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PERSPECTIVE

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Petitions in scientific argumentation: Dissecting the request to retire statistical significance

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1 | INTRODUCTION

Petitions have a long history of being used for political, social, ethical and injustice issues. The accumulation of large numbers of signatories suggests that a given cause has wide popular support and deserves attention from those who can act to address the concerns of the petitioners.[1,2] It is unclear whether this method of raising attention and instigating change can or should also be implemented in the context of scientific argumentation. We use the term 'petition' not in the strict sense of addressing a cause to a court or magistrates but in the broad sense of collecting multiple signatures to try to influence an agenda of decision-making or practice.

Scientists have signed petitions on political, social, ethical and injustice matters where science is relevant, such as climate change, priorities for research, alluded ethical breaches or calls to retract flawed papers.[3] Additionally, scientists have organized petitions in order to influence aspects of the scientific ecosystem in which they operate. For example, over 80 academic signatories with editorial positions in diverse scientific journals petitioned for journals to offer the *Registered Reports* article format which they claimed will reduce bias and improve the quality of scientific outputs.[4]

Recently, more than two thousand researchers signed a petition to boycott a new journal - *Nature Machine Intelligence*—on the grounds that it was not open access[5] and a petition supporting funder-mandated open access has gained over 1900 signatories.[6] Conversely, a petition opposing an initiative to mandate open access for scientific publications resulting from European public grants ('Plan S')—has gained over 1700 signatories.[7] The rationale in these cases is similar to the rationale behind the collection of signatories from the general population: by weight of numbers, the organizers are hoping to draw attention to their cause and convince key decision-makers to act in their favour.

In the cases described above, the argument is of the form: *N* people support this view; therefore, this view deserves attention. However, this strategy may not be appropriate in the context of scientific argumentation in which one is trying to convince others that the signed viewpoint is 'correct'. In this case, the argument is of the form: *N* people support this view; therefore, this view is correct. This approach is arguably a logical fallacy (argumentum ad populum) because it conflates *justification* of a belief with the *acceptance* of a belief by a given group of people.[8] Science is a communal effort, and it is essential to integrate the contributions of all scientists; however, the validity of arguments and data should take precedence over number of voters. A single scientist may be correct in a debate against thousands, if his/her evidence or argument is stronger.

Recently, *Nature* invited a commentary[9] to accompany the release of an issue of *The American Statistician* with over 40 papers on the theme of statistical inference in the 21st century ('Moving to a World Beyond "$P < .05$").[10] In the commentary, Amrhein and colleagues explicitly and strongly urged the abandonment of the notion of 'statistical significance' across science. The use and abuse of null hypothesis significance testing as a mechanism of scientific inference has been

a hotly debated topic over many decades.[11] Very different views have been expressed, and consensus is distinctly lacking among experts (eg see 21 heterogeneous commentaries accompanying the American Statistical Association's 2016 Statement on *P*-Values[12]). Lack of consensus is also immediately manifest in everyday statistical practice and scientific publications, where statistical methods and inference tools are variably used, misused and debated.[13,14]

Amrhein inquired with Nature how to handle potentially multiple authors, as a very large number of people had expressed interest in these concepts. Given the difficulty of having many authors in a short commentary, *Nature* instead proposed to limit the number of the authors of the commentary to only three, and have additional scientists be signatories. A campaign followed that aimed at the collection of signatures in what was called a 'petition' on the widely popular blog site of Andrew Gelman.[15] Ultimately, 854 scientists signed the petition and the list of their names was published along with commentary.[9] We should clarify that the authors of the Nature commentary expressly stated when we sent them a pre-print of this Perspective that they do not see their paper as a petition.

During the process of signature collection, invited scientists were given a short description of the effort (eg 'Our comment is titled Retire Statistical Significance-…and it focuses on the absurdities generated by so-called "proofs of the null"') and asked to sign in support. Invitations were distributed via social media (Twitter) and e-mail communications. Typically, the full comment was not sent alongside the invitation but the inviting authors said they 'would be delighted to send you a near final draft of the comment (subject to sub-editing by the journal)'. Signatories also received a link with the final version of the commentary just prior to its publication.

