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Going viral: A science communication collaboration in the era of COVID-19 and social media

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On 9 March 2020, 2 days before the World Health Organization declared COVID-19 a global pandemic, two of the authors (microbiologist and infectious diseases expert Associate Professor Siouxie Wiles and cartoonist Toby Morris) released their first output together: an animated GIF (Graphics Interchange Format) known as “Flatten the Curve”. The graphic went viral on Twitter with over 10 million impressions in 3 days. Flatten the Curve was the first of more than 70 graphics produced by our collaboration, all designed as accessible visual communication about COVID-19. The graphics, all released under a Creative Commons CC-BY-SA-4.0 license, have been translated into multiple languages, used by communities, politicians, and public health officials around the world, and the collaborators have won multiple awards for their work.

KEYWORDS

science communication, health communication, visual communication, cartoons, graphics, COVID-19, pandemic, flatten the curve

1. Introduction

The COVID-era collaboration between two of the authors (microbiologist and science communicator Associate Professor Siouxie Wiles and cartoonist Toby Morris) has produced more than 70 visually engaging and sharable graphics (Table 1), aimed at helping people grasp the evolving scientific understanding of the virus and the public health measures introduced in response to the pandemic.

Many of Aotearoa New Zealand's five million residents were on summer holidays when news of what would become the COVID-19 pandemic started emerging in late 2019/early 2020. When one of the authors (Wiles) returned home in mid-January from a trip to Europe, she soon found herself responding to requests from TV, radio, print and online journalists.

Wiles identified a need for information about the science of the emerging pandemic, and the importance of working collectively to get through what was likely to be an extremely disruptive and distressing time, so began writing explainers and opinion pieces for online magazine The Spinoff. Taking advantage of New Zealand's dark hours to catch up with northern hemisphere news, Wiles got into a routine of late-night reading of situation reports by the World Health Organization (WHO), European Center for Disease Prevention and Control (ECDC) and the United States Centers for Disease Control and Prevention (CDC), the latest scientific papers and pre-prints, and tweets by trusted scientists—distilling the information into articles to go live the next morning. Soon Wiles was writing new articles almost daily, many focused on how New Zealanders could prepare for the arrival of COVID-19 (Wiles, 2020a,b).

TABLE 1 Graphics produced by Wiles and Morris.

Graphic	Date of release	Description	Ref
Pandemic/infection dynamics related			
Flatten the curve	9 March 2020	Adaptation of Dr Drew Harris' "Flatten the curve" graph	Wiles and Morris, 2020r
Stop the spread	14 March 2020	Adaptation of "Flatten the curve" graphic incorporating information from Anderson et al. (2020)	Wiles and Morris, 2020d
The lag	27 March 2020	Graphic illustrating that because of the incubation period, current COVID-19 cases reflect transmissions that occurred as many as 2 weeks earlier.	Wiles and Morris, 2020x
What happens when people get COVID-19	12 April 2020	Graphic adaptation of data on hospitalizations and deaths gathered during the joint World Health Organization/China mission in February 2020	Wiles and Morris, 2020w
Prevalence: how common is COVID-19?	29 April 2020	Graphic explaining the difference between high prevalence and low prevalence	Wiles and Morris, 2020p
When success looks like an over-reaction	28 April 2020	Adaptation of a graph released by Prof Shaun Hendy and the COVID-19 modeling team showing the success of New Zealand's Alert Level 4 public health measures.	Wiles and Morris, 2020s
Remember what could have been	28 April 2020	Adaptation of "Stop the spread" graphic, reminding people to follow the Alert Level 3 public health measures to prevent a resurgence of COVID-19.	Wiles and Morris, 2020s
COVID-19: our body vs the virus*	6 May 2020	Graphic illustrating how the amount of virus and antibodies changes during an acute COVID-19 infection. Adapted from Adams et al. (2020) and He et al. (2020) .	Wiles and Morris, 2020v
The lag (level 3 editions)	7 May 2020	Adaptation of "The lag" graphic, illustrating that current cases reflect control measures taken 2 weeks earlier.	Wiles and Morris, 2020aa
The disease triangle	30 August 2020	Graphic illustrating the concept of the disease triangle	Wiles and Morris, 2020u
COVID-19 risk meter	30 August 2020	Graphic illustrating how differences in the host and environment can impact on the risk and consequences of being infected with COVID-19.	Wiles and Morris, 2020u
COVID-19 variants	26 January 2021	Graphic illustrating how new COVID-19 variants arise using the analogy of a bicycle lock.	Wiles and Morris, 2021j
RATs vs. PCR*	9 March 2022	Graphic illustrating the time course for people testing positive by rapid antigen test.	Wiles and Morris, 2022c
Why people who've had COVID still need to be cautious*	15 June 2022	Graphic explaining the concepts of waning immunity and variants on protection from future infection	Wiles and Morris, 2022a
COVID-19 negative feedback cycle*	20 July 2022	Graphic adaptation of a graph created by Professor Christina Pagel and shared on Twitter illustrating the COVID-19 negative feedback cycle.	Wiles and Morris, 2022b
Flatten the curve-2022 edition*	27 February 2022	Update to Flatten the curve graphic	Wiles and Morris, 2022e
Transmission-related			
Break the chain	22 March 2020	Graphic illustrating exponential growth and how individual actions can break transmission chains	Wiles and Morris, 2020b
Exponential growth	26 March 2020	Adaptation of "Break the chain" graphic just showing exponential growth and transmission chains.	Wiles and Morris, 2020ad
Transmission chains	18 April 2020	Graphic adaptation of a graphic created by Professor Trevor Bedford and shared on Twitter illustrating the concept of transmission chains.	Wiles and Morris, 2020y
Genome sequencing	13 August 2020	Graphic illustrating how genome sequencing can be used to link COVID-19 cases	Wiles and Morris, 2020j
Contacts: close vs. casual	22 August 2020	Graphic defining what is meant by the terms close and casual contacts, clusters, and community transmission	Wiles and Morris, 2020g
COVID-19 transmission 101—full version*	5 February 2021	Graphic illustrating when people are likely to be infectious, the various routes by which COVID-19 transmits, and the conditions under which super spreading events happen.	Wiles and Morris, 2021b
COVID-19 transmission 101—when are people infectious?	5 February 2021	Graphic illustrating when people are likely to be symptomatic and when they are likely to be infectious after being exposed to COVID-19.	Wiles and Morris, 2021b
COVID-19 transmission 101—how does the virus spread?*	5 February 2021	Graphic illustrating the various routes by which COVID-19 is likely transmitted.	Wiles and Morris, 2021b
COVID-19 transmission 101—super-spreaders*	5 February 2021	Graphic illustrating the conditions under which super spreading events happen.	Wiles and Morris, 2021b

(Continued)

TABLE 1 (Continued)

Graphic	Date of release	Description	Ref
Cracking the case*	17 February 2021	Graphic describing how New Zealand uses PCR and antibody testing, genome sequencing, and contact tracing working to trace the origins of any transmission chains to help understand how COVID-19 transmits and make the country's border controls more robust.	Wiles and Morris, 2021g
Sound advice on COVID-19	18 May 2020	Graphic illustrating COVID-19 transmission and providing advice on how to lower the risk of transmission in some settings.	Wiles and Morris, 2020b
Chasing down an outbreak*	20 August 2021	Update to the graphic describing how New Zealand uses PCR and antibody testing, genome sequencing, and contact tracing working to identify transmission chains as the country experiences an outbreak of the delta variant. Update includes the addition of wastewater testing.	Wiles and Morris, 2021m
COVID-19 transmission 101—updated*	19 August 2021	Update to the previous COVID-19 transmission 101.	Wiles and Morris, 2021f
Five factors for COVID-19 safety*	22 December 2021	Graphic describing five factors that influence the risk of catching and spreading COVID-19.	Wiles and Morris, 2021e
COVID-19 symptoms related			
COVID-19 vs. colds and flu	2 April 2020	Graphic showing the difference between symptoms of COVID-19, flu, and colds.	Wiles and Morris, 2020c
COVID-19 symptom chart—updated	30 April 2020	Updated version of the COVID-19 symptom chart to include new symptoms like loss of smell.	Wiles and Morris, 2020z
Potential symptoms of COVID-19—updated*	18 August 2021	Updated graphic describing the various potential symptoms of COVID-19	Wiles and Morris, 2021c
Bubble-related			
Don't pop your bubbles! Version 1	26 March 2020	Graphic illustrating the breaking of household bubbles by visiting others.	Wiles and Morris, 2020ad
Don't pop your bubbles! Version 2	26 March 2020	Graphic illustrating the breaking of household bubbles by visiting others.	Wiles and Morris, 2020ad
Stay in your bubble	1 April 2020	Graphic illustrating how COVID-19 could transmit between households if people didn't follow the Alert Level 4 public health measures.	Wiles and Morris, 2020ab
Apartment bubbles	3 April 2020	Graphic explaining the concept of household "bubbles" in the context of an apartment.	Wiles and Morris, 2020a
Cleaning shared spaces	3 April 2020	Graphic explaining the importance of regularly cleaning shared areas to prevent the transmission of COVID-19.	Wiles and Morris, 2020a
Back in our bubbles	12 August 2020	Graphic illustrating the public health measures to eliminate community transmission of COVID-19 during an outbreak of the delta variant in New Zealand.	Wiles and Morris, 2020i
Contact tracing-related			
Contact tracing	18 April 2020	Graphic illustrating how contact tracing works to break chains of transmission.	Wiles and Morris, 2020y
Contact tracing apps	23 May 2020	Adaptation of the "Contact tracing" graphic to explain the difference between centralized and decentralized contact tracing apps.	Wiles and Morris, 2020f
New phone who this?!	23 May 2020	Graphic explaining the need for contact tracers to have to date contact information on the population	Wiles and Morris, 2020f
Facemask-related			
Facemasks	6 April 2020	Graphic explaining the difference between respirator, surgical, and cloth masks, and how to wear masks correctly to prevent droplet transmission.	Wiles and Morris, 2020m
Masks in NZ	6 April 2020	Graphic explaining why masks weren't required to be worn in public in New Zealand	Wiles and Morris, 2020m
Masks and COVID-19 transmission risk	15 August 2020	Graphic illustrating the differences mask-wearing makes to the risk of spreading COVID-19.	Wiles and Morris, 2020ac
Universal masking	15 August 2020	Graphic illustrating how universal masking protects the community from those who are infectious.	Wiles and Morris, 2020ac
Masks 101—updated*	19 August 2021	Update to previous graphic on masking.	Wiles and Morris, 2021f
Wishing it's over doesn't make it over*	13 July 2022	Graphic likening wearing a mask when COVID-19 is in the community to wearing a seatbelt.	Wiles and Morris, 2022d

