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Flight or flight? - How the coronavirus pandemic has affected scientists' willingness to engage with the public

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During the coronavirus pandemic, scientists who worked to overcome the outbreak received recognition, but also opposition and even hostility. This article examines how the experience of the pandemic has affected the willingness of scientists to engage with the public. Derived from a comprehensive survey of 4207 scientists at German universities and research institutions, animosity towards scientists during the pandemic has created a sense of insecurity that may cause them to withdraw from the public eye. Depending on the relative strength of two cognitive appraisals, the severity of the threat and the appropriateness of the retreat option, the likelihood of respondents engaging with the public varies significantly.

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The COVID-19 pandemic (2020–2023) placed science at the forefront of public discourse as never before. Extensive media coverage allowed the public to witness, in real-time, the rapid identification of viral transmission pathways and the unprecedented development of effective vaccines. In the European Union, the BioNTech/Pfizer vaccine received approval in December 2020. Alongside discussions of vaccine types and mechanisms, methodological aspects of medical research, such as vaccine efficacy estimation, became focal points in media narratives. Scientists assumed dual roles as researchers and communicators, elucidating the pandemic's origins, societal and economic consequences, and public health measures through news media and personal communication channels. Initially dominated by virologists and epidemiologists, this discourse expanded to include economists and psychologists (Maurer et al., 2021). Some researchers gained public prominence almost overnight, becoming regular media figures and widely respected by audiences (Gaiser & Utz, 2022).

However, science's central role in managing the crisis also incited resistance. Protests against Germany's coronavirus policies, which emerged in March 2020 and intensified thereafter (Vieten, 2020), were accompanied by growing scientific scepticism, often radicalizing over time (Mede & Schäfer, 2020). As pandemic fatigue set in, media scrutiny of scientists increased (Hart et al., 2020), particularly toward those advocating continued restrictions (e.g., school closures, contact limits). Consequently, hostility toward scientists escalated. A survey published in *Nature* (October 2021) reported that nearly 60% of scientists who publicly commented on COVID-19 across multiple countries faced hostility, with 15% receiving death threats (Nogrady, 2021).

The COVID-19 case aligns with a broader history of scientific scepticism and denialism, often accompanied by harassment and intimidation, potentially chilling scientific discourse (Lewandowsky et al., 2016). Similar reactions have been observed regarding research on tobacco's health effects, HIV/AIDS, genetic engineering, evolution, climate change, and vaccination (Zimmerman et al., 2005; Kalichman, 2009; Powell, 2011). Public resistance typically arises when scientific findings challenge personal beliefs or lifestyles. However, scepticism is highly context-dependent and heterogeneous, both in terms of the respective predictors and the affected domains (Rutjens et al., 2022). It has been shown that scepticism about science is not necessarily based on a fundamental lack of understanding or general negative predisposition toward science, but is rather influenced by other factors, such as political ideology or religious beliefs (Fuglsang & Losi, 2024). Indeed, there is no empirical evidence for a systemic crisis of trust in science (Cologna et al., 2025).

While research has extensively examined the development of skepticism toward specific scientific facts, less is known about its impact on scientists themselves—an issue central to this study. The long-term implications of the pandemic for scientists' willingness to engage publicly remain unresolved. As the article's title suggests, two opposing reactions appear equally plausible: heightened awareness of public science communication's importance may encourage engagement, while the risks associated with public visibility may deter participation. This article presents three contributions to the ongoing debate: (1) It provides new data on how scientists at German universities and research institutions have responded to the experience of the COVID-19 pandemic. (2) It extends research beyond the circle of those directly affected by examining potential effects on scientists who have never publicly commented on COVID-19 themselves (spillover effect). (3) It shows how the cognitive response to the threatening situation and the appraisal of one's own protective options influence subsequent behavioural reactions. These findings help explain the mixed evidence in prior studies. The study is based on a survey of more than 4000 *Web of Science* (WoS) authors affiliated with a German university or research institution.

State of the literature

The COVID-19 pandemic has triggered a level of anti-scientific sentiment that went well beyond unfounded criticism and generalised rejection that many scientists have already experienced. Hostility towards scientists during the pandemic has ranged from questioning scientific findings and scientific integrity to hateful comments and harassment, serious threats of violence, camping in front of private homes, and actual physical abuse (Makri, 2021; Nogrady, 2021; Nölleke et al., 2022, 2023; O'Grady, 2022). In all, 52.8% of researchers who have conducted and published research on COVID-19, had never experienced that kind of harassment before the pandemic, and 17.9% stated that they perceived harassment much less before the pandemic (O'Grady, 2022). Social media in particular held space for personal attacks against scientists, with a third of scientists who commented on COVID-19 on X/Twitter being "usually" or "always" attacked on that platform (Nogrady, 2021, p. 253). On social media, hate against scientists can easily be organised and spread by quickly forming anti-science and anti-elitist groups (Nölleke et al., 2023). Many scientists view polarisation online as a breeding ground for a hostile environment (Makri, 2021). Not being able to separate private and professional online persona enhanced the negative effects of online harassment on researchers' personal as well as academic lives (Gosse et al., 2021).

