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Abstract

The Covid-19 pandemic escalated demand for scientific explanations and guidance, creating opportunities for scientists to become publicly visible. In this study, we compared characteristics of visible scientists during the first year of the Covid-19 pandemic (January to December 2020) across 16 countries. We find that the scientists who became visible largely matched socio-cultural criteria that have characterised visible scientists in the past (e.g., age, gender, credibility, public image, involvement in controversies). However, there were limited tendencies that scientists commented outside their areas of expertise. We conclude that the unusual circumstances created by Covid-19 did not change the phenomenon of visible scientists in significant ways.

Keywords

History of public communication of science; Public understanding of science and technology; Science and media

DOI

https://doi.org/10.22323/2.22010204

Submitted: 22nd July 2022
Accepted: 31st October 2022
Published: 18th January 2023

Introduction

In her landmark study of visible scientists of the 1960s and 70s, A. R. S. Goodell [1975] noted that, when unusual circumstances coincide with unusual characters, the stage is set for some scientists to become highly visible in the public domain. This coincidence occurred on a global scale in 2020 — a time dominated by the Covid-19 pandemic when scientists emerged as trusted and sought-after actors [Bucchi, Fattorini & Saracino, 2022; Abdool Karim, 2022]. As politicians, civil servants, journalists, and citizens turned to scientists for guidance and reassurance, scientists became symbols of hope, media stars, and even cult figures [Kupferschmidt, 2020; Stevis-Gridneff, 2020; Fahy & Lewenstein, 2021; Naidu,

2021]. Media outlets branded these highly visible scientists as 'pandem-icons',[1] 'pop stars of the pandemic', and 'heroes of the coronavirus era' [Butler et al., 2021, p. 436]. However, scientific fame during a pandemic did carry its own risks and some scientists who spoke publicly about Covid-19 faced abuse in the form of personal attacks, trolling, and even death threats [Limb, 2021].

To date, studies of visible or celebrity scientists have largely focused on single countries [e.g. Fahy, 2015; Joubert & Guenther, 2017; Fahy & Lewenstein, 2021]. Very little research has explored the concepts of visibility and celebrity in science across different national and cultural contexts through the lens of the characteristics of these scientists. However, the Covid-19 pandemic has created a situation that enabled us to consider scientists' public visibility and the characteristics that make them visible (or even turn some into celebrities) across a range of countries during the same time period.

The differences and overlaps between 'visibility' and 'celebrity' in science

Historically, in the science communication literature, the terms 'visibility' and 'celebrity' in science have been used differently over time, and there is an ongoing discussion about the boundaries and overlaps between these phenomena. A. R. S. Goodell [1975] focused her study on 'visible scientists', but the term 'celebrity scientists' is more commonly (and more recently) used to describe famous scientists [Fahy, 2015; Fahy & Lewenstein, 2021].

Bucchi [2015, p. 244] shows that visible scientists emerged notably in the second half of the twentieth century largely because of mass media effects: "Increasingly, scientists became not only visible by virtue of an 'internal' reputation… but also because of their ability to match — and to exploit — the operational logic of the mass media". Fahy and Lewenstein [2021] confirm this argument and add that the transformation of scientists into celebrities reflects an intensification in the cultural role and reach of the media and its ability to shape public opinion and the meaning of science in public life.

Fahy and Lewenstein [2021] describe a conceptual shift, which mirrors a historical shift from discussions about visible scientists of the mid-twentieth century to celebrity scientists of the twenty-first century. The growing incidence and use of the concept of 'celebrity' is an indicator of the increasing integration of science into popular culture. Fahy and Lewenstein [2021] note that earlier authors [e.g., R. Goodell, 1977] used celebrity and visibility as synonyms, but that new ideas that have emerged since the late 1970s from the field of celebrity studies provide a new set of conceptual tools to examine scientific stardom. They note, however, that the characteristics that R. Goodell [1977] identified as typical of visible scientists (that they are articulate, controversial, have a colourful image, a credible reputation, and work on hot topics) remain useful in broad terms for describing a set of personal and professional attributes necessary for a scientist to earn wider cultural visibility. The authors note that the increase in the variety of media platforms has made celebrity an omnipresent feature of contemporary culture. They single out Carl Sagan as a notable scientist who made the shift from 'visible' scientist to 'celebrity' scientist, noting that this took place in a culture that increasingly valued the idea of celebrity for its own sake.

[1] With acknowledgement to Butler, Farzin and Fuchs [2021] where we first noted the term 'Pandem-Icons'.

Notably, not all highly visible scientists become celebrities. Instead, celebrity builds on visibility and invokes popular culture, and is therefore not reliant on exposure to mainstream media only. In general, only a small number of highly visible scientists become celebrity scientists [Bucchi, 2015]. In our study, we focused on 'visible' scientists, which, to some extent, conflates the historical terms that have described scientists as 'visible' or 'celebrity' figures.

The social functions of visible scientists and its ambiguity

To millions of people, visible or celebrity scientists are the public face of science, giving them power in the public sphere, but also within science [Fahy, 2015]. Because of their prominence, they can circulate new ideas, shape public discussions, and influence public opinion, thereby making science part of mainstream society [Joubert & Guenther, 2017; Fahy & Lewenstein, 2021]. Visible scientists can not only enhance public understanding of science, but also spark social movements and influence policy debates [Fahy, 2015].