(Continued)

TABLE 1 (Continued)

Graphic	Date of release	Description	Ref
Other public health measures-related			
Get tested	30 April 2020	Graphic illustrating the importance of getting tested quickly to prevent transmission chains growing	Wiles and Morris, 2020z
Keeping safe at level 2	14 May 2020	Graphic illustrating the public health measures in place to keep people safe from COVID-19 when New Zealand was at Alert Level 2.	Wiles and Morris, 2020n
The Emmental (Swiss) Cheese model—International edition	22 October 2020	Graphic illustrating the Swiss Cheese model of systems accidents as it can be applied to managing COVID-19.	Wiles and Morris, 2020h
The Emmental (Swiss) Cheese model—New Zealand edition	22 October 2020	Graphic illustrating the Swiss Cheese model of systems accidents and describing how it was being applied by New Zealand to manage COVID-19.	Wiles and Morris, 2020h
The Emmental (Swiss) Cheese model—now with added vaccines*	20 February 2021	Update of the Swiss Cheese model graphic to include vaccines as another layer of protection.	Wiles and Morris, 2021i
We've done it before*	18 August 2021	Graphic reminding people of the public health measures when New Zealand moved into lockdown due to an outbreak of the delta variant.	Wiles and Morris, 2021c
Immunization/vaccine-related			
Vaccine strategies	28 July 2020	Graphic illustrating the main ways to make a vaccine, including using the whole microbe, its proteins, or its genetic material.	Wiles and Morris, 2020q
Why we immunize	13 November 2020	Graphic illustrating the different reasons people get vaccinated. Created in paid partnership with Te Hiringa Hauora New Zealand Health Promotion Agency.	Wiles and Morris, 2020o
Polio in New Zealand	13 November 2020	Graphic illustrating how vaccines impacted polio cases in New Zealand. Created in paid partnership with Te Hiringa Hauora/Health Promotion Agency.	Wiles and Morris, 2020o
Community immunity	13 November 2020	Graphic illustrating the concept of community immunity. Created in paid partnership with Te Hiringa Hauora/Health Promotion Agency.	Wiles and Morris, 2020o
The Pfizer/BioNTech vaccine explained*	24 February 2021	Graphic illustrating what the Pfizer/BioNTech mRNA COVID-19 vaccine is and how it works.	Wiles and Morris, 2021h
How were COVID-19 vaccines developed so fast?*	3 September 2021	Graphic illustrating the journey vaccines take through clinical trials to approval and manufacturing and how these processes were streamlined for the COVID-19 vaccines.	Wiles and Morris, 2021i
Power up*	16 September 2021	Graphic using the analogy of computer gaming and cheat codes to explain vaccination. Also released as a narrated video on YouTube (https://youtu.be/YVzhJ_sb9Cc)	Wiles and Morris, 2021d
Looking forward to summer*	11 October 2021	Graphic illustrating the timing of vaccine doses to be protected from the delta variant in time for Christmas 2021.	Wiles and Morris, 2021a
Vaccines work against delta—cases*	29 October 2021	Graphic showing the impact of the Pfizer vaccine on cases during New Zealand's delta outbreak.	Wiles and Morris, 2021o
Vaccines work against delta—hospitalisations*	29 October 2021	Graphic showing the impact of the Pfizer vaccine on hospitalisations during New Zealand's delta outbreak.	Wiles and Morris, 2021o
Misinformation/disinformation-related			
Mis/disinformation	8 September 2020	Graphic illustrating the differences between misinformation and disinformation and including an adaptation of the “Break the chain” graphic, applying it to the spread of mis/disinformation.	Wiles and Morris, 2020l
How to bridge the gap	15 September 2020	Graphic illustrating how to talk to someone about misinformation and disinformation. Created in collaboration with the New Zealand Science Media Center and Dr Liz Neeley.	Wiles and Morris, 2020e
The red flags of COVID misinformation*	21 August 2021	Graphic illustrating the differences between misinformation and disinformation and describing the red flags to look out for.	Wiles and Morris, 2021n
Miscellaneous			
Non-contact greetings	22 March 2020	Examples of non-contact greetings	Wiles and Morris, 2020k
A few definitions	24 April 2020	Graphic illustrating the differences between some words when used by researchers vs. the public.	Wiles and Morris, 2020t
COVID-19 variants	26 January 2021	Graphic illustrating how new COVID-19 variants arise using the analogy of a bicycle lock.	Wiles and Morris, 2021j

(Continued)

TABLE 1 (Continued)

Graphic	Date of release	Description	Ref
3 things to know about antibiotics	29 November 2021	Graphic illustrating the issue of antibiotic resistance	Wiles and Morris, 2021p
How to take a nasal swab*	9 March 2022	Graphic illustrating the correct way to take a nasal swab, adapted from a photo shared on social media by Dr Eric Levi.	Wiles and Morris, 2022c
Monkeypox: stop the stigma, stop the spread*	22 August 2022	Graphic Illustrating the ways in which monkeypox can spread and some information on the 2022 global outbreak	Wiles and Morris, 2022f

*indicates those graphics to which a date was added on release.

The collaboration that is the subject of this paper began after one of the authors (Wiles) saw a post on Twitter in late February 2020 by health policy and population health educator Dr Drew Harris (@drewaharris) (Figure 1A) (Harris, 2020). Harris' tweet reminded people that while COVID-19 control measures may only delay cases rather than prevent them, that could be “the difference between finding an ICU bed and ventilator or being treated in the parking lot tent”. The tweet included a graph illustrating the concept of using protective measures to “flatten the curve” and keep cases within the capacity of healthcare systems.

What struck Wiles about Harris' graph was that it didn't articulate how individual attitudes and actions could impact the spread of COVID-19 and thus help “flatten the curve”. Wiles felt that such an important and empowering message needed to be clear and more visually engaging. With a history of working closely with artists, animators, and illustrators on a variety of science communication projects (Wiles and Harris, 2013; Wiles and Klee, 2013, 2015; Wiles, 2014), Wiles asked The Spinoff editor Toby Manhire if Morris—whose cartoons on political and social issues she admired—would be interested in illustrating a new version of the graph. Wiles and Morris, who had never met, were soon on the phone discussing ideas.

This paper documents some of the key outputs of the Wiles Morris collaboration then comments more broadly about the collaboration and offers advice for other scientists and illustrators working together. It includes quotes from a series of Zoom interviews by one of the authors (Priestley) with Wiles and Morris, as well as with The Spinoff editor Toby Manhire and publisher Duncan Greive. These interviews were conducted between July and October 2020 under Victoria University of Wellington Human Ethics Committee approval #28669 and written informed consent was obtained for both participation in the research and for the publication of identifiable information. Unless otherwise specified, all social media analytics reported are for the period March–October 2020.

2. Context

Aotearoa New Zealand is an island nation in the South Pacific with a population of more than five million people. The islands were settled by Polynesian voyagers in the 13th century then colonized by the British in the 1800s. One in six people in the country now identify as having Indigenous Māori ethnicity (Stats NZ, 2020). While English is the predominant language spoken, the country's official languages are te reo Māori and New Zealand sign language (O Tātou Reo | Ministry for Ethnic Communities, n.d.).

Aotearoa New Zealand's first COVID-19 case was reported on 28 February 2020, in a woman who arrived from Iran (New Zealand Ministry of Health, 2020). Three weeks later, with 28 confirmed

cases of COVID-19, the government sealed the borders to everyone except citizens and residents (Unite against COVID-19, 2021). On 23 March a national state of emergency was declared, and the country pivoted from a mitigation approach to an elimination strategy. On 26 March, following the country's first confirmed case of community transmission, the New Zealand government implemented one of the world's strictest lockdowns according to the Oxford Coronavirus Government Response Tracker (OxCGRT) Stringency Index (Hale et al., 2021)—Level 4 of a four-level alert system—while scaling up testing and contact tracing (Unite against COVID-19, 2021). New Zealand's first COVID-19 death was reported on 29 March and daily cases peaked at 89, on 5 April. On 9 June 2020, after 1,154 confirmed COVID-19 cases and 22 deaths, but with no active cases, the country lifted all restrictions except those in place at the border.

Over the next year, restrictions came and went as different regions, and sometimes the whole country, cycled in and out of different alert levels in response to the detection of community transmission of COVID-19. Rollout of the Pfizer/BioNTech vaccine began in February 2021, with priority given to border and managed isolation and quarantine (MIQ) workers, healthcare workers and vulnerable and elderly populations (Hipkins, 2021).

After 100 days with no community transmission of the virus, on 17 August 2021 detection of the Delta variant of COVID-19 led to an immediate nationwide lockdown which lasted for 2 weeks and continued for longer in the country's biggest city of Auckland. In December 2021, as the Omicron variant was spreading around the world, all of New Zealand moved away from the COVID-19 Alert System to the COVID-19 Protection Framework, a three-tiered (red, orange, and yellow) traffic light system which offered greater freedom to those who were vaccinated (Unite against COVID-19, 2022). Omicron was found to be spreading in the community in January 2022 and the entire country moved to “red”.

As part of the response to the pandemic, the government introduced contact tracing requirements, vaccine mandates, and mask mandates. For example, rolling out from October 2021 vaccine mandates were introduced to workers in health and disability services, Police, Defense Force, Fire and Emergency services, schools, and border and corrections services. Masks were required on flights, public transport, in taxis, retail, public facilities, in some education settings, and in close proximity businesses, food and drink businesses, public events, and gatherings.