Experienced harassment during the pandemic affected scientists in one of two ways: withdrawal from the public or eagerness not to be silenced. On one hand, researchers who reported a high rate of occurrences of hostility and threats were most likely to be hesitant to give journalistic interviews or to generally speak publicly in the future (Makri, 2021; Nogrady, 2021; O'Grady, 2022). It is a matter of debate among scientists whether more individualistic forms of communication, such as posting on social media, would provide more control over the narrative than journalistic interviews, or rather expose scientists to a more hostile media environment (Makri, 2021). Some have reported wanting to stay silent even on uncontroversial topics or withdraw from the public eye altogether to avoid inadvertently involving colleagues in hostilities (Nogrady, 2021). U.S. scientists state higher rates of science hostility (44% experienced hostility, compared to 32% on average in ten surveyed countries) and see this as a main barrier to communicating publicly (Economist Impact, 2022). On the other hand, a scientist who experienced harassment may choose a path other than withdrawal: Scientists might feel all the more obligated to speak up to not let the wrong people take over the narrative, especially in times of crisis (Nölleke et al., 2022). To hold themselves to this idealistic standard, they invent coping strategies to deal with harassment after public statements. Some attacked scientists involve the police in public appearances and take measures to protect their families, e.g., by improving home security, moving to safe houses, or withholding private information (O'Grady, 2022). They block users online or even delete their social media accounts (Makri, 2021; Nogrady, 2021; Nölleke et al., 2023; O'Grady, 2022), use email filters to block certain words or implement staff to screen their inboxes, self-censor (Makri, 2021), talk to colleagues, or form support networks (Nölleke et al., 2023). Notably, scientists who experienced hostility were more likely to block users on social media or stop reading comments than to turn down opportunities for publicity (O'Grady, 2022). Reactions to the pandemic experience are likely to be shaped by scientists' previous communication

practices, which are known to differ considerably. For example, age is a determining factor in the preferred channel of science communication. While older, more senior scientists in leadership positions prefer the traditional route via journalists, younger scientists who are at the beginning of their academic careers tend to favour self-produced online communication (Ho et al. 2020; Lo 2016). Dialogic engagement activities in particular are more likely to be considered important by younger scientists (Besley and Nisbet, 2013; Rainie and Funk, 2015; Rose et al. 2020). According to Ho et al. (2020), younger scientists view public engagement primarily as an activity aimed at enthusing the public about science rather than convincing them of their arguments. Older scientists also have more negative views of external factors influencing research decisions in their own field, such as the influence of the media on policy decisions (Besley and Nisbet, 2013; Entradas, 2016). However, some scientist surveys also found no age effect (Besley et al. 2018; Hennig and Kohler, 2020; Lo, 2016).

In sum, the literature reports contrasting reactions from scientists to hostility in the context of the coronavirus pandemic. Some may suppress their anxiety and are still prepared to expose themselves publicly. Others are trying to remove the basis for the threat by not (or no longer) doing so. In the following, we will draw on considerations from (health) psychology to provide an explanation for these differences in behaviour. Furthermore, most of the studies conducted so far have focused solely on the impact of COVID-19 on scientists who themselves spoke publicly about the virus and were exposed to hostility; however, those scientists who did not directly participate in the corona discourse but witnessed how other scientists were attacked have probably also drawn consequences for their behaviour towards the public without this having been documented by surveys so far.

Theoretical considerations & hypothesis

According to the parallel response model of coping with dangerous situations (Leventhal, 1970) hostility from other people will trigger one of two reactions: on the one hand, a reflection on how to deal with the threat experienced and how to protect oneself from it; Leventhal coins this *danger control*. The other process is an emotional one. Anyone who feels threatened is afraid, at least if the threat is experienced as serious and one perceives oneself as vulnerable. Thus, they must find ways to cope with their own fear (*fear control*). Leventhal (1971, p. 1210) assumes that the two processes take place in parallel, not serially. They are therefore not interdependent, for example in the sense that considerations about how to deal with the source of threat are not even made if no fear has arisen. This is exactly why older models of dealing with fear-inducing messages assumed that fear was the actual driver of protective behaviour. In Leventhal's model, both reactions are simultaneous consequences of hostility, which is why it is referred to in the literature as the 'parallel process model'. The model considers the mental examination of potential coping strategies as the primary cause of one's behavioural reactions. In contrast, efforts to overcome fear tend to be seen as an obstacle to adequate danger control. In particular, if the level of fear is too high, there is a risk of reactance (Leventhal, 1971, p. 1220). The so-called protection motivation theory of Ronald W. Rogers (1975) stands in the same tradition of thought. In its original formulation, the theory assumes that an external threat triggers three appraisals in parallel cognitive processes: assessment of the threatening nature of an object of fear, estimation of the probability of individual harm, and assessment of the effectiveness of a possible countermeasure. All three perceptions have a positive effect on the development of protective motivation, which mediates as an intervening variable between threat and the corresponding behavioural response. In a later extension of the theory (Rogers, 1983), attention is drawn to the importance of self-efficacy for the development of motivation. According to this theory, the person affected must consider themselves capable of taking an effective countermeasure in order for protective motivation to arise. On the basis of this work, Kim Witte (1992) developed an extended parallel process model (EPPM) of dealing with threat and fear, whose main contribution is to specify the conditions for different behavioural reactions in propositional form. Like Rogers (1983) before her, she draws on the distinction introduced by Leventhal between fear control and danger control. If a potentially dangerous situation does not trigger a feeling of an immediate, serious, and personally relevant threat in an observer, it will remain inconsequential. If, on the other hand, the threat scenario catches on, but at the same time the impression arises that the available countermeasures are effective and realistically implementable, then the tendency to change behaviour in order to avoid the danger arises (danger control). Finally, if the feeling of threat is high, while at the same time an impression of helplessness emerges because the measures in question do not appear to be effective or feasible, then those affected will tend to fight their fear rather than the source of danger (fear control), for example by suppressing their anxiety or denying it to themselves. A change in previous behaviour is not to be expected. People carry on as before and learn to live with their anxiousness.

Originally developed to guide the effective design of fear appeals in instrumental health communication, the EPPM is widely used in the current research literature to predict and explain people's reactions to communicatively conveyed threats. For example, it was used to analyse the development of stay-at-home intentions (Tsoy et al., 2022) or the willingness to be vaccinated (Roberto and Zhou, 2023) during the COVID-19 Pandemic. It thus seems promising to use the elements of EPPM to analyse the protective behaviour of scientists in the face of a hostile public sphere. In order to do so we must first assume that growing hostility to science from parts of the public is perceived as a serious and relevant threat within the scientific community. This can certainly be assumed for those scientists who have already been personally harassed after speaking publicly. Anyone who has been the victim of animosity will have to suppose that it can happen again if they again expose themselves publicly. Depending on the type of hostility experienced (verbal attack, physical attack, death threat, etc.), the threat posed will be perceived as more or less severe. Furthermore, it can be assumed that public hostility towards science is also perceived as threatening by scientists who have not yet been victims of attacks but who have heard or read about them. The more frequently and directly one's peer group has been affected (e.g., colleagues in one's department, members of one's university, representatives of one's discipline, etc.), the more serious and immediate the threat will appear. Given the group identity of academia, even attacks on colleagues with whom one has little professional or institutional connection might be perceived as an attack on one's own integrity. According to social identity theory (Tajfel, 1978; Tajfel and Turner, 1979), members of a group will tend to integrate the views, feelings, and behavioural dispositions of other group members into their own self-perception. In the case of science, this will lead to academics feeling under attack when they realise that other members of the scientific community have been antagonised.