However, scientists who become highly visible must deal with an inherent ambiguity in trying to meet the demands of the media and the public, while continuing to work professionally within the normative structure of science [Rödder, 2012]. There has long been some discomfort and even disdain amongst scientists regarding those who become (too) visible [A. R. S. Goodell, 1975]. More recent research continues to show that there are powerful forces pulling scientists in opposite directions as far as public engagement is concerned, ranging from career penalties for those who are deemed to spend too much time on engagement, to prestigious rewards for those who do become highly visible [AbiGhannam & Dudo, 2022].

Peer censure about high visibility in science is often linked to the time demands of building a high media profile, leading some to believe that in the process of becoming highly visible, scientists may "let science slide", so that the communication eventually becomes more important than the science [Rödder, 2012, p. 165]. According to this line of thinking, a highly visible scientist can no longer focus on research, which, according to this view, is the most important part of scientific work. Therefore, scientists may agree that it is "a good thing" to have science out there in the public, but at the same time are critical of their colleagues who "appear to be a little too comfortable with the camera and the microphone" [Rödder, 2012, p. 163]. This explains why highly engaged scientists tend to overproduce academic outputs in order to sustain their academic credibility, and why they are selective about the information they share with peers about their involvement in public engagement activities [AbiGhannam & Dudo, 2022].

Notably, many of the characteristics of highly visible scientists are media-orientated, meaning that they represent examples of the so-called 'medialisation of science' — a phenomenon describing how science and the media are increasingly coupled to the extent that media criteria become relevant for those working in science [Peters et al., 2008; Rödder, 2012]. This fuels further concern that the lure of the media could detract from the integrity and credibility of science [Weingart, 2012].

While the idea that a high public profile could tarnish a scientific career persists [Rödder, 2012] there are some indications that media and public engagement is

becoming more accepted within the fluid norms of science [Peters, 2013; Entradas & Bauer, 2019; Joubert, 2019].

The characteristics of publicly visible scientists

The characteristics of visible or celebrity scientists provide a framework for understanding the requirements and risks that accompany high visibility, but also illuminates how science becomes increasingly embedded in popular culture [Fahy & Lewenstein, 2021]. Many scholars have described the typical characteristics of visible and celebrity scientists [e.g., R. Goodell, 1977; Missner, 1985; Fahy, 2015; Davies & Horst, 2016; Fahy & Lewenstein, 2021; Olesk, 2021].

We furthermore drew on studies focussing on behavioural theories that have been applied to better understand scientists' communication behaviour [e.g. Poliakoff & Webb, 2007; Dudo, 2013; Joubert, 2018]. Based on this literature, we created a list of 12 characteristics that are typical of visible (or celebrity) scientists, as listed and briefly described below.

1. *Age*

   Older scientists are more likely to become visible in the media as their confidence about media interactions grows over time, along with their experience and institutional support [A. R. S. Goodell, 1975; Greenwood & Riordan, 2001; Searle, 2011]. Senior scientists are also more in demand as media sources [Peters et al., 2008; Dunwoody, Brossard & Dudo, 2009; Bucchi & Saracino, 2012] and are more likely to engage with the public [Bauer & Jensen, 2011]. R. Goodell [1977] even suggested that scientists should postpone media engagement until later in their careers when they have reached the kind of status that means they will no longer be concerned about whether their peers will approve of their media prominence.

2. *Gender*

   When considering famous scientists in history, it is evident that men have dominated the arena of scientific celebrity [Fahy & Lewenstein, 2014; Fahy & Lewenstein, 2021]. The typical celebrity scientist has even been described as "a white man of high education whose fame has been reached through hard work in competition with others of the same kind" [Ganetz, 2016, p. 234]. Iconic scientists include Charles Darwin and Albert Einstein, while famous scientists of the late 20th and early 21st Century include names such as Stephen Jay Gould, Richard Feynman, Carl Sagan, Richard Dawkins, M. S. Swaminathan, and Stephen Hawking. Today, Neil deGrasse Tyson, Brian Greene, and David Attenborough continue to enjoy star status [Golden, 1999; Fahy & Lewenstein, 2014; Fahy & Lewenstein, 2021]. There are, of course, examples of legendary women in the history of science, including Marie Curie, Jane Goodall, and Katherine Johnson, but most studies of visible scientists have included more men than women. For example, A. R. S. Goodell [1975] identified only two women in her list highly visible scientists, while Fahy [2015] included only one woman in his book about scientific celebrities.

   More broadly, research evidence confirms that male scientists are especially in demand as media sources [Crettaz von Roten, 2011; Torres-Albero, Fernández-Esquinas, Rey-Rocha & Martín-Sempere, 2011] and that they are

quoted and profiled as experts far more frequently compared to their female colleagues [Niemi & Pitkänen, 2017]. The dominance of male expertise in the mass media has once again been highlighted during the Covid-19 pandemic [Kassova, 2020; Joubert, Guenther & Rademan, 2022].

3. *Scientific credibility and reputation*

   The scientific elite — i.e., academic performers who are held in high esteem by their peers — are generally also more visible to the outside world, because they are sought after as public speakers and media sources [Jensen, 2011; Dudo, 2013; Peters, 2013, 2014]. This results in a cyclical connection between high-quality research and public dissemination [Wigren-Kristoferson, Gabrielsson & Kitagawa, 2011]. The characteristics leading to public visibility are often similar to those demanded of success within science, such as ambition, energy, creativity, aggressiveness, and intelligence [A. R. S. Goodell, 1975]. Because of its protective effects, a high level of credibility within science may even be a prerequisite for successfully achieving and sustaining a high public profile [R. Goodell, 1977; Rödder, 2012]. Similarly, AbiGhannam and Dudo [2022] found that scientists who are highly engaged with public audiences mitigate the resulting pressures by overproducing academic research.