Compliance levels with the mandates were moderate to high (Kaine et al., 2022) but at the same time as two of the authors were publishing their graphics, there was a rise of disinformation and anti-government sentiment (Soar et al., 2020). On 6 February 2022, a day when there were 208 new community cases of COVID-19, groups of protesters began traveling to New Zealand's Parliament grounds for what became an illegal occupation of the grounds and surrounding

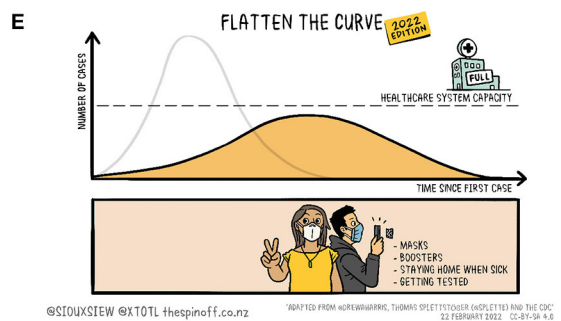
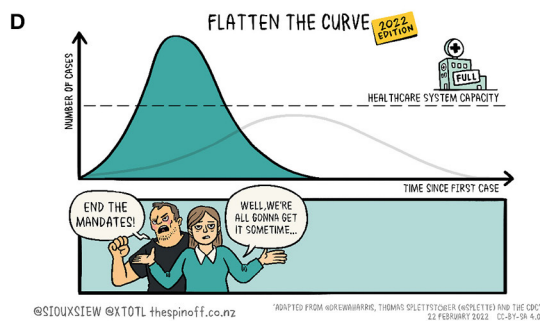
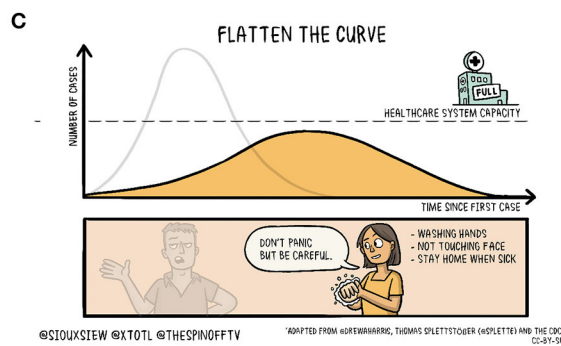
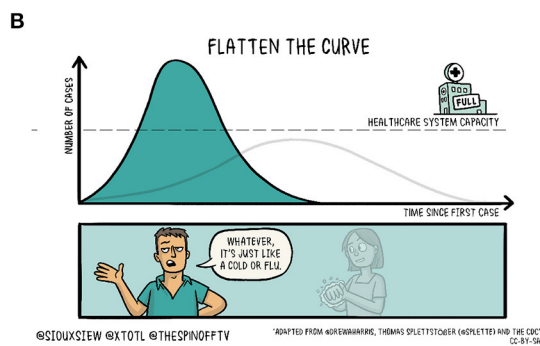
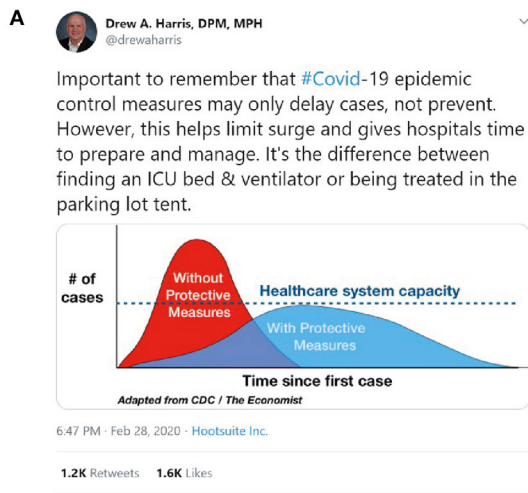


FIGURE 1 Graphic representations of “Flatten the curve”. Wiles and Morris based their graphic on a Tweet by Dr Drew Harris (A). The first version Wiles and Morris released was a GIF which presents expected daily COVID-19 case numbers where no action is taken (B) and where people adopt a “careful” approach, which included washing hands, not touching faces, and staying home when sick (C). An updated version was released by Wiles and Morris in 2022 where the “whatever” approach now included an anti-mask/vaccine mandate protestor (D) and the “careful” approach now included references to masking, vaccination, and other public health measures (E).

streets. By 2 March 2022, when the final protesters were forcibly removed from Parliament, daily community cases of COVID-19 reached 22,152. Fuelled by online mis- and disinformation about the safety of the Pfizer/BioNTech vaccine, as well as far-right anti-government propaganda, the disorganized group of protesters called for the end of all COVID-19 restrictions, including mask and vaccine mandates, and made violent threats to government leaders, journalists, academics, and public officials involved in, or reporting on, the COVID-19 response (Hannah et al., 2022).

In September 2022 the COVID-19 Protection Framework was retired, replaced by a set of public health advice that specified

mask-wearing under some circumstances, most notably in settings such as aged care and healthcare facilities (Unite against COVID-19, 2022). The requirement for household contacts of COVID-cases to isolate was also removed, unless they also tested positive, and New Zealand’s border fully reopened, including to unvaccinated travelers.

Compared to other countries, New Zealand has had high uptake of the initial two dose COVID-19 vaccine regimen. According to Manatu Hauora Ministry of Health statistics, as of October 2022, 11,826,909 total vaccine doses have been administered in New Zealand (New Zealand Ministry of Health, 2022b). This equates to 90.2 percent of the eligible 12+ population having completed the

primary course, 73.2 percent of the eligible 18+ population having received a first booster, and 41 percent of the eligible 50+ population having received a second booster (New Zealand Ministry of Health, 2022b). A pediatric vaccine is also available to those aged 5–11 and as of October 2022, 268,012 first doses and 151,816 second doses have been administered (New Zealand Ministry of Health, 2022b). As of 23 October 2022, the Manatu Hauora Ministry of Health reported 1,831,233 confirmed cases of COVID-19 (New Zealand Ministry of Health, 2022a). The widespread use of at-home rapid antigen tests since the emergence of the Omicron variant means that this is almost certainly an underestimate due to under-self-reporting; it is likely that to date at least half of all people in New Zealand have had a COVID-19 infection. As of 23 October 2022, there have been 2,095 deaths attributed to COVID-19 (New Zealand Ministry of Health, 2022a), one of the lowest cumulative per capita death rates in the world.

The focus of this paper is a series of graphics produced by two of the authors in response to the COVID-19 pandemic. Wiles is a microbiologist and infectious diseases expert and one of New Zealand's most visible and celebrated science communicators. Her awards include the inaugural 3Rs Prize from the UK National Center for the Replacement, Refinement, and Reduction of Animals in Research (NC3Rs) in 2005 and the New Zealand Prime Minister's Science Media Communication Prize in 2013. In 2019 she was appointed a member of the New Zealand Order of Merit for services to microbiology and science communication. Morris is an award-winning illustrator, comic artist, and writer with a Bachelor of Arts in English literature and political science. He is well known for highlighting important social issues in his non-fiction online comics, including *The Pencilsword* for New Zealand broadcaster RNZ (Morris, 2017) and *The Side Eye* for online magazine *The Spinoff* (Morris, 2022). The Spinoff is an independent New Zealand-based media brand and content agency founded in 2014 (Spinoff, 2022). It covers current affairs and pop culture in an online magazine style, focusing on features, analysis, and opinion.

3. Scientist-cartoonist collaboration

3.1. Flattening the curve

“Duncan Greive, the managing editor, and I were a bit shell shocked—as was most of the country—but we realized that what *The Spinoff* was at that point had to change because the mood of the country had changed, and this was an issue that was too pressing and serious to treat the way we would treat any old cultural or political news story. . . . One of the decisions we made when things became serious is that the last thing people need now is hot takes, which would surprise some people, given *The Spinoff* is, you know, not afraid of a hot take on a whole lot of cultural and political elements, but we thought that it was just too serious and too complex to have people smashing out 600 word polemics or opinion pieces.”

Toby Manhire, *The Spinoff* editor, 28 July 2020

As previously described, two of the authors began collaborating after Wiles saw Dr Drew Harris' tweet describing the concept of “flatten the curve” in late February 2020 (Figure 1A) (Harris, 2020).

The result was a GIF that alternated between a “whatever” approach, where no action is taken (Figure 1B), and a “careful” approach, which included washing hands, not touching faces, and staying home when sick (Figure 1C). Morris replaced the red and blue colors of the original graph because of their affiliation with certain political parties in New Zealand, the USA, and many other countries. He also added an illustration of a hospital with a “full” sign to signify health system capacity.

Our “Flatten the curve” GIF was released under a Creative Commons CC-BY-SA-4.0 license and accompanied by an article on *The Spinoff* (Wiles and Morris, 2020r). Wiles shared the GIF on Twitter on 9 March 2020. It was an instant success, gaining 1.9 million impressions within 48 h. The New Zealand Prime Minister Jacinda Ardern used it at a national press conference on 14 March. It spread around the world, gaining over 10 million impressions. International news media published it in their articles about COVID-19. After being translated into several European languages by volunteers, coder Marc Sutter (@marcsutter on Twitter) developed an automated system to translate the graphic into any language (Sutter, 2020b). Our “Flatten the curve” GIF went, pardon the pun, viral. The GIF was updated in February 2022 to reflect changes in health measures, such as the use of masks and vaccines, since the GIF was first released (Figures 1D, E; Table 1) (Wiles and Morris, 2022e).

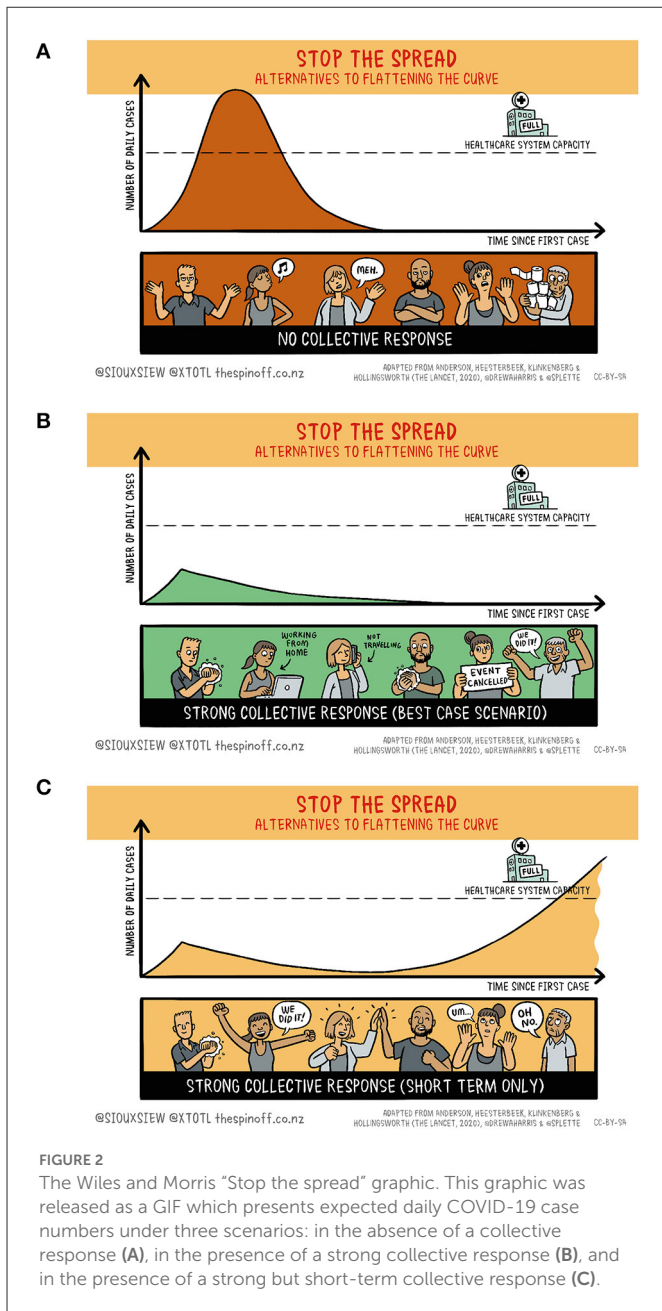
3.2. Stop the spread: The elimination message

“I knew immediately when I saw [Stop the Spread] that it was going to go around the world. It's an incredible piece of communication that in the space of seconds conveys the critical importance of taking responsibility for what you do and its impact on other people. I remember seeing that on a Saturday evening and just thinking this is going to be massive and I scheduled it to run on Twitter the next morning, and by the time I woke up it had, you know, thousands of shares already.”