The commentary received enormous attention upon its publication resulting in the highest Altmetric score ever to-date.[16] Clearly, the social dynamics of having so many co-signatories contributed to this wide dissemination. Concurrently, strong opposing views were also expressed, finding major problems with the proposal and concluding that abandoning statistical significance would do more harm than good across science.[17-20]

Given that this is a very unusual, but also interesting opportunity, we decided to perform a survey of the signatories to understand how and why they signed the endorsement, and their scientific perspectives on various aspects of abandoning statistical significance. The survey instrument (available here: https://osf.io/zkwgf/) consisted of 10 multiple choice questions presented on a single webpage. All questions were optional. The survey invitation e-mail (available here: https://osf.io/b9sdv/) was dispatched from the e-mail address of the first author (TEH) using the survey software *SoSci Survey* (https://www.soscisurvey.de/). Contact e-mail addresses were provided by signatories alongside their signatures.[9]

Bullet points

- Petitions have a long history of being used for political, social, ethical and injustice issues; however, it is unclear how/whether they should be implemented in scientific argumentation.
- Recently, an extremely influential commentary published in Nature (Amrhein et al, 2019) calling for the abandonment of 'statistical significance' was signed by 854 scientists.
- We surveyed signatories and observed substantial heterogeneity in respondents' perceptions of the petition process, motivations for signing and views on aspects of abandoning statistical significance.
- The top-cited signatories were strongly concentrated in a few scientific fields.
- In a random sample of 100 signatories, 62 published at least one paper in 2018 using statistical inference and most of them had used the phrase 'statistical significance'.
- When scientists sign petitions, they may have variable views on important aspects and it is useful to understand this diversity.

We aimed to publish an editorial perspective along with a survey of this sort where fellow expert scientists are asked voluntarily and anonymously to express their scientific opinions on technical statistical, not private, matters. Nevertheless, we did seek independent approval and in consultation with the leadership of QUEST where METRIC-B is hosted in Berlin determined that no IRB approval is needed for this survey. QUEST itself was not involved in any way in the survey or the perspective.

The invitation was sent on 4 April 2019, and the survey was closed two weeks later on 18 April. No reminders were sent. For each signatory, the invitation e-mail contained a unique and anonymous link to the survey which allowed them to complete the survey only once. This prevented any nonsignatories from completing the survey, unless a signatory shared their link with somebody else and had not already completed the survey via that link themselves. The link could be revisited if responses remained incomplete. Due to the 'Anonymous' privacy mode of the SoSci Survey software (see https://perma.cc/XP69-HCPK), it was impossible for anybody to link participants' responses to their identities or to see who had or had not participated. One scientist changed their mind and wanted to have their responses removed, but this was not possible.

TABLE 1 Responses to survey questions. Verbatim free-text responses for 'Other please specify' options are available in Table S1

Question and response options	n	Percentage (95% CI)
Q1. When Amrhein et al invited signatories they initially provided a summary statement about the Comment and offered to share a draft version of the Comment upon request. How did you decide to sign?		
A. I requested and read the draft version of the Comment before signing and had no concerns/comments to share with the authors	172	69% (64%-75%)
B. I requested and read the draft version of the Comment, made queries/comments to the authors and waited for satisfactory replies before signing	6	2% (0%-8%)
C. I requested and read the draft version of the Comment before signing and made queries/comments to the authors but did not feel they were so essential as to have to wait for their responses before I signed	13	5% (0%-11%)
D. I did not read the draft version of the Comment and I signed based on the summary statement since this is what my support was intended for	43	17% (12%-23%)
E. Other, please specify	13	5% (0%-11%)
Not answered	1	0% (0%-6%)
Q2. Amrhein et al also sent a link to the finalized version of the Comment to all people who had signed the petition. Did you read the finalized version of the Comment before its publication in Nature?		
A. Yes	194	78% (73%-83%)
B. No, but I read it after its publication	35	14% (9%-19%)
C. No, but I may read it in the future	12	5% (0%-10%)
D. No, and I do not plan to read it	4	2% (0%-6%)
E. Other, please specify.	2	1% (0%-6%)
Not answered	1	0% (0%-5%)
Q3. To what extent do you agree with the final published Comment?		
A. I agree 100% with every single word and every claim made in it	38	15% (9%-22%)
B. I agree with the large majority of what is stated there[a]	96	39% (32%-45%)
C. I agree with the majority of what is stated there	97	39% (33%-46%)
D. I agree with a minority of what is stated there, but still felt that it was worth supporting	3	1% (0%-8%)
E. I have not read it	5	2% (0%-9%)
F. Other, please specify	8	3% (0%-10%)
Not answered	1	0% (0%-7%)
Q4. Are you concerned that abandoning (retiring) statistical significance may lead to people interpreting results subjectively and with biased preconceptions?		
A. I am very concerned about this possibility	8	3% (0%-10%)
B. I am somewhat concerned about this possibility	53	21% (15%-28%)
C. I am a little concerned about this possibility	90	36% (30%-43%)
D. I am not at all concerned about this possibility	90	36% (30%-43%)
Not answered	7	3% (0%-10%)
Q5. Are you concerned that abandoning (retiring) statistical significance may make things worse overall across the scientific literature?		
A. I am very concerned about this possibility	3	1% (0%-8%)
B. I am somewhat concerned about this possibility	19	8% (2%-14%)
C. I am a little concerned about this possibility	75	30% (24%-37%)
D. I am not at all concerned about this possibility	145	58% (52%-65%)
Not answered	6	2% (0%-9%)
Q6. What do you think about replacing 'confidence interval' with 'compatibility interval'?		
A. I strongly prefer 'compatibility interval' over 'confidence interval'	29	12% (6%-19%)
B. I modestly prefer 'compatibility interval' over 'confidence interval'	68	27% (21%-34%)
C. I have no preference for either term	107	43% (37%-50%)