4. *Personable public image*

   Visible scientists are usually charismatic individuals that become popular in the public domain, especially as mass media sources. They are able to hold the media spotlight by being articulate, and interesting, complemented by a compelling presence, and good looks [R. Goodell, 1977]. They touch the right chords with the public, make a good impression, and they have the right appearance and personality [Missner, 1985]. Television, in particular, requires scientists not only to perform but also to show a distinct personality [Ganetz, 2016]. For example, South African heart transplant pioneer Christiaan Barnard reached and sustained celebrity status for many years [Joubert, 2017], and reporters often commented on his charisma and good looks. Barnard himself thought that if he had been fat and bald, media interest would have died down sooner [Logan, 2003].

5. *High media visibility*

   For scientists, high visibility in the public sphere is inseparably linked to a high media profile [R. Goodell, 1977; Peters, 2014; Joubert & Guenther, 2017; Fahy & Lewenstein, 2021]. Bucchi and Trench [2016] describe celebrity scientists as a specific type of visible scientist who are part of today's modern, media-driven celebrity culture. Similarly, Rödder [2012, p. 160] describes visible scientists as "occupants of a boundary role at the science-media interface". In addition, 'visibility feeds visibility', with the implication that scientists who regularly participate in public communication about their work gain future visibility via the self-reinforcing feedback loops of media attention [Peters, 2008], and the process of reciprocal intensification [Marcinkowski, Kohring, Fürst & Friedrichsmeier, 2014]. The process of 'celebrification' depends on a scientist's acceptance of public communication as a responsibility; their awareness and mastery of media logic; their purposeful use of the mass media; and institutional support for their media efforts [Olesk, 2021].

6. *Understanding the needs of the media*

   Highly visible scientists rise to prominence through their awareness of and compliance with mass media needs and demands [Peters, 2013; Olesk, 2021]. Instead of viewing journalists as nuisances, visible scientists profit from their relationship with journalists by gaining influence and building their public profiles [R. Goodell, 1977]. They make time to engage with journalists and are mostly willing to appear on camera and pose for photos [Peters et al., 2008; Missner, 1985; Joubert, 2018]. Not only do these scientists go to great lengths to cooperate with journalists, but they also tolerate the failings of the media [R. Goodell, 1977]. By taking advantage of media opportunities, visible scientists typically develop strong relationships and sophistication in their dealings with journalists, resulting in a synergistic relationship between high-profile scientists and journalists [R. Goodell, 1977; Fahy, 2015]. Therefore, visible scientists gain a public voice not just by virtue of their expertise and reputation within science, but also because of their ability to match — and to exploit — the operational logic of the mass media [Bucchi, 2015; Olesk, 2021].

7. *Accessible communication styles*

   Exceptional communication skills and eloquence are key requirements for scientists to achieve and sustain a high media profile, and therefore visible scientists are typically well-spoken and able to communicate about research in accessible language and quotable quotes [A. R. S. Goodell, 1975; Missner, 1985; Joubert, 2018]. They provide a human dimension to their science, thereby helping people to make sense of science during difficult times [Fahy & Lewenstein, 2021]. Their communication style is often described as warm and credible [Gustafson & Rice, 2020; Joubert, 2020; Baram-Tsabari & Lewenstein, 2013], which contributes to their perceived credibility in the public eye [Fiske & Dupree, 2014].

8. *Blurring of professional and private lives*

   The process of scientific celebrification involves an intense personalisation of how an individual is portrayed in the media, including a merging of their public and private lives [Fahy, 2015; Fahy & Lewenstein, 2021]. Media coverage that blurs the private and professional lives of high-profile scientists was already evident in the case of Darwin [Turner, 2004; Browne, 2003], with Dawkins, deGrasse Tyson, and Greenfield as more recent examples [Fahy & Lewenstein, 2021]. Evidence for this can also be seen during televised broadcasts of the Nobel banquet during which the media construct personalities of winners by highlighting their personal interests and attributes, that they are "charming, funny, sullen, nice, reserved, kind, and extroverted" and that "one scientist plays the piano, while others are wine connoisseurs, anglers, skiers, mountain climbers, connoisseurs of Tibetan art, collectors of beetles, or take drugs" [Ganetz, 2016, p. 241]. Sometimes, it is the visible scientists who choose to reveal private information about themselves as a way to educate and inspire public audiences, particularly by sharing their own health narratives [Beck, Chapman, Simmons, Tenzek & Ruhl, 2015].

9. *Commenting outside areas of expertise*

   Once scientists become publicly visible figures, media representatives often seek and broadcast their views on topics that go well beyond their areas of

recognised expertise [Bucchi & Trench, 2016]. This can occur to the extent that visible scientists become spokespersons for science in general [Marsh, 2019]. For example, Sagan often spoke on topics outside his specific area, prioritized critical thinking over disciplinary expertise, and did not distinguish his personal views from scientific consensus [A. R. S. Goodell, 1975; Marsh, 2019]. As with Sagan, scientists speaking on wider topics may attract criticism from peers who argue that scientists should refrain from commenting on topics outside of their domains of expertise [A. R. S. Goodell, 1975; Fahy & Lewenstein, 2021; Groves, 2021].

10. *Involvement in controversy*

    Visible scientists have been described as fearless and assertive, intensely competitive and ambitious; they are individuals who thrive at the centre of attention and who do not shy away from controversy [A. R. S. Goodell, 1975; Fahy, 2015; Marsh, 2019]. In fact, controversies often elevate specific scientists to visibility and even celebrity. Fahy and Lewenstein [2021] note Gould and Dawkins as examples of this and Marsh [2019] writes about Fred Hoyle and Lynn Margulis who promoted their own controversial and polarising theories.