Toby Manhire, *Spinoff* editor, 28 July 2020

On 11 March 2020, just days after our “Flatten the curve” GIF was released, the WHO declared COVID-19 a global pandemic (Ghebreyesus, 2020). Two days earlier, on 9 March 2020, Professor Roy Anderson and colleagues had published an article in *The Lancet* (Anderson et al., 2020) expressing their view that COVID-19 had developed into a pandemic and small chains of transmission were occurring in many countries, alongside the extensive spread already being seen in countries such as Italy and Iran. In their paper they illustrated an alternative to “flattening the curve,” where interventions reduced cases to near background levels. It also cautioned that this approach came with the risk of a resurgence if the interventions were lifted too soon.

Motivated by the success of “Flatten the curve”, their shared values, and the ease with which they had collaborated, Wiles asked Morris if he would work with her again to illustrate the alternate pandemic management strategy highlighted by Anderson and colleagues. Wiles and Morris dubbed this strategy “Stop



the spread” but in epidemiological terms it is better known as elimination. Again, Wiles wanted to show the public that their actions mattered. The new GIF cycled through three scenarios (Figure 2). In the first, the lack of a collective response sees cases rapidly overwhelm health system capacity (Figure 2A). In the second, a strong collective response results in the elimination of COVID-19 as the best-case scenario (Figure 2B). In the final scenario, a strong but short-term collective response results in a resurgence in cases (Figure 2C).

The “Stop the spread” GIF was released under a Creative Commons CC-BY-SA-4.0 license and accompanied by an article on The Spinoff (Wiles and Morris, 2020d). Wiles shared the GIF on Twitter on 13 March 2020, and it soon gained more than one million impressions, including more

than 4,300 retweets and 5,100 likes. While this GIF did not achieve the international success of “Flatten the curve”, which saw 10 million impressions, it was useful within New Zealand to help the public understand the elimination strategy which the government began pursuing in the latter part of March 2020.

3.3. Breaking the chain of transmission

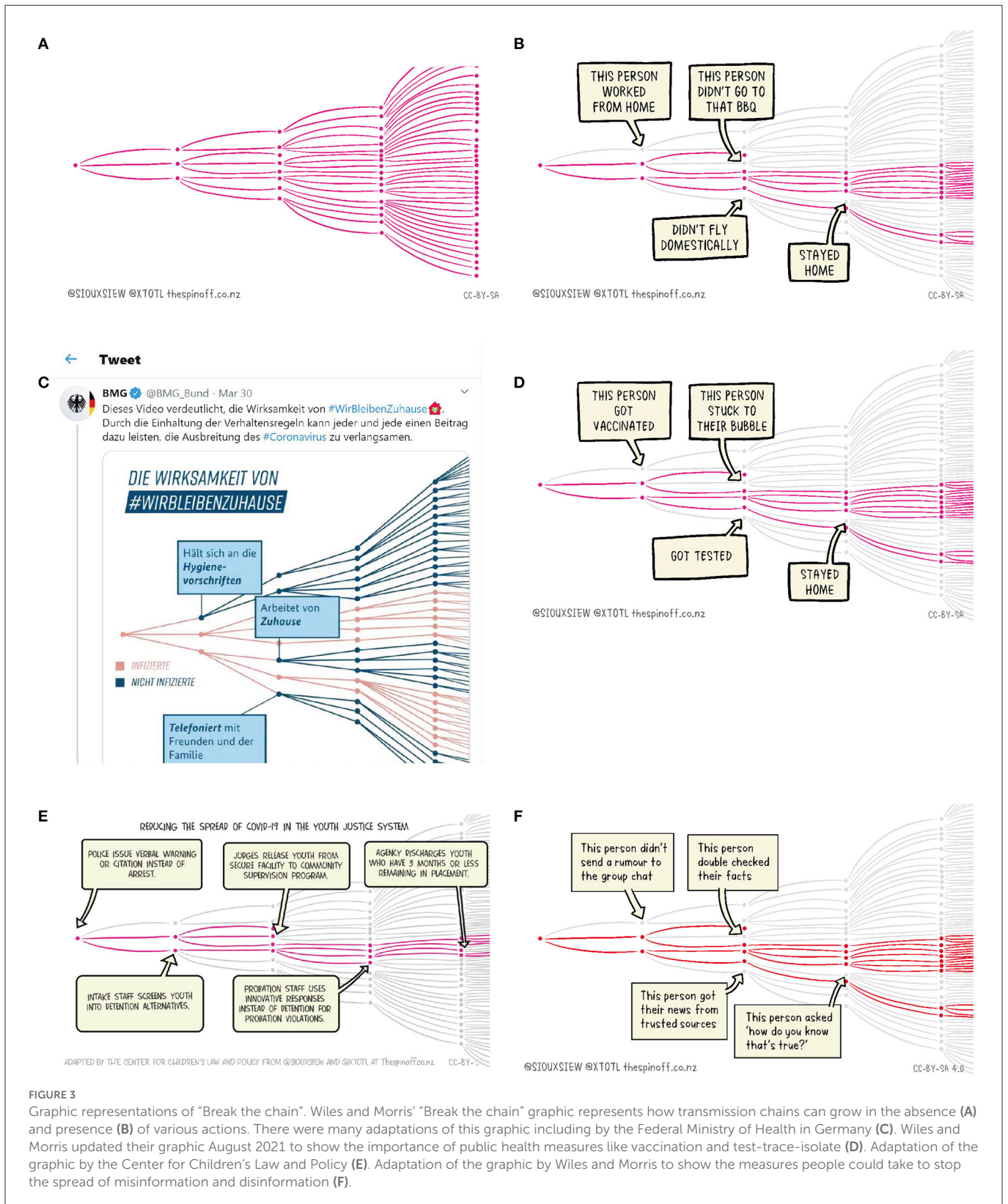
“I think that magenta just sort of clicked with me as being quite a bright and distinctive color and it was very useful to have that as a visual shorthand. I sent Siouxsie an email saying I hope you are comfortable with this, people have pointed out that it’s matching your hair, I hope you’re not thinking that I’m making you synonymous with a virus or something like that. And she said, no, no, it’s fine. It works, so let’s keep rolling with it.”

Toby Morris, 10 August 2020

With cases growing rapidly around the world, after “Stop the spread” Wiles’ next goal was to explain the concept of exponential growth and show how one case can quickly branch out into more and more transmission chains. She also wanted to illustrate how individual decisions and actions can end a chain of transmission. In “Breaking the chain”, Morris chose to depict COVID-19 cases as pink dots, with each case resulting in a further two to three cases connected by pink lines (Figure 3A). Chains are broken—and the pink dots and lines turn gray—by actions such as working from home, or not attending a social gathering (“this person didn’t go to that BBQ [barbeque]”) (Figure 3B). The suggested actions reflected Wiles’ advice at the time that people begin working from home if possible and minimize their contact with others.

Again, the GIF was released under a Creative Commons CC-BY-SA-4.0 license and accompanied by an article on The Spinoff (Wiles and Morris, 2020k). Wiles shared the GIF on Twitter on 22 March 2020 where it gained more than 2.5 million impressions, including more than 13,700 retweets and 16,000 likes. Soon afterwards the GIF began being adapted and adopted by official communications channels in many countries, including Argentina, Australia, Germany (Figure 3C), and Scotland. Wiles and Morris updated the GIF in August 2021 to reflect the change in recommendations for reducing transmission since the release of the original GIF (Figure 3D).

One of the most striking adaptations of “Breaking the chain” was by the Center for Children’s Law and Policy, an organization based in Washington D.C, USA, which focuses on protecting the rights of children within the youth justice and other systems. In their adaptation, actions such as working from home or not attending a social gathering are replaced with actions to reduce the spread of COVID-19 in the youth justice system (for example, “police issue verbal warning or citation instead of arrest” and “judges release youth from secure facility to community supervision program”) (Figure 3E).



In September 2020, we adapted the “Breaking the chain” GIF for a series of graphics about the “infodemic” (Zarocostas, 2020)—the overabundance and rapid spread of both accurate and inaccurate

information about the pandemic—featuring measures people could take to stop the spread of misinformation and disinformation (Figure 3F; Table 1).

3.4. Communicating key public health measures and scientific concepts

[We wanted to] “help people explain the idea that we have to stay close to each other, and not mix groups and stuff. And I had gotten off the phone and been sketching ideas of family units or whatever the term for it could be. And later the Prime Minister had a press conference and she said the word “bubble” in that. And I was watching, with my notepad, half listening and half working, and was like “bubble!” You know, like, that’s it. And within a minute I had a text from Siouxsie and from Toby [Manhire] saying “the Prime Minister just said bubble”, like, that’s it, that’s the term that we were trying to think of. And that was a really effective metaphor, very easy to grasp, because, it’s you know, very fragile. The bubble, you know that you’re inside it, or it’s broken. And as soon as we had that idea, it seemed like that would be an effective visual metaphor, be easy enough to draw, something that explained the idea very clearly.”

Toby Morris, 10 August 2020

On 26 March 2020, 5 days after the introduction of the four-tiered Alert Level system, New Zealand began one of the world’s strictest lockdowns. Again, we (Wiles and Morris) immediately began producing graphics to help people understand the importance of following the public health measures of the Alert Level system. For example, in announcing the move to Alert Level 4, Prime Minister Jacinda Ardern suggested everyone think of themselves as being in a “bubble” with the people they live with (Kearns et al., 2021). Under Alert Level 4 people had to stay in their bubble so if someone within a household was incubating COVID-19, spread beyond that bubble would be limited. The bubble concept, first suggested by academic Tristram Ingham for use in the disabled community, was used widely by the government and the media (He Kitenga, 2020). We produced a series of graphics showing, for example, bubbles being popped by people visiting other households (Figure 4A) and how COVID-19 could spread between bubbles if just one person from each household did not follow the rules (Table 1).