This is not to claim that the perceived threat is a constant. Of course, individual scientists may also conclude that they will never be personally affected, for whatever reason. Or they may consider hostility to science a trivial fringe phenomenon that does not pose a serious threat to individuals or even to academia. Furthermore, it can be assumed that withdrawing from the public

sphere is intuitively seen as the obvious and most effective approach to dealing with hostile reactions after public appearances. It requires neither specific skills nor special activities but is a simple act of omission. It corresponds to the innate flight instinct with which every living creature – after an initial freeze response – reacts when confronted with danger (Gray, 1987). That is why it does not take lengthy reflection or even external advice to come up with escape behaviour as a solution to an immediate problem. These considerations lead to our first two hypotheses, which take up the idea of parallel processes:

H1) Scientists who have directly or indirectly faced hostility after speaking publicly about the COVID-19 pandemic will perceive hostility towards science as a serious and personally relevant threat.

H2) Scientists who have directly or indirectly faced hostility after speaking publicly about the COVID-19 pandemic will perceive withdrawal from the public eye as an effective and available countermeasure.

It can be assumed that most scientists rate the effectiveness of withdrawal from the public as particularly high. Obviously, this applies above all to the so-called response efficacy, since an attack is not provoked merely by holding an opinion—grounded in scientific evidence—that the aggressor finds objectionable. Rather, it occurs only insofar as this opinion is publicly expressed. By refraining from such expression, the source of the threat is effectively neutralized. In this regard, the efficacy of the measure is self-evident. If one further assumes that most employed scientists are still free to engage publicly or not to do so, then self-efficacy in relation to this behaviour should generally be high as well. Consequently, the retreat option should be a likely behavioural response, especially if no other protective mechanisms, for example from the institutional side, are available. While academic institutions actively promote and endorse public communication, they provide minimal support to scientists facing hostile environments (Economist Impact, 2022). According to the Nature survey referenced earlier, only ten percent of those targeted for their statements on COVID-19 received assistance from their home institution (O'Grady, 2022). Similar patterns emerge in Germany: a 2021 survey conducted by the National Institute for Science Communication found that over eighty percent of respondents sought institutional support in cases of negative media coverage, online trolling, threats, or harassment (NaWik, 2021). These findings suggest that academic institutions frequently misinterpret hostility as a personal rather than an institutional issue, reinforcing our assumption that scholars in such situations tend to seek individual rather than systemic solutions. Based on the theoretical considerations outlined above, a perceived threat will lead to the behaviour referred to as danger control if the perceived effectiveness of an available countermeasure is high. Our third hypothesis is as follows:

H3) If scientists perceive attacks from the public as a serious and personally relevant threat, but at the same time believe that they can protect themselves effectively by withdrawing from the public eye, their willingness to expose themselves publicly will be comparatively low.

Although the instinct to flee is inherent in human biology, there may be situations in which biological predispositions and socio-cultural imperatives come into conflict (Bracha et al., 2004, p. 448). In these cases, people will not necessarily react to danger in the way that their natural dispositions would suggest. In fact, a number of such norms can be identified that can prevent scientists from fleeing the public sphere. For example, the literature shows that many scientists have a strong sense of public duty and feel an obligation to give something back to the lay public, especially if they work in publicly funded institutions (Besley et al., 2018, 2021). This sense of duty should be particularly strong in medical professionals during a public health crisis (Nölleke et al., 2023), which could prevent them from fleeing the public eye. A less altruistic motive could be that public engagement activities are increasingly demanded as a condition of successful academic advancement, which is why scientists believe that they cannot simply refrain from them without jeopardising their own careers (Peterman et al., 2017). As part of their third mission, one's university or research institution could formally demand that its scholars at least sometimes engage in public science communication. One could also think of the more informal social pressure from colleagues in one's own research unit who continue to face the public and media despite an increasingly harsh public climate. In short, there can be a variety of context-dependent reasons for scientists who generally regard withdrawal from the public eye to be an effective response to hostility but who nevertheless do not consider it a realistic option for themselves. According to the extended parallel process model, they will engage in *fear control*. The corresponding hypothesis reads as follows:

H4) If scientists consider attacks from the public to be a serious and personally relevant threat, but withdrawing from the public eye is not an option for them, they will not reduce their public engagement despite being fearful.

The considerations presented here show that there can be different and even diametrically opposed reactions from scientists to the pandemic experience, depending on their subjective appraisals of the situation and of their own possibilities, which in turn may be shaped by the objectively different circumstances of individual research institutions and disciplines. Figure 1 shows the hypothesised relations as a conceptual model.

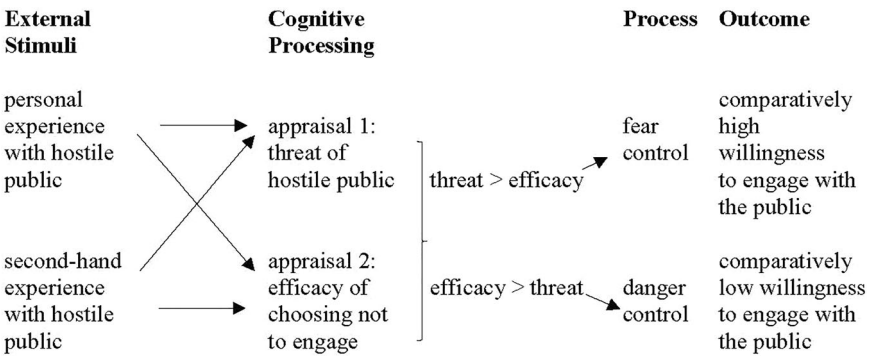

Fig. 1 Conceptual model of presumed COVID Effect on Scientists' Willingness to Communicate Publicly, adapted from the EPPM (Witte, 1992).