11. *Handling criticism*

    Researchers have established that scientists who become highly visible on the public stage enjoy praise and adulation, but also endure peer criticism and disdain [Schäfer, 2011; Martinez-Conde, 2016; Martinez-Conde, Macknik & Powell, 2016]. Visible scientists have been criticised for facilitating excessive media coverage and commanding too much authority; their peers may comment that their credibility with public groups is overrated and that their visibility is linked to a political role, rather than their scientific expertise alone [A. R. S. Goodell, 1975]. Visible scientists have been found to mostly handle this kind of criticism well, especially when they are protected by their scientific reputations [Rödder, 2012] and therefore criticism does not deter them from media engagements [Poliakoff & Webb, 2007]. While visible scientists are not immune to intense public and peer scrutiny, and some may even fear criticism, A. R. S. Goodell [1975, p. 178] notes: "In some cases, criticism has had a very positive effect on visible scientists' productivity. Hardly deterring them, it spurred them on to write and speak more, explain their views better, strengthen their position".

12. *Becoming tradable commodities*

    Visible scientists — especially when they reach celebrity status — may become tradeable cultural commodities, so that their names and images are used to promote ideas and to sell products such as books and podcasts [Fahy & Lewenstein, 2021]. Some visible scientists participate in the commodification process by contributing their own cultural products. For example, Darwin mass-produced photographs of himself, signed autographs, and answered fan mail [Browne, 2003]. Heart transplant pioneer Christiaan Barnard was a popular speaker on luxury ocean cruises and appeared in several advertisements for a range of products, including skin products, breakfast cereals, and car engine oil [Van Niekerk, 2007].

The current study

In the current study, we used these characteristics of visible scientists, as discussed above, as a framework to identify the common and contrasting characteristics of 16 visible scientists in 16 countries who emerged during the Covid-19 pandemic. In doing so, we aimed to analyse how the identified characteristics of visible scientists manifested in scientists from different national contexts.

Our focus is on explaining and exploring the similarities and differences. Did the 16 scientists act in the same way, or how did they differ? We considered their profiles, affiliations, personalities, as well as their tendencies to comment outside their areas of expertise. We also looked at their public image, their compliance with media demands, and their media skills and performance.

Based on earlier evidence that broad scientific field has an effect on scientists' public communication behaviour [e.g. A. R. S. Goodell, 1975; Peters, 2013; Marcinkowski et al., 2014], as well as findings about the under-representation of social scientists' voices in the media during the Covid-19 pandemic [e.g. Joubert et al., 2022], we also explored the broad field of each of the visible scientists in our study.

Study methodology

For each of the 16 countries included in our study, we selected one scientist who was considered by the authors to have reached the highest level of public visibility during January to December 2020 — the first year of the Covid-19 pandemic (see Table 1). Our selections were based on media diaries we kept for data collection during an earlier study [Metcalfe et al., 2020], researchers' local knowledge about their own national contexts, and in some cases relied on Google Trends or Factiva searches for mentions in journalistic outlets. The final selection was justified and discussed in group meetings among the authors.

Table 1. 'Most visible scientists' in the current study, with basic demographic information.

Country	*Name*	*Gender*	*Age (as of 1st January 2020)*
Australia	Peter Doherty	Male	79
Brazil	Atila Iamarino	Male	37
Canada	Horacio Arruda	Male	60
China	Wenhong Zhang	Male	50
Denmark	Lone Simonsen	Female	61
Germany	Christian Drosten	Male	47
India	Soumya Swaminathan	Female	68
Israel	Ronni Gamzu	Male	54
Italy	Roberto Burioni	Male	57
Kenya	Patrick Amoth	Male	54
Russia	Alexander Gintsburg	Male	69
South Africa	Salim Abdool Karim	Male	59
Spain	Fernando Simón	Male	56
Sweden	Agnes Wold	Female	64
U.K.	Neil Ferguson	Male	52
U.S.	Anthony Fauci	Male	79

We then asked if, and to what extent, the 16 selected scientists matched the characteristics in our framework. Next, we determined alignments and contrasts across countries.

Characteristics associated with scientists' visibility

Based on our framework of 12 characteristics of visible scientists, we created a template and associated research questions (see Table 2). After testing and refining the template by piloting the analysis of the characteristics with one of the scientists in our study, we used the template to capture data for all 16 cases.

To collect this information and to populate the template, we relied on our Covid-19 media diaries, which included media and social media searches. We also searched for articles, photographs and social media profiles of the 16 scientists identified for our study.

Research team members met fortnightly over the course of one year to discuss and debate our findings. We used templates and prosopography techniques (also referred to as 'collective biographies') to help us document common and contrasting socio-cultural criteria and characteristics relevant to the visible scientists we were studying and comparing [Verboven, Carlier & Dumolyn, 2007].

Table 2. Visibility characteristics and associated research questions.