As case numbers continued to rise and New Zealand began to record deaths from COVID-19, we produced graphics explaining the concept of the “lag” (Figure 4B) so people would understand that it would take several weeks to begin to see the impact of the Alert Level system measures. Because of the incubation period of the virus, which at the beginning of the pandemic was 2 to 10 days for most people, daily case numbers reflected infections that occurred in the previous 1 to 2 weeks. Similarly, because it took many weeks for some people to become seriously ill from COVID-19, deaths were expected to continue for many weeks after case numbers had begun to decline.

One graphic was inspired by confusion over the word “elimination” which has a different meaning in epidemiology (to reduce to zero or near zero in a particular area) than in everyday use (to get rid of completely). We brainstormed other dual-meaning words that the public would be hearing during the pandemic and the result is the “A few definitions” graphic (Figure 4C). One of the words included in this graphic is “model”. In science, a model is a simulation or representation of the real world, whereas in everyday language a model is a small replica, or a person who demonstrates clothes. Morris represented the word model using a mouse and fly, which

researchers commonly use as surrogates for humans in scientific experiments, as well as the mathematical formula initially used by one of the teams modeling potential COVID-19 cases in New Zealand (Binny et al., 2021).

Over the course of the pandemic, we continued to produce graphics with most falling into one of two categories: (1) explaining scientific concepts and (2) explaining public health measures. Their efforts to explain scientific concepts included a graphic that showed the different ways of detecting a COVID-19 infection before the rollout of vaccines (Figure 4D) and a graphic that used the analogy of a bicycle lock to explain how different COVID-19 variants arise (Figure 4E). To help explain public health measures, we produced graphics covering interventions such as masks (Figure 4F), vaccines (Figures 4G–I), and contact tracing (Figure 4J). When communicating about vaccination, they not only explained the diverse ways vaccines are made, but specifically focused on how mRNA vaccines work (Figure 4G), and how the COVID-19 vaccines were developed so fast (Figure 4H). We used the concept of multiplayer video games to explain how vaccines work and “community immunity” (Figure 4I). This graphic was also turned into a video for release on YouTube (Wiles and Morris, 2021k). We also adapted graphics by Jono Hey (@sketchplanator on Twitter) (Hey, 2020), and Dr Ian M. Mackay (@MackayIM on Twitter) (Mackay, 2020) based on Professor James Reason and colleagues’ “Swiss cheese model of system accidents” (Eagle et al., 1992; Reason, 2000) to show how public health measures can work together to protect people from COVID-19 (“The Swiss cheese model”, Figure 4K). When rapid antigen tests became more widely available in New Zealand, we made a graphic explaining how to correctly take a nasal swab (Figure 4L) based on advice posted online by otolaryngologist Dr Eric Levi (@DrEricLevi on Twitter) (Levi, 2022). Early in the pandemic Morris also worked with Wiles on a longer form comic (Morris, 2020) exploring what was known or suspected about COVID-19 at the time.

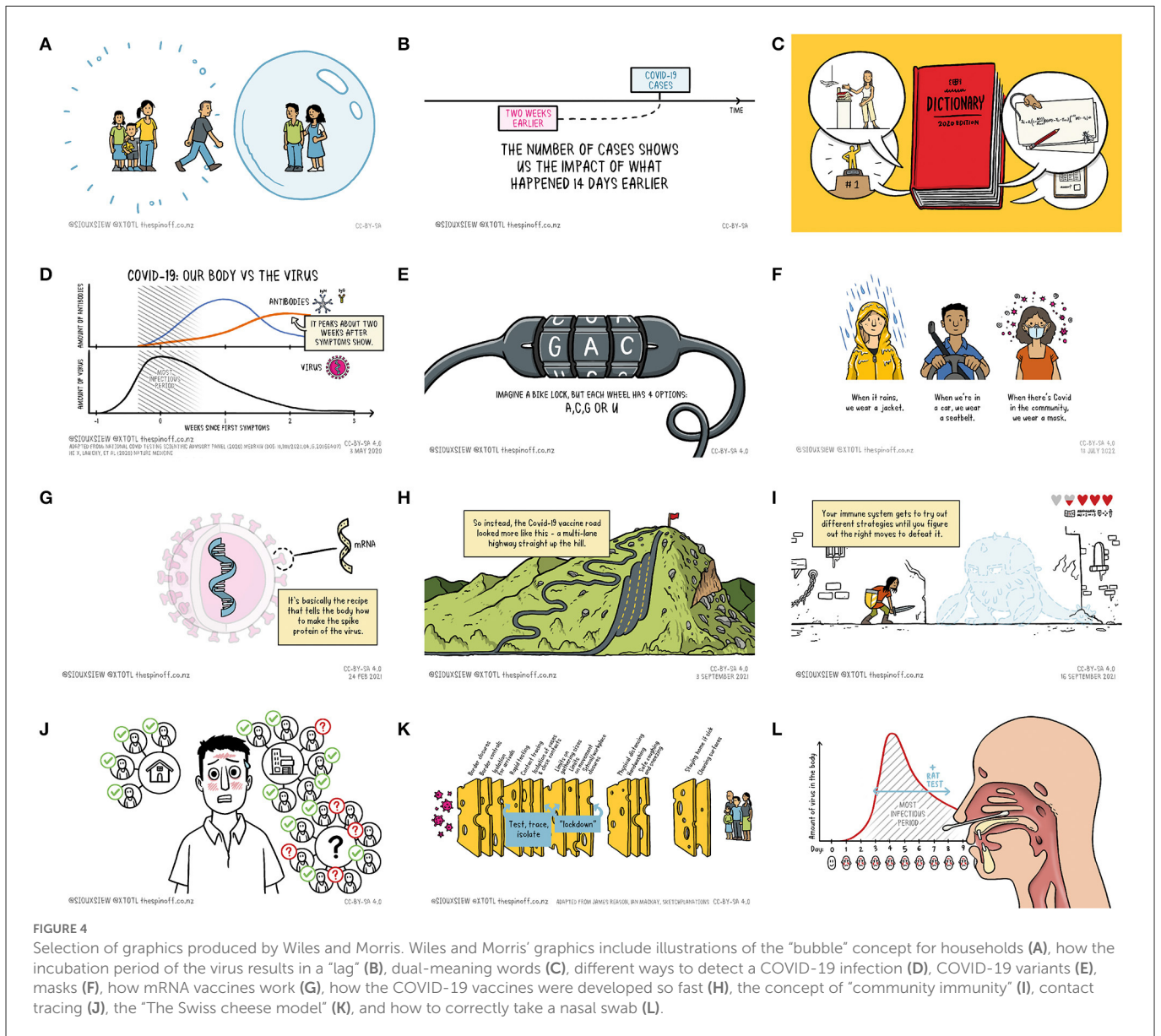
While communicating about COVID-19 has been the focus of the Wiles-Morris collaboration, we have more recently used their platform to communicate about other health issues such as antibiotic resistance (Wiles and Morris, 2021p) and the 2022 Monkeypox epidemic (Wiles and Morris, 2022f).

4. Discussion

“The work they did had a measurable and real impact in New Zealand and around the world, and will have saved people’s lives. I sort of pinch myself saying that, but I think the ability to be able to communicate those concepts and why they matter so much will have changed people’s decision-making.”

Toby Manhire, The Spinoff editor, 28 July 2020

In Aotearoa New Zealand, public communications about the COVID-19 pandemic initially came from daily briefings from the Prime Minister Jacinda Ardern and the Director-General of Health Ashley Bloomfield, supported by a government communications campaign (Beattie and Priestley, 2021). But direct communication by scientists such as Wiles, along with others such as epidemiologist Professor Michael Baker, public



health expert Dr Ayesha Verrall, and COVID-19 modelers Professors Shaun Hendy and Michael Plank, also played a key role in educating New Zealanders, and then the world, about COVID-19.

4.1. Lauded and harassed

"... people were so hungry for information they could rely on, information which, in an accessible way, conveyed the health and science implications of the pandemic ... and the beautiful thing about Toby and Siouxsie's work was that it had a calm voice, you know it spoke to you in a way which, after consuming [it, you were like] okay, this is really scary, but I can deal with it."

Duncan Greive, The Spinoff managing editor, 14 October 2020

As a result of the success of our (Wiles and Morris) collaboration, in November 2020 the Designers Institute of New Zealand awarded us the "Purple Pin" Public Good Award, with judges describing our work as taking "a simple and human approach to a once in a lifetime problem," providing "complex information in an accessible, clear and concise fashion" in "an environment where science and facts were highly contested" (Design Institute of New Zealand, 2020). On 31 March 2021, Wiles was named 2021 Kiwibank New Zealander of the Year, with the citation acknowledging her work with Morris creating graphics "seen by millions and even used by governments and organizations as part of their official pandemic communications" (Kiwibank New Zealander of the Year Awards, 2020). In recognition of the collaboration, Morris won Best Graphic Artist and Cartoonist of the Year at the Voyager Media Awards 2021 and the Prime Minister's Science Communication Prize 2021 for producing "some of the most effective science communication on COVID-19 seen anywhere in the world" (The Prime Minister's Science Prizes, 2021). The success of our collaboration led the

New Zealand Science Media Centre to encourage further scientist-illustrator collaborations, holding a Drawing Science workshop in June 2021 and collaborating with The Spinoff and Daylight Creative to publish an illustrated guide for researchers who want to learn how to collaborate with illustrators (Science Media Centre, 2022).

But there has been a dark flipside to the success of this campaign, and Wiles' visibility through the pandemic. Already used to a certain level of harassment as an outspoken pink-haired woman with a public profile, the pandemic has seen Wiles subject to violent online abuse, harassment and threats from those opposed to strong interventionist COVID policies, including disinformation campaigners who accuse her of, for example, "misleading the public" and "supporting a government to perform medical experiment (sic) on it's (sic) citizens" (Wiles, 2022).

4.2. Creative commons licensing of GIFs and graphics

"Siouxsie said sort of almost in passing "hey, do you think we could make this work Creative Commons", and I sort of went "oh?" And I remember thinking about it very briefly, because you wouldn't normally do that when it's copyrighted work for a publication. It's not the normal thing to give it away. But these were strange times and it was important work and I said, "well yes okay let's do that, why not?" And we did. And it meant that [the graphics] could be translated by people elsewhere, it meant that people could adapt it for their own purposes, it meant that people could kind of build on the work that had started and get it in front of as many eyeballs as possible without feeling as though they had to check in with us ... It sort of became almost a running joke, the ways that different parts were used, and sometimes bastardized in different comms operations around the world. We haven't got them all, but I've got many of them in a folder which make quite interesting viewing. You know, we got sent photos of a phone box in Berlin that had Toby's illustration on it."