Data and Methods

The population for this study consists of scholars who have contributed to scientific discourse with at least one peer-reviewed scientific publication in the three years preceding our data collection (2019–2022) and who were working at an academic institution at the time of publication. Similar to other studies (Allum et al., 2023; Economist Impact, 2022), we used Clarivate's Web of Science (WoS) as our database to collect email addresses provided on research articles. The platform is said to be "structurally biased against research produced in non-Western countries, non-English language research, and research from the arts, humanities, and social sciences" (Tennant, 2020). Since our study is limited to research institutions in Germany, the lack of coverage of the global research landscape in the WoS is not relevant in this context. To mitigate potential biases arising from the disproportionate representation of different research fields, we included disciplinary affiliation as a control variable in the statistical analyses presented in the results section. However, it remains a fact that authors who published exclusively in German and outside established academic channels during the relevant period—such as through blogs, podcasts, or popular science books—had no chance of being included in the sample. Although it is unlikely that this group perceives and assesses hostility differently from the respondents in our survey, it is reasonable to assume that the results obtained here only apply to the WoS population.

After collecting WoS-indexed publications, we checked if the author was affiliated with a German university or research institution, and checked for duplicates, TLDs (.de, .com), and syntax. In all, 50,000 randomly selected email addresses were contacted over the course of five days with two reminders from 14 November to 14 December 2022. With 12.4% failed deliveries due to, e.g., change of workplace, 43,800 scientists received our survey invitation. In all, 4312 scientists completed the questionnaire, giving a response rate of 9.8%, which is comparable to that in other scientist surveys (Besley et al., 2018). We obtained informed consent from our survey participants by clearly communicating our data policy, which they had to accept before starting the survey. We also assured them that all responses would be anonymised to safeguard their privacy. Our questionnaire received ethical approval from our university's ethics board. After clearing data for inconsistencies, a final sample of $N = 4207$ scientists remained for our analysis. Detailed information about the sample can be found in Table 1.

The measurements of the variables are described in the next section, in which we also report descriptive findings.

Table 1 Percentages for gender, position, field of science, and affiliation.

Variable	%
Gender	
Male	61.8
Female	34.6
Other	0.3
Missing	3.2
	($N = 4207$)
Position	
Doctoral student	18.2
Post-doc	24.5
Professor	19.4
Researcher	25.3
Other	12.4
Missing	0.1
	($N = 4207$)
Field	
Humanities & Social sciences	20.8
Life sciences	38.3
Natural sciences	18.8
Engineering & technology	15.8
Interdisciplinary	1.9
Missing	4.3
	($N = 4207$)
Affiliation	
Research university	44.1
University of applied sciences	6.0
Research institutes	22.9
University clinic	8.7
Research department in a company	7.9
Research department of public administration	3.6
Other	6.7
Missing	0.1
	($N = 4207$)

Table 2 Independent Variables – Means and Standard Deviations for Perceived Hostility Towards Scientists.

Variable	*M*	*SD*	*n*	*Pct of persons concerned*
Have you ever experienced hostility (e.g., insults, threats of violence, physical attacks e.g.,) after speaking about COVID-19 ...				
In news media	1.27	0.733	1673	14.9
At face-to-face events	1.46	0.848	2323	28.9
In online media	1.55	0.978	2041	29.8
How often have you heard that ...				
Your close colleagues have experienced hostility	1.90	1.058	3512	51.3
Colleagues from other institutions have experienced hostility?	2.82	1.153	3563	83.2

Results

Descriptives. As this study is specifically interested in experiences during COVID-19, we asked about hostility following public statements about the pandemic. Exactly 1673 of 4207 surveyed scientists stated that they had made statements on this topic in news media, 2,041 commented on COVID-19 in online media, and 2323 gave talks on the pandemic at in-person events. Answers to the question about negative experiences were given on a 5-point scale from 1 = *never* to 5 = *very often*. Table 2 shows the mean values and standard deviations for these three communication channels. It reveals that hostility towards scientists was most common in online environments, while a presence in traditional media provoked less hostility. This is in line with other studies identifying social media platforms as breeding grounds for science hostility. Overall, however, the mean values indicate that direct experiences with hostility were limited. In addition to the mean values of the original coding, the rightmost column shows the proportion of those who were attacked on at least one occasion or heard about attacks on colleagues at least once. Nearly 15% of the scientists reported having had at least one negative experience after being present in news media; the proportion is just under 30% for those who commented via online media or at face-to-face events.

Indirect experiences of hostility towards science during the coronavirus pandemic are, as expected, much more common. The mean values of both variables are significantly higher. The proportion of those who heard of such events at least once gives a vivid impression of how widespread hostility towards science was recognised within the scientific community. More than half of

Table 3 Mediators – Means and Standard Deviations for Threat and Efficacy Appraisals.

Variable	M	SD	Alpha	n
To what extent do you agree or disagree with the following statements?[a]				
Threat[b]	3.45	0.698	0.74	4183
Efficacy[b]	3.09	0.854	0.77	4165

[a]Examples of items: "Hostility towards scientists is a serious problem" (threat), "I think it is possible that I will experience hostility if I speak out publicly" (threat), "Withdrawing from the public is effective in preventing hostility" (efficacy), "Refraining from speaking out publicly is an adequate means for preventing hostility" (efficacy). Responses were coded from 1 (*strongly disagree*) to 5 (*strongly agree*).
[b]Mean value index for six items.

Table 4 Dependent Variables – Means and Standard Deviations for Willingness and Intention.