Visibility characteristic	*Linked research question (RQ)*
1. Age	RQ1: Were the most visible scientists mostly older?
2. Gender	RQ2: Were the most visible scientists mostly male?
3. Scientific credibility and reputation	RQ3: Did the selected scientists occupy positions of leadership, and were they publicly rewarded for their achievements?
4. Personable public image	RQ4: Did the selected scientists have an amiable public image that helped to make them more popular with the media and public audiences?
5. High media visibility	RQ5: Did the selected scientists achieve and sustain high media visibility before and during our study period?
6. Understanding the needs of the media	RQ6: How did the selected visible scientists interact with the media, and is there evidence that they were able to match media needs?
7. Accessible communication style	RQ7: What communication style characteristics did the selected visible scientists have in common?
8. Media blurring of professional and private lives	RQ8: To what extent did the media report on the personal lives of the selected scientists?
9. Commenting outside area of expertise	RQ9: To what extent did the selected scientists comment on topics outside their area of expertise?
10. Involvement in controversy	RQ10: Were the selected scientists involved in controversies during the pandemic?
11. Ability to handle criticism	RQ11: Were the selected scientists criticised and how did they respond?
12. Becoming tradable commodities	RQ12: How were the selected scientists involved in promoting commodities before and during the pandemic?

Analysing and condensing textual information

In order to answer our 12 RQs, we analysed the information captured through our templates according to the 12 characteristics in our framework (see Table 2). Each question was allocated to a sub-group of two or three research team members who collaborated to develop a coding frame for their specific question. These indicators (and the associated coding frames) were developed deductively, based on the existing literature. However, during subsequent group discussions and after gathering the relevant information for all 16 cases, we agreed to add more codes inductively. Hence, we followed the process logic of qualitative content analysis. To increase the reliability of our data, each researcher was asked to check the coding attributed by research teams to the visible scientists in their country of residence. Following this process, each research team wrote up a summary of their findings, which was, again, shared and discussed.

Below we present a synthesis of the results linked to each RQ and discuss their implications, which compare the socio-cultural criteria and characteristics of visible scientists across the selected countries during the Covid-19 pandemic.

Results and discussion

When evaluating the 12 socio-cultural criteria and characteristics for visible scientists from the existing science communication literature, we found that all 16 visible scientists aligned with these characteristics, at least to some extent. However, we identified key differences, based on the roles they played within their countries, the ways that they became visible during the pandemic, and the differing cultural contexts in which they were operating. In discussing our results below, we provide illustrative examples rather than a detailed comparison of similarities and differences amongst the 16 visible scientists.

1. *Age: most visible scientists were older than 50*

   The average age of the 16 visible scientists in our study was 59 years (as of 1 January 2020). Ages ranged between 37 and 79, with a median age of 58 and 25% of scientists 65 years or older. Only one scientist, Iamarino from Brazil, was younger than 40, and one, Christian Drosten of Germany, was younger than 50. The rest (14 of the 16 scientists) were 50 or older. At 79, Fauci (U.S.) and Doherty (Australia) were the oldest scientists in the study. This finding corresponds with reports in the literature that older, and more senior scientists are more in demand as media sources and more confident and able to engage with journalists [e.g. Dunwoody et al., 2009; Petersen, Anderson, Allan & Wilkinson, 2009].

2. *Gender: most scientists who become Covid-19 media stars were men*

   Consistent with earlier research, we found that the visible scientists in this study were mostly male (13 men, compared to 3 women) i.e. only 19% (one fifth) were women. These findings echo recent research about the notable under-representation of female expertise in the media during the pandemic [Carr, 2020; Haq, 2021; Kassova, 2020; Refsing, 2020; SDG Knowledge Hub, 2020; Joubert et al., 2022].

3. *Scientific credibility and reputation: most scientists were recognised as credible leaders*

   Our findings on the scientific credibility and academic reputations of the selected scientists are based on our assessment of their leadership roles, and the awards and prizes bestowed upon them. We found that most of the 16 scientists were recognised as leaders in their field, highly acclaimed for their achievements, and enjoying an exceptional standing within the science arena.

   Of the selected scientists, 10 held high-profile positions before the pandemic, including international leadership roles. For example, since March 2019, Swaminathan (India) served as the Chief Scientist at the World Health Organisation. Existing roles as high-level policy advisors were typical for many of the scientists in our study. Being directly accountable for public healthcare, these researchers were well placed to reach even higher levels of public visibility during the pandemic.

   In terms of recognition through scientific awards and prizes, Doherty (Australia) was one of the most highly recognised. In addition to receiving the Nobel Prize for Medicine in 1996, he was a recipient or co-recipient of many other prizes. Fauci (U.S.) stood out as another recipient of numerous prestigious awards, including the Presidential Medal of Freedom (the highest honour given to a civilian by the President of the U.S.). Abdool Karim (South Africa) has also won a long list of awards and prizes, including the Kwame Nkrumah Continental Scientific Award from the African Union, the most prestigious scientific award in Africa. Drosten (Germany) received the "Verdienstkreuz 1. Klasse" (Officer's Cross) of the Federal Republic of Germany for his civil service in the time of Covid-19.

   Some scientists in our study were recognised earlier for their work during previous epidemics. For example, Ferguson (U.K.) was appointed an Officer of the Order of the British Empire (OBE) in 2002 for his work modelling the 2001 U.K. foot-and-mouth outbreak. Gintsburg (Russia) was awarded with the Russian Federation Government award in the field of science and technology (in 2003 and 2020) for his work on treatments against infectious diseases and for the development of vaccines against Ebola and Covid-19.

4. *Public image: most scientists were charismatic and likeable*

   Most of the visible scientists were reported as trustworthy, direct, and confident. For example, South Africa's Abdool Karim was perceived to have a strong, warm, and confident presence, and to be professional, honest, and maintaining his composure even when faced with public misinformation and paranoia.

   Through studying media appearances and the demeanour of the 16 selected scientists, we found that most of them came across as publicly relatable, warm, and friendly, with a genuinely caring attitude towards issues of public health. Notable exceptions were Zhang (China) and Gintsburg (Russia) who were both considered very serious in their media performances and appeared somewhat distanced and detached from public audiences. Italy's Burioni deserves a special mention here because public opinion was divided about his personality: some viewed him as a serious and competent scientist, while others considered him arrogant and even brutal at times.