Toby Manhire, The Spinoff editor, 28 July 2020

One of the key factors in these graphics being shared so widely, in New Zealand and around the world, and adapted to a range of different languages, cultures and environments, is the Creative Commons licensing. Creative Commons licenses are free, easy-to-use copyright licenses that provide a simple, standardized way for content creators to maintain their copyright while giving others permission to share and use their creative work without the individual negotiations necessary under the more traditional "all rights reserved" form of copyright (Creative Commons, n.d.). There are a range of Creative Commons licenses available which allow the content creator to specify whether their work can be distributed, remixed, adapted, and built upon, and whether this can be done commercially or non-commercially.

All the images produced as part of our collaboration were released under a Creative Commons CC-BY-SA-4.0 license. This means that anyone is free to use them, and adapt them, providing they give appropriate credit and share them under the same conditions. As previously described, coder Marc Sutter developed an automated system to translate the "Flatten the curve" graphic into any language

which he posted to the online open-source software hosting service GitHub on 28 March 2020 (Sutter, 2020b). By April 2020, Sutter had done the same for the "Breaking the chain" graphic (Sutter, 2020c) and the "Stay in your bubble" graphic (Sutter, 2020a). In April 2020, The Spinoff also arranged for all the graphics and GIFs produced to date to be translated into te reo Māori (Hayden, 2020). In August 2020 in response to a community outbreak of COVID-19, several more graphics and GIFs were translated into te reo Māori and into Cook Islands, Samoan, Tongan, and Niuean languages in collaboration with Moana Connect (formerly Moana Research).

Over the weeks and months that followed, people continued to translate and share the graphics and GIFs around the world. In June 2020, the World Health Organization contracted The Spinoff's Auckland-based team to develop COVID-19 communications resources for the global organization which saw many of our original GIFs and graphics adapted and released to a global audience.

4.3. Developing effective science communication collaborations

"Usually, I would read [Siouxsie's] first go at it and I would make a very scruffy sort of pencil sketch animation, just with a few crude frames, like spend half an hour on it or something, and send that back to her and Toby and say, "this is how I've understood what you said, am I on the right track, have I understood you right here?" And sometimes that would be like "yep, that's right, let's go for it". Other times, it would need a bit more conversation back and forth, she'd have some sort of clarifications or corrections, or sometimes I would have missed the point and she would explain it to me more clearly. But to me, it starts to make sense when I start to actually draw it rather than chatting about it back and forth, sometimes it's easier to sketch it rather than describe what I'm going to sketch initially."

Toby Morris, 10 August 2020

For scientists wanting to improve their science communication efforts by working with visual communicators, we advise that they understand the limits of their own communications expertise and seek out collaborators with complementary skillsets. We also suggest you consider collaborating with others with a shared set of values as some agreement on why you're communicating can help build rapport and synergy between collaborators. It is also helpful to build long-term relationships and credibility with journalists, artists, and visual communicators. We recommend that you ask for advice from academics and practitioners who work and research in the field of science communication and be prepared to read some of the theory. Finally, we ask that you consider sharing your successes and failures with the wider community, through conference presentations, blogs, and academic articles.

For visual communicators wanting to improve their science communication efforts by working with scientists, we advise that effective collaboration is a lot about respecting each other's expertise and playing to each other's strengths. The scientists will likely be the experts in what you're going to say, and you can help with how you're going to say it. We also suggest you work together to figure out precisely what it is you're trying to say, and then stick to the point. It's more effective to say one thing clearly than several things

cluttered. We also believe that sometimes working with unfamiliar subject matter can be an advantage; in many respects you as a visual communicator are probably in the same position as the audience. If you find a way—a metaphor, a diagram, an analogy perhaps—that helps you understand the science, that’s likely to help your audience understand it too. Simplicity is also key, so we advise trying to trim out any elements that aren’t working toward making your point clearer. Similarly, the visuals should be used for communication, not just as decorations. We recommend finding ways where you can condense information into the imagery and trim out words; showing someone doing something can be more effective than telling them about it. Finally, we advise that you be aware of subconscious messaging. Images are great at communicating information, but also, less obviously, tone. Images can feel warm or cold, calm or hectic, welcoming or aggressive. Think about the colors you use, the style of your artwork, and the complexity of your layouts. These can be used subtly to help set the mood your communication will be received in.

4.4. Engaging with design and science communications principles and theories

“There was ... a massive hunger for information and heaps of information out there, but knowing what to listen to and what to trust was hard. And I think the two of us both managed to hit a tone, that felt clear without being kind of either too techy and too complicated or too patronizing and overexplaining, or like you’re talking down to people.”

Toby Morris, 10 August 2020

As an investigator with Te Pūnaha Matatini, a cross-institutional, multi-disciplinary research center “highly committed to creating a research culture that values equity, diversity, indigenous knowledge and public engagement” (Bailey et al., 2022). Wiles had, in February 2020, participated in an “engagement incubator”, a workshop retreat designed to empower scientist communicators to engage with science communication theory and to become more reflexive about their own roles and the purpose of their science communication. In 2017, Salmon, Priestley and Goven proposed that scientist communicators be more reflexive about the personal, political and institutional context of their science communication (Salmon et al., 2017). In an effort to enact this theory, Bailey et al. developed the engagement incubator, in which design is used to convey key concepts of science communication theory to practitioners and stimulate reflexivity about their role as public scientists (Bailey et al., 2022). Wiles’ timely participation in this workshop allowed her to explore concepts such as the role of public engagement in enabling informed design making and the public role of scientist communicators against the backdrop of the emerging COVID-19 pandemic. It provided her with foundational communication and public engagement principles to sit alongside what she had learned from Te Pūnaha Matatini colleagues and from accessible works aimed at scientists communicating with publics such as Jess Berentson-Shaw’s book *A Matter of Fact* (Berentson-Shaw, 2018) and the *Debunking Handbook* (Lewandowsky et al., 2020).

So while our work was not explicitly driven by theory, it was grounded in theory. We had enough foundational knowledge and awareness of audience—and the subgroups within an

audience—to produce work that adhered to WHO principles of effective communication, with GIFS conveying messages that were accessible, actionable, credible, relevant, timely and understandable (World Health Organization, n.d.).

Rodriguez Estrada and Davis argue for science communicators to have visual literacy (Rodríguez Estrada and Davis, 2015). In this collaboration, a visually literate scientist communicator collaborated with an illustrator using a fast iterative process involving a multidisciplinary team (scientist, illustrator, and editor). While the communication produced could be seen as one-way—the GIFS were produced by an expert team and disseminated to public audiences—the messages in the GIFS responded in real time to the evolution of the virus and the latest scientific and government response to the pandemic. They also explicitly addressed public concerns about COVID-19, and the response to the pandemic, as expressed *via* social media and news media. Sharing of the GIFs on social media allowed a wide range of publics, scientists, and health officials to comment on, share and adapt the communications for other audiences. As a result, these GIFs became a key resource that could stimulate and inform dialogue, rather than simply being one-way communication (Bucchi and Trench, 2021).

5. Conclusion

In this paper we have documented the accessible visual COVID-19 communications produced by two of the authors, microbiologist and infectious diseases expert Associate Professor Siouxsie Wiles and cartoonist Toby Morris. Our collaboration began with the release in early March 2020 of an animated GIF known as “Flatten the Curve” (Wiles and Morris, 2020r). We went on to produce more than 70 graphics (Table 1), all released under a Creative Commons CC-BY-SA-4.0 license, many of which have been translated into multiple languages, and used by communities, public health officials, governments, and organizations all around the world. One of the main limitations of developing communications during the pandemic, has been the speed with which both understanding about COVID-19 has changed as new evidence emerges but also how the emergence of new variants of the virus impacted on infection dynamics and public health measures. For this reason, in February 2021, we began dating our graphics, and added a disclaimer that information may change with the emergence of new variants.

As the COVID-19 virus continues to spread, evolve, and claim lives around the world there is an ongoing need for accessible and effective public health messaging. All our graphics (Table 1) are available on the Spinoff website, along with information about how to use and credit them (The Spinoff, 2021).

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

Interviews were conducted between July and October 2020 under Victoria University of Wellington Human Ethics Committee

approval #28669 and written informed consent was obtained for both participation in the research and for the publication of identifiable information.

Author contributions

SW, TM, and RP contributed to the conception and design of the study. SW and RP wrote the first draft of the manuscript. All authors contributed to manuscript revision, read, and approved the submitted version.