Variable	M	SD	n
How willing are you currently to speak in the news media (online media, at present events)?[a]			
Willingness (for public engagement)[b]	3.317	0.984	4207
And what does the foreseeable future look like? I will speak out in the media (online media / at present events) when I have the opportunity[c]			
Intention (to speak publicly)[b]	3.026	1.220	3988

[a]Responses were coded from 1 (*not at all willing*) to 5 (*very willing*).
[b]Mean value index for three items.
[c]Responses were coded from 1 (*very unlikely*) to 5 (*very likely*).

those surveyed experienced close colleagues at their own institution being the victim of anti-science attacks. Well over 80% heard about scientists from other institutions and disciplines being victimised by anti-science attacks.

To measure the appraisals, we adapted the 12 items of the Risk Behaviour Diagnosis Scale (RBDS) for our use case (Witte et al., 1996). Six items each represent one appraisal. The test for reliability provides reasonably good values for Cronbach's alpha (above 0.70), so we calculated the items into two mean indices. Table 3 shows mean values and reliability for the two scales.

It may not come as a surprise that respondents considered anti-scientific hostility a serious problem, which is indicated by a mean above the midpoint of the scale. Withdrawal from the public sphere is certainly seen as an effective protection against anti-science attacks, even if the efficacy appraisal is not as strong as might be expected. The mean value is just above the midpoint of the scale, with the standard deviation being slightly higher than that of the threat perception.

Table 4 presents the dependent variables of our conceptual model. The general willingness of the scientists surveyed to engage with the public was fairly high, with a mean value above 3 on a 5-point scale. Individual evaluations of the three items show that readiness to participate in face-to-face events is clearly highest, while readiness to make public statements in online environments is considerably lower. The same pattern can be seen in the question about concrete intentions for the near future. The intention to participate in events is comparatively strong, the intention to communicate online is significantly lower, with the intention to appear in the news media in between.

Test of Hypotheses. Hypothesis 1 states that the perceived threat is intensified by one's and others' experiences with the public during the pandemic. We calculated a hierarchical regression model to predict the level of perceived threat among scientists (see Table 5). In the first step, three socio-structural variables were included; it shows that members of the life sciences felt more threatened than members of other disciplines. This is hardly surprising, as biology, medicine, virology, etc., were at the centre of criticism from parts of the population and the media. Younger respondents tended to be less concerned by public hostility towards science than their older colleagues. In the second step, experiences with attacks after speaking publicly about the coronavirus pandemic were analysed. Since only part of the sample had publicly commented on COVID-19, and only these were asked about direct experiences with hostility, missing values are excluded pairwise in this analysis. The model showed that, above all, hostility following statements in social media significantly increased the sense of being under attack. Harassment following appearances in the news media or public speeches, on the other hand, was not significantly associated with individual feelings of threat. The final model added second-hand experience, which significantly increased the explained variance of the dependent variable. In fact, the observation that colleagues from other disciplines and institutions were being attacked was by far the strongest predictor in the final model. Those respondents who heard about such incidents also felt more at risk themselves, which led them to consider hostility to science to be a particularly severe social problem. Overall, the final model accounted for 12.5% of the variance in individual threat appraisals, with experience on social media and second-hand experience by observing the treatment of colleagues as significant predictors. Thus, the first hypothesis is accepted by the data.

Overall, the efficacy appraisal was much less well explained by the exogenous factors, which merely confirms that everyone has the flight instinct, regardless of specific characteristics and circumstances. Nevertheless, two observations are worth mentioning. Age was negatively associated with the target variable. This means that younger respondents tended to be less convinced that withdrawing from public communication was an appropriate response to public hostility towards science. The same applies to respondents who were personally confronted with harassment when giving a public lecture. Contrary to hypothesis 2, negative experiences at face-to-face events did not lead to the assessment that refraining from such activities was an adequate reaction but to the opposite assessment. In contrast, observation of hostility towards third parties led to a more pronounced assessment of the efficacy of avoiding public appearances. Hence, we observe exactly opposite effects of direct and indirect experiences of anti-scientific hostility on efficacy appraisal: while the latter strengthened belief in the efficacy of escape, the former mitigated this appraisal. In this respect, hypothesis 2 must be rejected in part, namely with regard to the effect of personally experienced hostility.

Hypotheses 3 and 4 are based on the distinction between danger control and fear control and assume that the different types of reaction depend on the relative strength of two appraisals: threat and efficacy. In order to measure this relationship, we first calculated a so-called discrimination value. To do this, a sum score was formed from all six items that measured the perceived threat. We proceed in the same way with the six items for measuring efficacy. Then, the threat score was subtracted from the efficacy score to form the discrimination score (cf. Witte et al., 2001, pp. 70–72). The indicator for differentiating between the two responses varies between −23 and +18. The mean value was $M = -2.18$ ($SD = 6.02$). For the following analysis, we used the score to build three groups of respondents. The first group comprised 1,364 respondents with a positive discrimination score. A positive value means that the respondent had a higher probability of danger control because the perceived effectiveness of retreat was greater than the perceived threat. Thus, according

Table 5 Results of Hierarchical Regression Analyses for Demographics and Experience of Hostility During the Pandemic on Threat and Efficacy Appraisal[a,b].

	Model 1			Model 2		
Independent Variables	**Threat Appraisal**			**Efficacy Appraisal**		
Step 1: Demographic variables	*B*	*SE B*	Beta	*B*	*SE B*	Beta
Age	−0.005**	0.001	−0.080	−0.008***	0.002	−0.119
Gender (female = 1)	0.068	0.036	0.056	−0.002	0.046	−0.001
Discipline (life sciences = 1)	0.080*	0.035	0.036	0.086	0.045	0.049
R^2	0.017			0.015		
F	9.064***			7.897***		
Step 2: Personal attacks						
Attacked after appearance in news media	0.006	0.032	0.006	0.008	0.041	0.006
Attacked after speaking in online media	0.070**	0.025	0.098	−0.016	0.032	−0.018
Attacked after public lecture	−0.046	0.024	−0.056	−0.113***	0.031	−0.112
R^2	0.049			0.030		
ΔR^2	0.032			0.016		
ΔF	17.567***			8.369***		
Step 3: Second-hand experiences of attacks						
Knowing of attacks on close colleagues	0.038	0.020	0.057	−0.043	0.026	−0.053
Knowing of attacks on other scholars	0.167***	0.016	0.276	0.048*	0.021	0.065
R^2	0.130			0.034		
ΔR^2	0.081			0.004		
ΔF	72.741***			3.062*		

[a]All entries are from the final step in the analysis. $n = 1673$–4183.
[b]Pairwise deletion of missing values.
*$p < 0.05$. **$p < 0.01$. ***$p < 0.001$.