Another characteristic that a number of visible scientists (e.g. China, Denmark, Germany, Spain, and U.S.) appeared to possess was the ability to be (or at least appear to be) humble. The *Financial Times* [Armstrong, 2020] says of Fauci: he "doesn't care about ratings, and this, paradoxically, has made him a television star. He is the master of anti-style style. Everything about him speaks of seriousness of purpose and absence of ego."

Some scientists were given nicknames by the media, like "Corona-Lone" for Simonsen (Denmark) or "Zhangba" and "Papa Zhang" for Zhang (China), possibly as a way to make these scientists more approachable.

5. *Media visibility: scientists gained a high media profile during the pandemic*

   All the visible scientists in this study had at least some media exposure before the pandemic, however only six (from Australia, Brazil, India, Italy, Sweden, and the U.S.) had a high media profile. For example, Iamarino (Brazil) was nationally recognised before the pandemic for his work on popularizing science on the YouTube channel *Nerdologia*. He was part of a digital platform for pop and youth culture, electronic games and youth content, called the Jovem Nerd group.

   Several scientists had emerging media profiles, and most were well known to the scientific world, but were not yet public 'household' names. For example, Abdool Karim (South Africa) was well known internationally in public health and epidemiological circles prior to the pandemic, but only became known to ordinary South Africans after his appointment to the Ministerial Advisory Committee early in 2020, which triggered multiple media appearances.

   The visible scientists in Germany and the U.K. had previously commented through the media on virus threats of the past such as Zika. Others had multiple engagements with the media due to their official position (e.g. Canada, India, and Spain). Several other scientists had interactions with the media, not because of their public roles, but because of their existing science communication activities. Doherty (Australia) can also be assigned to this group as his media exposure touched on a wide variety of scientific issues.

6. *Understanding the needs of the media: most scientists knew how to use the media*

   We found that most visible scientists made use of media and social media during the pandemic, making themselves visible and accessible to journalists. For example, in February 2021, Simonsen (Denmark) reported spending 20 hours each week on media contact. A few scientists, like Drosten (Germany), were asked to participate in media channels — in his case regular podcasts — to deal with the number of requests they were receiving from journalists. Drosten's podcast became a very popular radio format in Germany. Iamarino (Brazil) used mass media intensively, especially television and YouTube, and he became a significant Covid-19 influencer. Sweden's Wold said that she was happy to work with tabloids and public service channels because she wanted to reach as many people as possible.

   Being a medical doctor in Kenya, Amoth was able to present facts backed by science and made peak-time appearances on television on behalf of the government as the pandemic worsened. When the Ministry of Health was trying to gain acceptance on wearing face masks, Amoth appeared on

television wearing a face mask and advocated for this preventative measure. He also promoted home care as a necessary step when the public felt that the government had failed to provide adequate personal protective equipment.

However, not all visible scientists were so accessible to media. Canada's Arruda kept his distance from the media. Italy's Burioni decided what types of media engagement he was willing to do. Ferguson (U.K.) began to restrict his media appearances after he was hit with a lockdown scandal and reflected that he had many regrets about going public with his research, although he felt obliged by a sense of public duty. The media appearances of Russia's Gintsburg were most likely coordinated by his employer, the Ministry of Health, making it difficult to determine if his media access was voluntary.

Of the 16, only three scientists (from Russia, U.S. and Spain) were not active on social media platforms in their personal capacities. This does not mean that these scientists were not featured on social media, only that they did not drive their own presence or agendas on these platforms. For example, during our study period, there were several active 'Fauci fan clubs' on social media, and the Twitter account @FauciFan had more than 71K followers (as of 19 May 2022).

Twitter was the predominant social media platform, with only a couple of exceptions. The scientist with the largest Twitter following, as in September 2021, was Brazil's Iamarino with 1.2M followers, with Germany's Drosten with 783.8K followers next. Zhang (China) was active on Weibo, and had the most followers overall, with 3.93 million people following his Weibo profile (as of 1 September 2021).

7. *Communication styles: most scientists had exceptional communication styles and skills*

   Most of the visible scientists demonstrated confidence in communicating with the public. They used narrative, anecdotes, or emotions in their communication efforts, while some used humour, analogies, or metaphors. At least seven received awards that specifically recognised their public communication skills during the pandemic. For example, Drosten's (Germany) skills were recognised with a prize for "outstanding science communication during the Covid-19 pandemic" by the German Research Foundation (DFG). Simonsen (Denmark) and Zhang (China) were recognised for making complicated science more accessible to the public. Burioni (Italy) received the Asimov prize for scientific popularisation for his book 'Il vaccino non è un'opinione' (Vaccine is not an opinion). The Swedish people chose Wold as "Woman of the Year 2021", as a result of a poll run by the largest Swedish newspaper Aftonbladet. Fauci (U.S.) and Abdool Karim (South Africa) shared the John Maddox Prize, which recognises the work of individuals who promote science and evidence, advancing the public discussion around difficult topics despite challenges.

8. *Blurring of personal and professional lives in mass media*

   Indicative of their new levels of visibility, journalists wanted to know more about the men and women 'behind' the scientists, which resulted in feature stories that often blurred the professional with the personal. An example is South Africa's Abdool Karim who featured in popular weekly family magazine called *You*, showing the scientist celebrating his 60th birthday in his home in July 2020. Fauci (U.S.) also appeared in multiple magazines, including

a feature in *InStyle* in July 2020 in which the scientist spoke frankly about his work and personal life.