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References

- Adams, E. R., Ainsworth, M., Anand, R., Andersson, M. I., Auckland, K., Baillie, J. K., et al. (2020). Antibody testing for COVID-19: a report from the National COVID Scientific Advisory Panel. *Wellcome Open Res.* 5:139. doi: 10.12688/wellcomeopenres.15927.1
- Anderson, R. M., Heesterbeek, H., Klinkenberg, D., and Hollingsworth, T. D. (2020). How will country-based mitigation measures influence the course of the COVID-19 epidemic? *The Lancet* 395, 931–934. doi: 10.1016/S0140-6736(20)30567-5
- Bailey, J., Salmon, R., and Horst, M. (2022). The 'Engagement Incubator': using design to stimulate reflexivity about public engagement with science. *JCOM* 21, A01. doi: 10.22323/2.21040201
- Beattie, A., and Priestley, R. (2021). Fighting COVID-19 with the team of 5 million: Aotearoa New Zealand government communication during the 2020 lockdown. *Soc. Sci. Human. Open* 4, 100209. doi: 10.1016/j.ssho.2021.100209
- Berentson-Shaw, J. (2018). *A Matter of Fact*. Wellington, New Zealand: Bridget Williams Books. doi: 10.7810/9781988545387_2
- Binny, R. N., Baker, M. G., Hendy, S. C., James, A., Lustig, A., Plank, M. J., et al. (2021). Early intervention is the key to success in COVID-19 control. *R Soc. Open Sci.* 8, 210488. doi: 10.1098/rsos.210488
- Bucchi, M., and Trench, B. (2021). Rethinking science communication as the social conversation around science. *JCOM* 20, Y01. doi: 10.22323/2.20030401
- Creative Commons (n.d.). *About CC Licenses*. *Creative Commons*. Available online at: <https://creativecommons.org/about/cclicenses/> (accessed October 28, 2022).
- Design Institute of New Zealand (2020). *Covid 19 - Siouxsie and Toby | Best Awards*. Available online at: <https://bestawards.co.nz/public-good-award/public-good-award/the-spinoff/covid-19-siouxsie-and-toby-1/> (accessed October 29, 2022).
- Eagle, C. J., Davies, J. M., and Reason, J. (1992). Accident analysis of large-scale technological disasters applied to an anaesthetic complication. *Can. J. Anaesth.* 39, 118–122. doi: 10.1007/BF03008640
- Ghebreyesus, T. A. (2020). *WHO Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020*. Available online at: <https://www.who.int/director-general/speeches/detail/who-director-general-s-opening-remarks-at-the-media-briefing-on-covid-19--11-march-2020> (accessed October 4, 2022).
- Hale, T., Angrist, N., Goldszmidt, R., Kira, B., Petherick, A., Phillips, T., et al. (2021). A global panel database of pandemic policies (Oxford COVID-19 Government Response Tracker). *Nat. Hum. Behav.* 5, 529–538. doi: 10.1038/s41562-021-01079-8
- Hannah, K., Hattotuwa, S., and Taylor, K. (2022). The murmuration of information disorders: Aotearoa New Zealand's mis- and disinformation ecologies and the parliament protest. *Pacific Journal. Rev.* 28, 138–161. doi: 10.24135/pjr.v28i1and2.1266
- Harris, D. A. (2020). *Flatten the curve*. *Twitter*. Available online at: <https://twitter.com/drewaharris/status/1233267475036372992> (accessed October 29, 2022).
- Hayden, L. (2020). *Covid-19: The Siouxsie Wiles and Toby Morris gifs now in te reo Māori*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/atea/01-04-2020/covid-19-the-siouxsie-wiles-and-toby-morris-gifs-now-in-te-reo-maori> (accessed October 29, 2022).
- He Kitenga (2020). *Bubble concept goes viral*. Available online at: <https://www.otago.ac.nz/hekitenga/2020/otago742700.html> (accessed October 29, 2022).
- He, X., Lau, E. H. Y., Wu, P., Deng, X., Wang, J., Hao, X., et al. (2020). Temporal dynamics in viral shedding and transmissibility of COVID-19. *Nat. Med.* 26, 672–675. doi: 10.1038/s41591-020-0869-5
- Hey, J. (2020). *The Swiss Cheese Model*. *Sketchplanations*. Available online at: <https://sketchplanations.vercel.app/the-swiss-cheese-model> (accessed October 12, 2022).
- Hipkins, C. (2021). *COVID-19 vaccine roll-out plan*. *The Beehive*. Available online at: <https://www.beehive.govt.nz/release/covid-19-vaccine-roll-out-plan> (accessed October 29, 2022).
- Kaine, G., Greenhalgh, S., and Wright, V. (2022). Compliance with Covid-19 measures: Evidence from New Zealand. *PLoS ONE* 17, e0263376. doi: 10.1371/journal.pone.0263376
- Kearns, N., Shortt, N., Kearns, C., Eathorne, A., Holliday, M., Mackle, D., et al. (2021). How big is your bubble? Characteristics of self-isolating household units ('bubbles') during the COVID-19 Alert Level 4 period in New Zealand: a cross-sectional survey. *BMJ Open* 11, e042464. doi: 10.1136/bmjopen-2020-042464
- Kiwibank New Zealander of the Year Awards (2020). *Kiwibank New Zealander of the Year*. Available online at: <https://nzawards.org.nz/awards/new-zealander-year/> (accessed October 29, 2022).

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Conflict of interest

TM is creative director of The Spinoff and former creative director and now freelance contributor to Daylight, a content creation agency based in Auckland, New Zealand.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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- Levi, E. (2022). *Nasal swabbing*. Twitter. Available online at: <https://twitter.com/DrEricLevi/status/1500419856193126403> (accessed October 29, 2022).
- Lewandowsky, S., Cook, J., Ecker, U., Albarracín, D., Amazeen, M., Kendou, P., et al. (2020). *The Debunking Handbook 2020*.
- Mackay, I. M. (2020). *The Swiss cheese infographic that went viral*. *Virology Down Under*. Available online at: <https://virologydownunder.com/the-swiss-cheese-infographic-that-went-viral/> (accessed October 12, 2022).
- Morris, T. (2017). *The Pencilsword: Greed vs Need*. RNZ. Available online at: <https://www.rnz.co.nz/news/the-wireless/374753/the-pencilsword-greed-vs-need> (accessed October 29, 2022).
- Morris, T. (2020). *The Side Eye: Viruses vs Everyone*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/covid-19/25-03-2020/the-side-eye-viruses-vs-everyone> (accessed October 13, 2022).
- Morris, T. (2022). *The Side Eye | The Spinoff*. Available online at: <https://thespinoff.co.nz/the-side-eye> (accessed October 29, 2022).
- New Zealand Ministry of Health (2020). *Single case of COVID-19 confirmed in New Zealand*. Available online at: <https://www.health.govt.nz/news-media/media-releases/single-case-covid-19-confirmed-new-zealand> (accessed September 27, 2022).
- New Zealand Ministry of Health (2022a). *COVID-19: Current cases*. Ministry of Health NZ. Available online at: <https://www.health.govt.nz/covid-19-novel-coronavirus/covid-19-data-and-statistics/covid-19-current-cases> (accessed October 28, 2022).
- New Zealand Ministry of Health (2022b). *COVID-19: Vaccine data*. Ministry of Health NZ. Available online at: <https://www.health.govt.nz/covid-19-novel-coronavirus/covid-19-data-and-statistics/covid-19-vaccine-data> (accessed October 28, 2022).
- O Tātou Reo | Ministry for Ethnic Communities (n.d.). *Our Languages*. Available online at: <https://www.ethniccommunities.govt.nz/resources-2/our-languages-o-tatou-reo/> (accessed October 29, 2022).
- Reason, J. (2000). Human error: models and management. *BMJ* 320, 768–770. doi: 10.1136/bmj.320.7237.768
- Rodríguez Estrada, F. C., and Davis, L. S. (2015). Improving visual communication of science through the incorporation of graphic design theories and practices into science communication. *Sci. Commun.* 37, 140–148. doi: 10.1177/1075547014562914
- Salmon, R. A., Priestley, R. K., and Goven, J. (2017). The reflexive scientist: an approach to transforming public engagement. *J. Environ. Stud. Sci.* 7, 53–68. doi: 10.1007/s13412-015-0274-4
- Science Media Centre (2022). *Working with illustrators*. Available online at: <https://www.sciencemediacentre.co.nz/drawing-science/> (accessed October 29, 2022).
- Soar, M., Smith, V. L., Dentith, M. R. X., Barnett, D., Hannah, K., Riva, V. D., et al. (2020). *Evaluating the infodemic: assessing the prevalence and nature of COVID19 unreliable and untrustworthy information in Aotearoa New Zealand's social media, January-August 2020*. *Te Pūnaha Matatini (Preprint)*. Available online at: <https://thedisinfoproject.org/wp-content/uploads/2022/05/tdp-2020-paper.pdf> (accessed January 31, 2023).
- Spinoff, T. (2022). *The Spinoff*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/> (accessed October 29, 2022).
- Stats NZ (2020). *New Zealand's population nears 5.1 million*. Available online at: <https://www.stats.govt.nz/news/new-zealands-population-nears-5-1-million> (accessed October 29, 2022).
- Sutter, M. (2020a). *Covid 19 Bubble Spread*. *GitLab*. *GitLab*. Available online at: <https://gitlab.com/msutter/covid-19-bubble-spread> (accessed October 27, 2022).
- Sutter, M. (2020b). *Covid-19-curves-graphic-social*. *GitLab*. *GitLab*. Available online at: <https://gitlab.com/msutter/covid-19-curves-graphic-social> (accessed October 27, 2022).
- Sutter, M. (2020c). *Covid-19-transmission-graphic*. *GitLab*. *GitLab*. Available online at: <https://gitlab.com/msutter/covid-19-transmission-graphic> (accessed October 27, 2022).
- The Prime Minister's Science Prizes (2021). *2021 TE PUIAKI WHAKAPĀ PUTAIAO SCIENCE COMMUNICATION PRIZE*. Available online at: <https://www.pmscienceprizes.org.nz/2021-te-puiaki-whakapa-putaiao-science-communication-prize/> (accessed October 29, 2022).
- The Spinoff (2021). *The bumper Toby Morris and Siouxsie Wiles Covid-19 box set*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/media/07-09-2021/the-great-toby-morris-siouxsie-wiles-covid-19-omnibus> (accessed October 29, 2022).
- Unite against COVID-19 (2021). *History of the COVID-19 Alert System*. *Unite against COVID-19*. Available online at: <https://covid19.govt.nz/about-our-covid-19-response/history-of-the-covid-19-alert-system/> (accessed October 29, 2022).
- Unite against COVID-19 (2022). *History of the COVID-19 Protection Framework (traffic lights)*. *Unite against COVID-19*. Available online at: <https://covid19.govt.nz/about-our-covid-19-response/history-of-the-covid-19-protection-framework-traffic-lights/> (accessed September 27, 2022).
- Wiles, S. (2014). *Biolumination - an art-science collaboration*. Available online at: <https://www.youtube.com/watch?v=v7iUX1E5cNY> (accessed October 29, 2022).
- Wiles, S. (2020a). *A practical guide to dealing with the arrival of the coronavirus in New Zealand*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/science/28-02-2020/seriously-dont-panic-but-we-must-get-prepared-for-the-arrival-of-coronavirus> (accessed October 29, 2022).
- Wiles, S. (2020b). *Covid-19 and kids: How to talk to children about the coronavirus*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/society/03-03-2020/covid-19-and-kids-how-to-talk-to-children-about-the-coronavirus> (accessed October 29, 2022).
- Wiles, S. (2022). *As a scientist commenting on Covid I've attracted a lot of haters - I won't let them silence me*. *The Guardian*. Available online at: <https://www.theguardian.com/world/commentisfree/2022/jan/08/as-a-scientist-commenting-on-covid-ive-attracted-a-lot-of-haters-i-wont-let-them-silence-me> (accessed October 29, 2022).
- Wiles, S., and Harris, L. (2013). *The Hawaiian bobtail squid - when science and nature collide*. Available online at: <https://www.youtube.com/watch?v=KCobcWsYOS8> (accessed October 29, 2022).
- Wiles, S., and Klee, R. (2013). *From the lab to the park*. Available online at: <https://labtothepark.wordpress.com/> (accessed October 29, 2022).
- Wiles, S., and Klee, R. (2015). *Biolumination II - a glowing sci-art spectacular*. Available online at: <https://www.youtube.com/watch?v=7vls0dULQ88> (accessed October 29, 2022).
- Wiles, S., and Morris, T. (2020a). *A note on apartments and bubbles*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/covid-19/03-04-2020/siouxsie-wiles-toby-morris-a-note-on-apartments-and-bubbles> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020aa). *Why our run of low Covid-19 numbers does not mean jump now*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/society/07-05-2020/siouxsie-wiles-toby-morris-why-a-run-of-low-covid-19-numbers-does-not-mean-jump-now> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020ab). *Why those bubbles are so important*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/covid-19/01-04-2020/siouxsie-wiles-toby-morris-why-those-bubbles-are-so-important> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020ac). *Why we're adding masks to our Covid-19 toolkit*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/science/15-08-2020/siouxsie-wiles-toby-morris-why-were-adding-masks-to-our-covid-19-toolkit> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020ad). *You're waking up in lockdown New Zealand. Here's how it works*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/politics/26-03-2020/siouxsie-wiles-toby-morris-youre-waking-up-in-lockdown-nz-heres-how-it-works> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020b). *A note on noisy places and Covid-19*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/science/18-05-2020/siouxsie-wiles-toby-morris-a-note-on-noisy-places-and-covid-19> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020c). *A simple thing you can do in seconds to help make NZ healthier*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/covid-19/02-04-2020/siouxsie-wiles-one-simple-thing-you-can-do-in-seconds-to-help-make-nz-healthier> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020d). *After 'Flatten the Curve', we must now 'Stop the Spread'*. *Here's what that means*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/society/14-03-2020/after-flatten-the-curve-we-must-now-stop-the-spread-heres-what-that-means> (accessed October 29, 2022).
- Wiles, S., and Morris, T. (2020e). *Bridging the gap with someone who's been pulled in by disinformation*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/society/15-09-2020/siouxsie-wiles-toby-morris-bridging-the-gap-with-someone-whos-been-pulled-in-by-disinformation> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020f). *Contact tracing apps, explained*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/society/23-05-2020/siouxsie-wiles-toby-morris-contact-tracing-apps-explained> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020g). *Contacts, community transmission and clusters - explained*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/science/22-08-2020/siouxsie-wiles-toby-morris-contacts-community-transmission-and-clusters-explained> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020h). *Covid-19 and the Swiss cheese system*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/science/22-10-2020/siouxsie-wiles-toby-morris-covid-19-and-the-swiss-cheese-system> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020i). *Don't panic. We can do this. Together*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/society/12-08-2020/siouxsie-wiles-toby-morris-dont-panic-we-can-do-this-together> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020j). *How genome sequencing could crack the case of the NZ Covid comeback*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/science/13-08-2020/siouxsie-wiles-toby-morris-how-genome-sequencing-could-be-key-in-the-hunt-for-nzs-covid-resurgence> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020k). *How you can break the Covid-19 chain*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/politics/22-03-2020/siouxsie-wiles-toby-morris-what-does-level-two-mean-and-why-does-it-matter> (accessed September 30, 2022).
- Wiles, S., and Morris, T. (2020l). *Now let's flatten the infodemic curve*. *The Spinoff*. Available online at: <https://thespinoff.co.nz/society/08-09-2020/siouxsie-wiles-toby-morris-now-lets-flatten-the-infodemic-curve> (accessed October 3, 2022).