Table 6 One-way Analyses of Covariance for Willingness and Intention by Relative Strength of Relevant Appraisals, controlled for age, gender and field of research.

Dependent Variable	***Group (Factor)***	***n (%)***	***M***	***SE***
Willingness	threat > efficacy	2245 (60.4)	3499[a]	0.020
	threat = efficacy	251 (6.7)	3302[a]	0.060
	efficacy > threat	1223 (32.9)	3092[a]	0.027
	$F(2, 3713) = 72{,}748$, $p < 0.001$, partial $\eta^2 = 0.038$			
Intention	threat > efficacy	2143 (60.6)	3268[a,b]	0.026
	threat = efficacy	240 (6.8)	2846[b]	0.077
	efficacy > threat	11153 (32.6)	2753[a]	0.035
	$F(2, 3530) = 74{,}557$, $p < 0.001$, partial $\eta^2 = 0.041$			

Mean values with identical letters differ significantly at $p < 0.001$ according to post-hoc statistics.

to the conceptual model, they would tend to refrain from the public eye. The second group comprised 2502 respondents with a negative discrimination score. A negative value for the discrimination score means that the perceived threat was greater than the assumed efficacy of escape behaviour. According to the theoretical model, respondents in this group are expected to control their fear while still being willing to expose themselves publicly. For 287 respondents, the strengths of threat and efficacy appraisals were balanced, so they have a discriminant value of zero and constitute the third group.

To test the corresponding hypotheses 3 and 4 in one step, we calculated two ANCOVAs (one-way analysis of covariance) with the grouping variable as a fixed factor and with general willingness as well as specific intention to communicate publicly as dependent variables. To rule out the co-founding of results, age, gender and research area of the respondents are included as covariates in the calculation. All three variables are used in exactly the same way as in the regression analysis (see Table 5). Homogeneity of regression slopes was not violated in relation to either dependent variable, since none of the interaction terms were statistically significant ($p > 0.05$). Homogeneity of variances was asserted using Levene's test, which showed that equal variances could be assumed for willingness ($p = 0.051$) and intention ($p = 0.148$). A statistically significant one-way ANCOVA only tells us that at least two groups differ statistically from each other, but not which ones. In order to compare all three groups in pairs, we calculate post-hoc tests with Bonferroni correction. As Table 6 shows, both ANCOVAs provide a significant result which means that belonging to one of the groups is associated with different levels of willingness and intention to communicate publicly after adjusting for age, gender und field of research. To examine it more closely, we will first look at the two groups for which we have formulated hypotheses. We see at first glance that the adjusted mean values between the first and third lines of each analysis differ in the expected direction on both dependent variables. Those respondents who felt threatened by hostility to science but do not believe in the efficacy of the disengagement option (threat > efficacy) had a higher willingness and also a stronger intention to further engage with the public than the comparison groups.

In short, the respondents in this group did what hypothesis 4 expected of them, namely control the fear: they did not let the

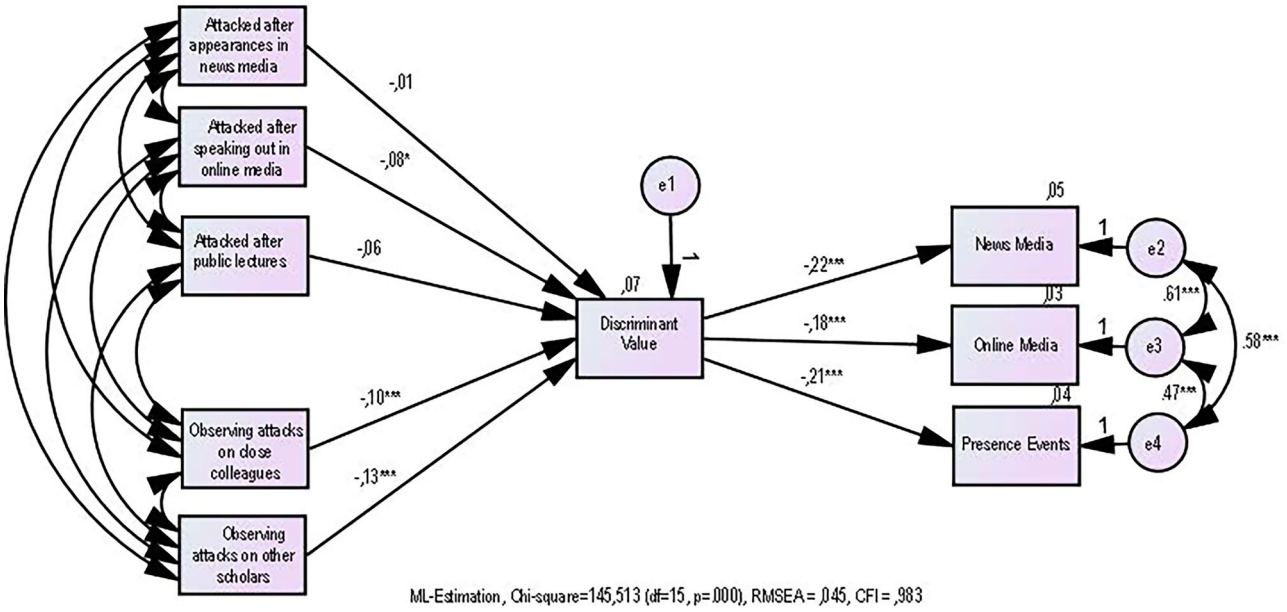

Fig. 2 Path analysis with standardised estimates of the likelihood of public communication by scientists, influenced by their experiences during the COVID-19 pandemic ($N = 4207$).

threat stop them, but rather coped with it and continued. The respondents in the comparison group (efficacy > threat) also reacted in the way hypothesis (H3) expects them to. They were less willing to engage with the public than the first group. Their concrete intentions for public communication were also significantly weaker than those of the comparison group, with a mean value below the midpoint of the scale. In short, they tended to avoid the public more than did their peers; in other words, they engaged in danger control. Bonferroni-corrected post-hoc analysis revealed a significant difference ($p < 0.001$) between willingness and intention for members of the two groups, after adjusting for our three controls.