We found some evidence that visible scientists may have been willing to 'play along' with this blurring of their public and private lives. For example, Wold (Sweden) often used personal anecdotes and humour in interviews and talked about "my poor husband" being in a high-risk group for Covid-19 (defined in Sweden as age 70+). Almost half of the scientists were depicted getting their Covid-19 shot as positive influencers of national vaccination campaigns (Australia, Brazil, Canada, China, U.S.A., Israel, Kenya).

9. *Commenting outside areas of expertise: most scientists stuck to the science*

   Almost all of the scientists in this study adhered to using evidence in their communication (i.e., 14 of the scientists explicitly mentioned evidence-informed policy and practice). However, there was larger variation when considering whether these scientists adhered to, or moved outside, their own area of scientific expertise. While most of the visible scientists appeared to adhere to their area of scientific expertise when communicating, some did not. Scientists from Brazil, Germany, Israel, Spain, and Australia spoke about findings from a variety of Covid-19 science-related topics. However, Doherty from Australia made it clear when he was stepping outside of his expertise, and in the cases of Brazil and Israel, stepping outside of one's scientific expertise in communication was directly related to being asked to provide policy advice.

10. *Controversy: most scientists were involved in and responded to controversy*

    Almost all of the scientists in this study were involved in some sort of public controversy, demonstrating the inherent risks of a high public profile. Notable exceptions were Doherty (Australia), Wold (Sweden), and Swaminathan (India). Sources promoting or maintaining controversy included policymakers, other scientists/colleagues, publics (e.g., religious groups, conspiracists), and the media (e.g., tabloid media). High-profile cases erupted when Arruda (Canada) and Ferguson (U.K.) violated Covid-19 restrictions.

    Many controversies related to governmental management of the pandemic and some of the regulations overall; they implicated Fauci (U.S.), Ferguson (U.K.), Abdool Karim (South Africa), Amoth (Kenya), and Simón (Spain). Only some controversies related to a critical stance of the visible scientists towards governmental regulations, for instance, regarding the pandemic control strategy (Zhang, China), travel advice and quarantine restrictions (Gamzu, Israel), or the testing strategy (Simonsen, Denmark). In China, Zhang was associated with a controversy regarding his alleged alignment with a Western lifestyle and China's Covid-19 strategy. Other controversies emerged because of these scientists' communication content, for example, perceived inappropriateness of statements by Gamzu (Israel) and Simón (Spain).

    Fauci (U.S.) was involved in several controversies related to conspiracy theories; Burioni (Italy) was associated with controversies because of changing his approach towards the pandemic and his communication 'war' against 'no-vaxxers'. Some controversies were related to scientists providing predictions about the pandemic that were either too negative (Iamarino, Brazil) or too optimistic (Simón, Spain). Drosten (Germany) was attacked for his

research, as well as for disagreement with other scientists. Russia's Gintsburg was involved in controversies regarding the development, efficiency, and safety of the Sputnik vaccine.

The scientists responded to the controversies associated with them in different ways. Some actively defended themselves and their positions (Iamarino, Brazil; Simonsen, Denmark; Burioni, Italy; Gintsburg, Russia); others remained calm and collaborative (Drosten, Germany), or appeared (partially) apologetic (Gamzu, Israel and Simón, Spain). Some scientists did not get personally involved in responding to controversy (Fauci, U.S.) or actively avoided engaging with others who promoted controversy involving them (Wold, Sweden). Zhang (China) never defended himself but at the same time, he did not touch upon the same topics that caused the controversies. Ferguson (U.K.) was self-critical and apologetic and resigned from his post following his lockdown scandal.

11. *Handling criticism: half of the scientists were criticised*

    Half of the scientists in this study experienced criticism in a variety of public and policy contexts and within various communication contents. For instance, Wold (Sweden) was criticised for commenting outside her field of expertise, with critics claiming that her field of expertise was not close enough to properly address the Covid-19 pandemic challenge. Burioni (Italy) was criticised for his frequent appearances on television. Others were criticised for their alarmist rhetoric (Doherty, Australia), pessimistic views (Iamarino, Brazil; Abdool Karim, South Africa, as "Dr. Death"), for addressing specific groups in controversial ways (Gamzu, Israel), or for flippancy (Arruda, Canada). Interestingly, the sources of criticism included policy makers, other scientists/colleagues, and specific publics, but also right-wing commentators or conspiracy theorists.

12. *Tradable commodities: only some scientists became tradable commodities*

    Fauci (U.S.) represents a notable example of how a scientist's image was commodified during the pandemic, with his image displayed on bottle-openers, coffee cups, adult colouring books, good-luck socks, bobbleheads, and bumper-stickers [Specter, 2020]. In May 2020, U.S. bakeries sold pastries with Fauci's face on them. Hollywood actor Brad Pitt received an Emmy nomination for his performance of Fauci on Saturday Night Live in 2020. In September 2021, National Geographic produced a documentary film about Fauci's life and career.

    By the time our study was concluded, four of the scientists — Doherty (Australia), Iamarino (Brazil), Simonsen (Denmark), and Burioni (Italy) — wrote books associated with the pandemic. A book published in German about the pandemic was written with scientific advice from Drosten (Germany). Seven of the scientists had collections of Covid-19 memes created about them: Drosten (Germany), Iamarino (Brazil), Arruda (Canada), Burioni, (Italy), Simon (Spain), Ferguson (U.K.), and Fauci (U.S.). Drosten (Germany) had a song written about him and his work, recorded during the pandemic by a punk band ZSK. However, not all scientists in our study became tradable commodities. For example, we found no evidence of commodification for the three female scientists in our study, i.e. Wold (Sweden), Simonsen (Denmark) and Swaminathan (India).