(Continues)

TABLE 1 (Continued)

Question and response options	n	Percentage (95% CI)
D. I modestly prefer 'confidence interval' over 'compatibility interval'	32	13% (7%-20%)
E. I strongly prefer 'confidence interval' over 'compatibility interval'	7	3% (0%-10%)
Not answered	5	2% (0%-9%)
Q7. Reliance on statistical significance may lead to unwarranted statements of 'no difference', but also unwarranted claims of associations that don't really exist. Which problem is more serious/common?		
A. Unwarranted statements of 'no difference' is a more serious/common problem than unwarranted claims of associations that don't exist	27	11% (5%-17%)
B. Unwarranted statements of 'no difference' and unwarranted claims of associations that don't exist are equally serious/common problems	163	66% (60%-72%)
C. Unwarranted statements of 'no difference' is a less serious/common problem than unwarranted claims of associations that don't exist	46	19% (13%-24%)
Not answered	12	5% (0%-11%)
Q8. When you signed the petition, what benefits did you feel this would bring to the argument to retire (abandon) statistical significance? (Please tick all that apply)		
A. I felt it would help to draw attention to the argument	207	83% (79%-88%)
B. I felt that it would make the argument more convincing	77	31% (25%-37%)
C. I did not consider the potential benefits to the argument of signing the petition	16	6% (4%-10%)
D. Other, please specify	39	16% (12%-20%)
Q9. In a recent pre-registered randomized trial comparing two septic shock treatments with formal power calculations for determining the necessary sample size to evaluate the primary outcome of mortality, the mortality was 43% for the older treatment and 35% for the newer one and the *P*-value was .06. What do you think about the statement 'the new treatment clearly reduced mortality'?		
A. I strongly agree. The treatment clearly reduced mortality. Claiming that there is no difference between the two treatments is appalling science	29	12% (6%-18%)
B. I mostly agree	55	22% (16%-28%)
C. I tend to agree	68	27% (21%-34%)
D. I tend to disagree	45	18% (12%-24%)
E. I mostly disagree	25	10% (4%-16%)
F. I strongly disagree. Claiming that there is a difference between the two treatments is appalling science	8	3% (0%-10%)
Not answered	18	7% (1%-14%)
Q10. For which fields do you currently find that the idea to abandon (retire) statistical significance is appropriate?		
A. It is appropriate for all fields of science	93	38% (31%-44%)
B. It is appropriate for my field and perhaps also other fields, but not necessarily all fields of science	123	50% (43%-56%)
C. It is mostly not appropriate for my field, but it is mostly appropriate for many other fields of science	5	2% (0%-9%)
D. At this point, I think it is mostly not appropriate	6	2% (0%-9%)
E. Other, please specify	16	6% (0%-13%)
Not answered	5	2% (0%-9%)

Abbreviation: CI, confidence interval.