- Wiles, S., and Morris, T. (2020m). *Should we all be wearing face masks to prevent Covid-19 spread? The Spinoff*. Available online at: <https://thespinoff.co.nz/society/06-04-2020/siouxie-wiles-toby-morris-should-we-all-be-wearing-face-masks-to-prevent-covid-19-spread> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020n). *Simple rules to play it safe at alert level two. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/14-05-2020/siouxie-wiles-toby-morris-simple-rules-to-play-it-safe-at-alert-level-two> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020o). *The astonishing, life-saving power of immunisation. The Spinoff*. Available online at: <https://thespinoff.co.nz/partner/te-hiringa-hauora/13-11-2020/the-astonishing-life-saving-power-of-immunisation> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020p). *The prevalence puzzle. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/29-04-2020/siouxie-wiles-magic-numbers-and-the-mystery-of-covid-19-silent-spread> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020q). *The race for a Covid-19 vaccine, explained. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/28-07-2020/siouxie-wiles-toby-morris-the-race-for-a-covid-19-vaccine-explained> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020r). *The three phases of Covid-19 – and how we can make it manageable | The Spinoff*. Available online at: <https://thespinoff.co.nz/society/09-03-2020/the-three-phases-of-covid-19-and-how-we-can-make-it-manageable> (accessed October 29, 2022).
- Wiles, S., and Morris, T. (2020s). *Welcome to alert level three. Now let's finish what we started. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/28-04-2020/siouxie-wiles-toby-morris-welcome-to-alert-level-three-now-lets-finish-what-we-started> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020t). *What do we mean when we talk about the 'elimination' of Covid-19? The Spinoff*. Available online at: <https://thespinoff.co.nz/science/24-04-2020/siouxie-wiles-toby-morris-what-do-we-mean-we-talk-about-the-elimination-of-covid-19> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020u). *What is the Covid-19 'triangle'? The Spinoff*. Available online at: <https://thespinoff.co.nz/science/30-08-2020/siouxie-wiles-toby-morris-what-is-the-covid-19-triangle> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020v). *What we don't know about Covid-19. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/06-05-2020/siouxie-wiles-toby-morris-what-we-dont-know-about-covid-19> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020w). *What we should expect next from Covid-19. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/12-04-2020/siouxie-wiles-toby-morris-what-we-should-expect-next-from-covid-19> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020x). *When will we know the lockdown is working? The Spinoff*. Available online at: <https://thespinoff.co.nz/politics/27-03-2020/siouxie-wiles-toby-morris-why-are-we-locked-down-for-so-long-blame-the-lag> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020y). *Why contact tracing is so crucial to moving out of lockdown. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/18-04-2020/siouxie-wiles-toby-morris-why-contact-tracing-is-so-crucial-to-moving-out-of-lockdown> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2020z). *Why getting tested quickly matters so much. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/30-04-2020/siouxie-wiles-toby-morris-why-getting-tested-quickly-matters-so-much> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021a). *As summer beckons, your vaccine questions – answered. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/11-10-2021/siouxie-wiles-toby-morris-as-summer-beckons-you-vaccine-questions-answered> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2021b). *Covid-19 transmission 101. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/05-02-2021/siouxie-wiles-toby-morris-covid-19-transmission-101> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021c). *Delta makes this a new kind of challenge. But we can smash it again. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/18-08-2021/siouxie-wiles-toby-morris-delta-makes-this-a-new-kind-of-challenge-but-we-can-smash-it-again> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021d). *Do I really need a Covid-19 vaccine, even if I'm fit and healthy? The Spinoff*. Available online at: <https://thespinoff.co.nz/society/16-09-2021/siouxie-wiles-toby-morris-do-i-need-a-covid-19-vaccine-even-if-im-fit-and-healthy> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2021e). *Five factors to help us avoid Covid-19 this summer. The Spinoff*. Available online at: <https://thespinoff.co.nz/covid-19/22-12-2021/siouxie-wiles-five-factors-to-help-us-avoid-covid-19-this-summer> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2021f). *How Covid vaccinated people can still get infected. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/19-08-2021/siouxie-wiles-well-vaccinated-people-still-have-a-small-chance-of-being-infected> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021g). *How NZ sleuths are investigating the new mystery Covid cases. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/17-02-2021/siouxie-wiles-toby-morris-how-nz-sleuths-are-investigating-the-new-mystery-covid-cases> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021h). *How the Pfizer vaccine for Covid-19 works. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/24-02-2021/siouxie-wiles-toby-morris-how-the-pfizer-vaccine-for-covid-19-works> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021i). *How the world sped to the Covid vaccine summit. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/03-09-2021/siouxie-wiles-toby-morris-how-the-world-spiced-to-the-covid-vaccine-summit> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2021j). *How worried should we be about the new Covid-19 mutations? The Spinoff*. Available online at: <https://thespinoff.co.nz/science/26-01-2021/siouxie-wiles-how-worried-should-we-be-about-these-new-covid-19-mutations> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021k). *Power up: Get vaccinated. Available online at: https://www.youtube.com/watch?v=YVzh_sb9Cc* (accessed October 29, 2022).
- Wiles, S., and Morris, T. (2021l). *The Covid vaccine is a delicious great big slice of cheese. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/20-02-2021/siouxie-wiles-toby-morris-the-covid-vaccine-is-a-delicious-great-big-slice-of-cheese> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2021m). *The hunt for the missing link in NZ's delta outbreak. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/20-08-2021/siouxie-wiles-toby-morris-heres-how-delta-spread-and-how-we-defeat-it> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2021n). *The red flags of Covid misinformation. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/21-08-2021/siouxie-wiles-toby-morris-the-red-flags-of-covid-misinformation> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2021o). *What difference does the vaccine make? Just look at this. The Spinoff*. Available online at: <https://thespinoff.co.nz/society/29-10-2021/siouxie-wiles-toby-morris-what-difference-do-covid-vaccines-make-just-look-at-this> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2021p). *Why you should care about antimicrobial resistance. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/29-11-2021/why-you-should-care-about-antimicrobial-resistance> (accessed October 3, 2022).
- Wiles, S., and Morris, T. (2022a). *Already had Covid? That doesn't mean you're invincible. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/15-06-2022/siouxie-wiles-toby-morris-already-had-covid-that-doesnt-mean-youre-invincible> (accessed September 30, 2022).
- Wiles, S., and Morris, T. (2022b). *Can we get off the Covid merry-go-round? The Spinoff*. Available online at: <https://thespinoff.co.nz/science/20-07-2022/siouxie-wiles-toby-morris-can-we-get-off-the-covid-merry-go-round> (accessed September 30, 2022).
- Wiles, S., and Morris, T. (2022c). *Feeling Covid-positive but your RAT is negative? Here's why. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/09-03-2022/siouxie-wiles-toby-morris-feeling-covid-positive-but-your-rat-is-negative-heres-why> (accessed September 30, 2022).
- Wiles, S., and Morris, T. (2022d). *How we can hold back the new omicron wave. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/13-07-2022/siouxie-wiles-toby-morris-how-to-slow-the-growth-of-the-latest-omicron-wave> (accessed September 30, 2022).
- Wiles, S., and Morris, T. (2022e). *Two years on, Flatten the Curve gets an update for 2022. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/27-02-2022/siouxie-wiles-two-years-on-flatten-the-curve-gets-an-update-for-2022> (accessed October 1, 2022).
- Wiles, S., and Morris, T. (2022f). *What to know about monkeypox. The Spinoff*. Available online at: <https://thespinoff.co.nz/science/22-08-2022/siouxie-wiles-and-toby-morris-what-to-know-about-monkeypox> (accessed September 30, 2022).
- World Health Organization (n.d.). *WHO principles for effective communications*. Available online at: <https://www.who.int/about/communications/principles> (accessed January 13, 2023).
- Zarocostas, J. (2020). How to fight an infodemic. *Lancet* 395, 676. doi: 10.1016/S0140-6736(20)30461-X