Conclusions

In this study of publicly visible scientists in 16 countries during January to December 2020 — year one of the Covid-19 pandemic — we identified several similarities and differences associated with the socio-demographic criteria and characteristics that have historically been used to describe highly visible scientists. Largely, the findings confirm that unusual circumstances such as the Covid-19 pandemic did not change the phenomenon of visible scientists in significant ways.

Our findings show that across the 16 cases included in this study, the most visible scientists matched at least eight of the twelve characteristics of visible or celebrity scientists in the literature either substantially or partially. In these unusual circumstances, the media and public demand for scientific expertise was high, meaning that some scientists became visible public figures, even though they may not match all the criteria that typify visible scientists in history.

The commonalities between their experiences are strong enough to confirm trends and observe patterns. Our findings confirm that visibility is related to scientists' media skills and willingness to engage, as well as their ability to respond to criticism and cope with controversy. While highly visible scientists clearly play a key social role during a time of crisis, our findings confirm that high public visibility goes hand-in-hand with high public scrutiny and controversy, which imply that these visible scientists may be personally vulnerable.

There are a number of notable differences in the science-media ecosystem that would have affected scientists who emerged as visible during Covid-19, compared to similar figures in history. The most obvious difference is the presence and influence of social media channels that would enable Covid-19 experts to engage more directly with public audiences, but also allowed broad sectors of the public to comment on their communication efforts. In addition, while visible scientists have historically endured peer and public criticism, we do not have evidence that they experienced the kind of threats and aggression that were targeted at some of the visible scientists during Covid-19. In addition, in the context of a global pandemic and a dramatic increase in the public demand for scientific explanation, scientists during this period may have experienced a particularly strong obligation and motivation to engage with public audiences at much higher intensities than before.

We acknowledge that the 16 scientists we studied include high-profile researchers, as well as those that became policy advisors during a public health emergency. This could explain why their characteristics could differ somewhat from scientists who became visible in different circumstances — i.e. not related to a health emergency. Notably, all the scientists in our study were in the broad fields of health sciences, or natural sciences linked to human health (such as virology, microbiology, bacteriology), etc. Given the nature of the Covid-19 pandemic, it is understandable that scientists who became highly visible would be in fields closely related to the pandemic itself. This does not mean that scientists from other fields — including social scientists — did not acquire media prominence, but their visibility probably never reached similarly high levels compared to the scientists included in our study. The distinction between being a 'celebrity' scientist and a 'visible' scientist remains an open question. For the purpose of this study about the characteristics of the 16 scientists who leapt to prominence for their public role in explaining Covid-19, we use the term 'visible', and leave it up to the reader to decide which of the 16 crossed the boundary and became celebrities.

Study limitations and suggestions for future research

It is necessary to acknowledge a number of limitations of the current study. Our study of visible scientists during year one of the Covid-19 pandemic focused only on scientists (that we considered to be among the most visible) across 16 countries, and it must be acknowledged that the national contexts would affect the processes whereby these scientists become visible or not. One could also argue that the scientists chosen in this study were selected based on their visibility, and that checking against criteria of visibility implicitly confirms these criteria. The definition of scientists' expertise — whether broadly or narrowly defined — would also differ across countries. We furthermore acknowledge that the study could be enriched and expanded by including more countries and more scientists per country, as well as by extending the time frame of the study to shed light on trends over time. Future research could focus on qualitative interviews to document the experiences of the scientists and journalists that are instrumental in achieving scientific visibility or celebrity. It would also be interesting to focus on (visible) scientists who are not aligned with the scientific consensus or who are even pseudo-scientists, and to assess how they compare with the group used in this study.

During the Covid pandemic, political dimensions played a key role in all countries and impacted scientists' interactions with the public and media. Due to the nature and urgency of this health crisis, politicians had to call on scientists for help, but did not relinquish decision-making power to them and left them little room to influence policy decisions. This was affected by the formal roles the scientists played: some were in official government positions and constrained by the positions they held (e.g. Fauci); others had no official positions but became prominent because of their eminence and their willingness to speak with the media. Many of the 16 scientists in our study acted as government spokesperson or advisers, but also commented on and criticised government inaction or misconduct. There is scope for future research to explore the relationships and interactions between visible scientists and policy alignments, as well as how scientists and science advise are politicised during a health crisis.

Interestingly, for some of the visible scientists in our study their high public profile during Covid-19 could be regarded as a 'second act' of public visibility. Two notable examples were Fauci and Abdool Karim, who were both highly visible during the HIV/Aids pandemic around 2000. A comparative study into this phenomenon could shed light on what has changed during their first and second acts of visibility, which would provide insight into how and why scientists' public visibility changes over time.

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How to cite

Joubert, M., Guenther, L., Metcalfe, J., Riedlinger, M., Chakraborty, A., Gascoigne, T., Schiele, B., Baram-Tsabari, A., Malkov, D., Fattorini, E., Revuelta, G., Barata, G., Riise, J., Schröder, J. T., Horst, M., Kaseje, M., Kirsten, M., Bauer, M. W., Bucchi, M., Flores, N., Wolfson, O. and Chen, T. (2023). ''Pandem-icons' — exploring the characteristics of highly visible scientists during the Covid-19 pandemic'. *JCOM* 22 (01), A04. https://doi.org/10.22323/2.22010204.

ISSN 1824-2049. Published by SISSA Medialab. jcom.sissa.it