as emotions, impulsiveness, spontaneity, or expressiveness become more dominant in a crisis; observing how scientists interact under such conditions provides signs as to the health of science.

We have discussed positive but also negative elements observed during the COVID-19 crisis, and this narrative discussion indicates that science is not free of human values. Such insights are not new to many scholars in the history of science (Oreskes 2019). There are many examples of important scholars with a clear agenda that was not free of values. For example, Karl Pearson tried to completely remove causation from science, seeing it as fetish of modern science and stressing that meaningful thoughts can only be reflected in patterns of observation – and these can be entirely described by correlations (Pearl and MacKenzie 2018). As Pearson's biographer, Porter (2004) wrote *Karl Pearson: The Scientific Life in a Statistical Age*, stressing that "Pearson's statistical movement had aspects of a schismatic sect. He demanded the loyalty and commitment of his associates and drove dissenters from the church biometric" (p. 249). But even he could not escape the discussion on spurious correlation that required references to causality (Pearl and MacKenzie 2018). Smolin (2019) discussed how David Bohm was attacked by scholars of the Copenhagen view when trying to invent a realist completion of quantum mechanics. Léon Rosenfeld (protégé of Bohr): "there is not truth in your suspicion that we may be talking ourselves into complementarity by a kind of magical incantation. I am inclined to retort that it is just among your Parisian admirers that I notice some disquieting signs of primitive mentality….". Even Robert Oppenheimer – Bohm's former mentor at Princeton – called Bohm's attempt "juvenile deviationism" and stated that [i]f we cannot disprove Bohm, then we must agree to ignore him". John Nash then wrote to Oppenheimer complaining about the dogmatic attitudes he found among Princeton physicists. Even Einstein struggled to understand his cosmological constant that he introduced to save the universe from collapsing or expanding. Georges Henri Joseph Édouard Lemaître estimated the rate at which the universe was expanding but when Einstein met him at a conference in 1927, he dismissed his work as mathematically sound but that his grasp of physics was abominable (Cowen 2019).

The insights offered here also raise questions as to whether there needs to be more detailed discussion within various scientific fields regarding the philosophical assumptions of the stereotypical nature of science; usually classified as detachment, objectivity, subjectivity, reliability of knowledge, value and precision (Maslow 1969). Scientists have their own goals and purposes and the sooner the scientists admit this, the easier it is to develop new methods for studying human elements in science. It is not only important to understand reproduction, replication, and robustness in scientific rigor but also revelation, namely the need for accountability and transparency by disclosing and communicating more effectively the reasoning for how scientists develop strategies, derive insights and draw conclusions (Pagan and Torgler 2015). Changing the way we communicate scientific findings by revealing all the confusions and ignoble thoughts would help to collect very valuable information that is often lost (Torgler 2020[38]).

General science is also personal science. Many scientific fields are used to put everything it its place; organizing the environment to be predictable, controllable, or safe. However, such a search for control may freeze scientists into static and unchanging patterns. On the other hand, rapid and efficient organization of large-scale surveys with minimal barriers is an indication that scientists and their institutions (at least in some fields) can adjust their common patterns based on changing environmental conditions. In addition, a major crisis naturally gravitates scientists to an important problem rather than approaching science purely with a method-centered motivation; doing something technically elegantly that attracts the approval of peers due to its rigor. In addition, experiential naïveté of how to cope with a new situation may allow scientists and their institutions to identify valuable new heuristics, as prior expectations or demands are absent. In a sense, the opportunity to see things with the fresh eyes of a child may help spark deeply needed reforms of some institutional conditions.

[38] https://socialsciences.nature.com/users/376755-benno-torgler/posts/64919-changing-the-way-we-communicate-scientific-findings

The current article touched on the psychology of science in a global crisis too. Future studies could provide more insights into how we can analyze crises, using findings from the growing literature in the area of psychology of science. This field tries to understand how science develops in individuals (Feist 2006) or the effect of cognitive aspects on scientific practices (Thagard 2012). Beyond these analyses, such insights need to be complemented with tools applied in the sociology and economics of science to better understand the incentives and institutional conditions of scientists. Future studies could explore in more detail how narrative elements can be investigated empirically.

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Appendix

Table A1: Field Contributions by Percentages

Field	Ebola	SARS (2002-2003)	SARS (since 2002)	Covid19
Medicine	34.89%	49.25%	26.91%	62.11%
Immunology and Microbiology	14.60%	2.60%	9.22%	7.34%
Biochemistry, Genetics and Molecular Biology	11.92%	10.34%	14.59%	6.10%
Social Sciences	5.23%	1.03%	2.62%	3.02%
Pharmacology, Toxicology and Pharmaceutics	4.06%	4.52%	7.01%	2.81%
Environmental Science	2.71%	1.58%	3.87%	2.78%
Health Professions	1.13%	0.41%	0.57%	1.93%
Nursing	2.08%	1.85%	0.88%	1.81%
Neuroscience	0.65%	0.48%	0.76%	1.60%
Engineering	1.38%	3.70%	2.93%	1.21%
Computer Science	1.11%	0.68%	1.39%	1.12%
Agricultural and Biological Sciences	6.41%	6.03%	10.69%	1.09%
Multidisciplinary	4.01%	2.33%	1.94%	1.06%
Psychology	0.32%	0.00%	0.36%	0.97%
Mathematics	1.83%	1.44%	1.32%	0.72%
Dentistry	0.02%	0.14%	0.09%	0.63%
Business, Management and Accounting	0.73%	2.74%	1.02%	0.63%
Chemistry	1.76%	3.22%	5.52%	0.45%
Energy	0.02%	0.00%	0.23%	0.45%
Chemical Engineering	0.74%	1.37%	1.22%	0.42%
Materials Science	0.63%	2.19%	1.20%	0.39%
Physics and Astronomy	0.73%	1.64%	1.72%	0.39%
Economics, Econometrics and Finance	0.40%	0.48%	0.33%	0.33%
Arts and Humanities	1.00%	0.07%	0.44%	0.27%
Decision Sciences	0.20%	0.21%	0.21%	0.18%
Veterinary	1.19%	0.27%	0.50%	0.15%
Earth and Planetary Sciences	0.28%	1.44%	2.38%	0.03%
Undefined				