[a]Note that, contrary to the pre-registered protocol, one of the response options for question 3 ('I agree with the large majority of what is stated there'.) was initially missing from the live survey due to researcher error (TEH). The omission was noticed within 60 min of the survey launch and corrected. At the time of correction, 25 complete surveys had been submitted, but an unknown number of surveys had been started.

[b]Percentages may not add up to 100% due to rounding (all equations except Q8) or because participants could select multiple responses (Q8 only).

Of all signatories, we received 248 survey responses (after removing one where no questions were answered): a 29% response rate. Responses are presented in Table 1.

As per our original protocol, we explored whether the responses to questions 8 (perceived benefits of signing the petition) and 10 (appropriateness for all science, own field and other fields) were associated with the responses to each of the other 8 questions of the survey. No strong associations were observed (see Table S1-S2).

Overall, although most respondents reported that they agreed with the 'majority', 'large majority' or 'every single word' of the commentary (Question 3), responses to certain

survey questions revealed some diversity of viewpoints that was not otherwise apparent. For example, the commentary focused on when reliance on 'statistical significance' might lead to unwarranted claims of 'no difference' but put less emphasis on the issue of unwarranted claims about associations that are actually spurious.[20] Most respondents (66%) felt that the two issues were equally serious/common and 19% felt that unwarranted claims of 'no difference' were less serious/common than unwarranted claims about associations that are spurious (Question 7). Similarly, Question 9 probed a statement by an extremely influential statistician (also a signatory), David Spiegelhalter. In a Financial Times interview,[21] Spiegelhalter, a towering giant in Bayesian statistics, described as 'appalling science' the conclusion of no difference in a large randomized trial of sepsis treatment[22] that was published in JAMA. The trial involved formal power calculations and mortality was 43% and 35%, respectively, in the two arms with $P = .06$. About one-third of signatories agreed with the interpretation in JAMA. If one has high scepticism and a low prior for effectiveness of sepsis treatments (many have been tested, but almost all have failed, despite frequent earlier promises) than the conclusion of no difference would be appropriate.

It is unclear whether the endorsement of the 854 signatories should be restricted to the request to abandon statistical significance or applied to the Nature commentary more broadly. Surprisingly, 6% of respondents reported that they had never read the Nature commentary and 14% only read it after publication (Question 2). 17% reported that they had signed on the basis of a summary statement and that this is what their support was intended for (Question 1). Notably, responses to the question about replacing the term 'confidence intervals' with 'compatibility intervals' (Question 6) suggested that many respondents (43%) were ambivalent on this issue and some (16%) even expressed the opposite preference. This definitional issue is somewhat tangential to the main goal of abandoning statistical significance, and these responses reinforce the idea that, at least for some signatories, their endorsement should not necessarily be interpreted as applying to all aspects of the commentary.

Most respondents stated that they signed the petition in order to draw attention to the statistical significance issue and almost a third also felt it would make the argument more convincing (Question 8). Arguably, the latter goal is a logical fallacy (argumentum ad populum).[8] Many respondents also used the opportunity to provide free-text 'other' responses to this question, some of which conveyed frustration about the decades long effort to address problems related to statistical significance (see Table S1). The sentiment among some appeared to be that scientific argumentation alone had not been sufficiently effective and that in order to address what they viewed as a cultural/political problem, a cultural/political solution (ie a petition) was justifiable.

As statistical methods are hotly debated and attract the interest of many scientists, several papers proposing ways to improve the current status include large numbers of authors. The Nature commentary increased 10-fold the number of names involved compared with previous papers, but did not ask the signatories to be involved at the level required for authorship. It is unknown to which depth formal authorship criteria can be met for all authors involved in extensively multi-authored papers. Conversely, it is also unknown whether disengaging scientists from the intellectual commitment and scrutiny required to reach authorship credit and asking them to be simply signatories is beneficial or harmful.