We had not formulated any theoretically backed expectations of the small group in the middle (threat = efficacy). However, the data show that the respondents in this group behaved similarly to the danger control group with regard to their communication intention. According to post-hoc tests, the mean differences between the two groups were not significant for intention ($p = 0.815$), while they differ significantly from the mean in the fear control group ($p < 0.001$). In contrast to this, the average willingness to communicate publicly differs significantly between the members of all three groups at $p < 0.010$.

To examine whether the link found between pandemic experience and withdrawal from public communication affects all forms and channels in similar ways, or whether there are substitution effects - especially at the expense of online communication - we finally specified the theoretical framework (Fig. 1) as a path model and estimated it with AMOS 29. It contains five independent variables known from the regression analysis in Table 5, the individual discrimination value as a mediator, which is used as a continuous variable in the analysis, and three dependent variables. In order to avoid having to estimate two models, one each for the general willingness and the specific intention to use the various channels of science communication, we used item parcelling when constructing the dependent variable. Specifically, we calculated the three pairs of items for willingness and intention into three mean value indices, which represent the individual likelihood to communicate science via news media, online media and at face-to-face events. Cronbach's alpha was above the critical threshold of .70 for all three item pairs, indicating satisfactory reliability for the three dependent variables. Figure 2 shows the result of the model estimation with standardised path coefficients. Unmarked paths were not estimated but zero-restricted according to the conceptual model (Fig. 1). Although the chi-square test became significant due to the sample size, the additional model fit indices indicated a good fit of the model to the data: chi-square 145,513 ($df = 15$, $p < 0.001$), RMSEA = 0.045, CFI = 0.983. Both indicators for second-hand experiences and personal experiences in online environments had a significant negative effect on the discriminant value, which, as mentioned, was the difference between the two appraisals (efficacy minus threat). Thus, the sign of the path coefficients corresponded to the theoretical expectation: The more frightening this experience was perceived to be, the stronger the threat appraisal and the lower the discrimination value.

For its part, the discriminant value was negatively correlated with all three dependent variables. This is in line with the theoretical assumptions. The more convinced someone is of the efficacy of withdrawing from the public sphere, the higher their discrimination score and the lower their tendency to expose themselves publicly. This tendency applies equally to all three channels of science communication: those with a higher discriminant value are less likely to communicate publicly, regardless of mode and channel. This is further underlined by the fairly strong correlation of the dependent variables.

Discussion

At the outset of this article, we outlined three original contributions of this study: first, a detailed empirical analysis of how scientists at German research institutions responded to their experiences during the COVID-19 pandemic; second, an examination of a potential spillover effect on scientists not directly engaged with the issue; and third, a theoretical framework to explain varying behavioural responses to identical experiences.

Among the empirical findings, two seem particularly worth discussing. As expected, the feeling of being exposed to a threat as a public scientist was widespread within the scientific community. Although we found small differences between members of

particular disciplines and age groups, this does not change the fact that the perceived threat was high, on average, for all respondents. What seems more important to us is the observation that the then-current sense of threat was not caused by the pandemic alone. As our data show, only a relatively small percentage of the variance in the individual threat perceptions of our respondents can be explained by their (direct or mediated) experiences during the pandemic. The feeling of being potentially exposed to danger as a public scientist seems to have been fed by many observations and experiences that scientists have made in the heated debates of recent years. Thus, the involvement of science in societal debates about how to deal with the virus obviously did not create a hitherto unknown sense of threat; it only updated and temporarily reinforced it. In an increasingly science-based and conflict-loaded society, anti-scientific sentiment can be expected to erupt at any time when scientific findings challenge the world views, religious feelings, political orientations or economic interests of parts of the population. What is described here is therefore not a unique case, but only one episode in a continuous process.

Contrary to expectations, however, the effectiveness of withdrawing from the public sphere as protection against this development was not as strong as we had assumed. This could be due to the fact that the respondents made a distinction between individual and systemic levels of the assessment. While refraining from public appearances certainly protects an individual from becoming a victim of anti-scientific hostility, it is doubtful that science scepticism within society can be effectively combated by removing science from the public sphere. We assume that such considerations are reflected in our measurement of the efficacy appraisal.

Two further observations are noteworthy in this context. Younger scientists were significantly less convinced than their older colleagues that withdrawing from the public sphere was an effective response to animosity from parts of the public. This may be due to the fact that political efforts to strengthen the so-called third mission and the resources that have been invested in the expansion of science communication have fallen on fertile ground, especially among younger scholars. They have been socialised into a scientific system in which reaching out is a natural part of their job description, so that withdrawing from the public sphere is not an option for them, despite the difficult conditions. Besides, age can be understood as a proxy for career status, suggesting that individuals who have yet to reach the peak of their professional trajectory may attribute greater importance to public engagement, anticipating that such efforts will yield future rewards. Another interesting observation is that those colleagues who had more direct contact with the lay public, for example by giving public lectures, doubted the suitability of the withdrawal option, even if they have had bad experiences on such occasions. One could speculate that scientific scepticism experienced face to face motivates countering it through increased communication efforts, while anonymous attacks, for example, on the internet, tend to motivate withdrawal from the public sphere. If this is true, then more direct contact between non-scientific target groups will strengthen the system's resilience to the 'chilling effect'.

The second important finding of our research concerns the so-called spill over effect. Obviously, scientists do not need to have experienced anti-scientific hostility themselves to consider it a serious and personally relevant threat. In fact, in our analyses, second-hand experiences were the strongest predictor for an individual's sense of threat and – since the threat appraisal shapes behavioural reactions – also for individual (communication) behaviour. The experiences that some scientists have had during the coronavirus pandemic therefore not only affect those directly involved but also have an impact on the entire community. Thus, we have to expect the 'chilling effect' to be fuelled with every new experience of scientists working on migration, global warming, abortion, or other controversial issues, taking a public stance on them, and being observed by others. We have not examined in detail the ways in which second-hand experiences are communicated, but we can reasonably assume that, in addition to personal conversations, news media coverage was the most important source for hearing of anti-science attacks on others. If this is the case, the well-known tendency of the media to dramatise such events could provide an explanation for the fact that the mediated experiences statistically shape the feeling of threat more strongly than the personal experiences of those affected. While those directly affected may tend to relativise the actual danger posed by a (verbal) attack for reasons of self-protection, the same situation may look much more dangerous in the media portrayal. This speculation cannot be substantiated by our data; nevertheless, on the basis of our results, it can be taken as certain that the media communication of hostility towards science plays an important role in the creation and dissemination of a perceived threat within the scientific community. Hostility towards science, therefore, shapes not only the relationship between science and society but probably also the relationship between science and news media.

The third original contribution of this study consists of the successful application of a theoretical concept that has so far been used primarily in the context of health communication (and especially fear appeal research) to issues of science communication. The model shows why people might react very differently to the same experience, depending on how they cognitively process it. This allows us to explain the contradictory findings of previous research on the subject, namely, through individually differing assessments of the actual danger posed by anti-scientific hostility and the appropriateness of fleeing the public eye as a possible reaction. The empirical use of the distinction between fear control and danger control also allows us to provide an answer to an important question that has been raised in connection with the pandemic (Makri, 2021): Will this exceptional event be a booster or a backlash for the public communication of science and technology? Neither is our answer. In fact, a large part of the scientific community tends to react to the threat experienced during the pandemic by refraining from public appearances. We find no evidence that scientists avoid one form of public communication in order to favour another all the more. Evidently, those who decide to withdraw from the public sphere do not do so halfway. Those who are convinced of the merits of withdrawal avoid media and personal communication equally, as our path analysis shows. In our sample, the group of those who tried to control the danger in this way accounted for about one-third of the respondents. According to the EPPM, this might be due to a lack of alternative protective measures that are perceived to be as effective and readily available as simply refraining from the public eye. This is where we need to start if we want to curb the deterrent effect. As long as such alternatives are not available and/or are not perceived as such, it is unlikely that this group will change its behaviour unless the threat perception is drastically reduced. Nevertheless, it cannot be assumed that the years of political effort for more public engagement by scientists have suffered a definitive setback. A majority of the scientists we surveyed were prepared to reach out and share their research with the public, despite feeling threatened and being scared.

These considerations finally led to the most serious limitation of our study. In principle, many measures are available to respond individually or institutionally to anti-scientific attacks. In many countries, institutions have now been set up to which scientists can turn for help in dealing with attacks and inappropriate conflicts in science communication (scicommsupport, science care). Of course, those affected can also contact the police and judiciary directly, seek help from colleagues or their own organisation, etc. In short, there are a multitude of protective measures that scientists could consider effective and available. All of

these options were ignored in our measurement of the efficacy appraisal, in favour of the option we were most interested in: the decision to flee the public sphere. For the interpretation of our results, this means that a more or less large proportion of those whose behaviour we interpreted as fear control actually engage in danger control, hoping to control the source of danger through measures other than fleeing the public sphere. Of course, it would be highly interesting – both theoretically and pragmatically – to know which measures against hostility towards science are considered just as effective or even more effective than refraining from public science communication. Clarifying this question must be left to follow-up studies. A second important limitation concerns the simple fact that we know nothing about the pre-pandemic level of public engagement of our respondents. What we can prove are significant group differences, but whether this also corresponds to variation over time cannot be tested with cross-sectional data. For instance, it cannot be ruled out that those who described withdrawal from the public sphere as a good idea in the survey were already very cautious in their public engagement before the pandemic and in this respect, were merely confirming their previous practice. Although this is very unlikely, since we do find significant correlations between the pandemic experience and both appraisals, this assumption could only be formally rejected with longitudinal data, which unfortunately we do not have available for this study.

Data availability

The data sets generated and analysed during the current study are not publicly available at present, as their analysis and publication is not yet complete. However, they can be requested from the corresponding author upon reasonable request.

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Author contributions

FM conceived the project and obtained the funding. He designed the theoretical framework and the central research hypotheses for the project and designed the questionnaire. FM analysed the data, wrote the manuscript and revised it on the basis of external comments. HdH contributed to the construction of the questionnaire, supported the data collection and helped with the data cleansing. She wrote the 'state of the literature' section of the paper and commented on prior versions of the complete paper. SK contributed to the construction of the questionnaire, administered the survey and was involved in the data cleansing.

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Competing interests

The authors declare no competing interests.

Ethical approval

This study was approved by the Ethics Committee for Non-Invasive Human Research of the Faculty of Arts and Humanities at Heinrich Heine University Düsseldorf. The approval (ID: 08042024) was granted on April 8, 2024. All research procedures were conducted in accordance with the ethical guidelines of Heinrich Heine University Düsseldorf and the EU General Data Protection Regulation (GDPR). The approval covers the anonymous online survey of adult researchers, data processing and secure storage, and the publication of anonymized findings.

Informed consent

Written informed consent was obtained from all participants via an online form prior to starting the survey. Participants were informed about the purpose of the study, their right to withdraw at any time, and that their data would be processed anonymously and used solely for research purposes. No minors or vulnerable individuals were involved. Data are stored securely on servers located in Germany and are only accessible to the research team.

Additional information

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