One perspective on scientific argumentation states that it is irrelevant *who* has made an argument; it is the substance of the argument that is of primary importance.[23] However, when a petition is used to support a scientific argument, the expertise, experience and perspective of the signatories seem highly relevant to how that petition should be interpreted. We selected a random sample of 100 individuals from the 854 signatories to examine their stance towards statistical significance in their own published work. For 7 of these signatories, we were unable to locate them in Web of Science or find a publicly accessible online profile. Among the other 93, CVs could be located for 13 individuals, but only 2 of

TABLE 2 Characteristics of paper-level analysis for random sample of 100 signatories

Characteristic	n
Published at least one article in 2018 reporting quantitative data	62
Most recent 2018 quantitative article…	
…reports inferential statistics	55
…uses the term '(statistically) significant' or '(statistical) significance'	43
…reports at least one *P*-value	35
…reports only *P*-values	20
…reports *P*-values and confidence intervals	14
…reports *P*-values and false discovery rate	1
…reports using only confidence intervals	17
…reports using only Bayesian techniques	3

TABLE 3 Characteristics of 68 signatories who were among the 'top-cited' 100,000 scientists

Characteristics	Median (25th-75th percentile)
Ranking (with self-citations)	28 379 (7881-51096)
Ranking (without self-citations)	28 370 (7827-49053)
	n
Most common higher-level Science-Metrix category (out of 22 categories)	
Medicine	25
Psychology & cognitive sciences	13
Public health & health services	10
Economics & business	5
Biology	4
Social sciences	4
3 others	<4
Most common Science-Metrix subject categories (out of 176 categories)	
Epidemiology	11
Social psychology	8
Oncology & carcinogenesis	5
Public health	5
Business & management	4
Ecology	4
21 others	<4
Second most common Science-Metrix subject categories (out of 176 categories)	
Epidemiology	7
General & internal medicine	7
Social psychology	6
Evolutionary biology	4
Experimental psychology	4
Obstetrics & reproductive medicine	4
Statistics & probability	4
25 others	<4

them had been definitely updated after the publication of the Nature commentary, so we cannot tell if/whether the signatories would eventually include the commentary in their CVs. As shown in Table 2, based on Web of Science slightly less than two-thirds of the sampled signatories had published at least one article in 2018 reporting quantitative data. When they did publish something, inferential statistics had almost always been used in their most recent 2018 quantitative article, with the large majority including the phrase 'statistical significance' (or similar)—the practice which the commentary suggests should be abandoned. We cannot exclude the possibility that these scientists were won over to the cause of abandoning statistical significance very recently, for example in 2019, or that they were pressured by reviewers, editors or funders to use terminology that they did not wish to use.

For each of the 854 signatories, we used Scopus to identify whether they were among the 'top-cited' 100 000 scientists across science based on a composite citation indicator[24] that combines total citations, H index, co-authorship adjusted Hm index, citations to papers as single author, as single or first author, and as single, first, or last author. Data have been extracted on these 6 indicators for citations received in 1995-2017 and the composite calculated on all author records in collaboration with Scopus/Elsevier.[25] Sixty-eight signatories (8%) were among the 'top-cited' 100 000 scientists across science based on that composite citation indicator. As shown in Table 3, Medicine, Psychology/Cognitive Sciences, Public Health/Health Services and Economics/Business were the most common fields for 53/68 top-cited signatories. Looking at more granular fields, for 44/68 top-cited signatories, 4 of the 176 fields of science (Epidemiology, Social Psychology, Oncology/Carcinogenesis, Public Health) were the most common or second most common field of their publications.

Interestingly, the heavily represented fields (epidemiology, public health, medicine, social psychology) among the top-cited signatories are mostly fields where serious concerns and debates about low reproducibility have been raised.[26-31] This gives some insight into certain characteristics of the signatories, but knowing the scientific field of all signatories would have been informative, particularly in light of responses to Question 10: 50% of respondents said they felt that abandoning statistical significance was appropriate for their field and were more cautious about whether it should also apply to other fields.

For fields where there are prevalent concerns about low reproducibility, abandoning the concept of statistical significance would make claims of 'irreproducibility' difficult if not impossible to make, although Amrhein and Greenland disagree with this perspective.[32,33] In our opinion, this approach may give bias a free pass.[19] There is tension therefore on whether abandoning statistical significance would improve statistical reasoning or inappropriately silence worrisome claims of irreproducibility in fields that seem to have the greatest problems of irreproducibility. The former consequence would be most welcome, while the latter could be a disaster.

Some important limitations and caveats should be considered. Firstly, it was not our intention to make broad inferences about the views of all scientists; the 854 signatories are likely a highly biased sample of the wider scientific community. They may not be representative even of all scientists who would otherwise support many of the positions in the Nature Comment, but for various reasons did not have an opportunity or did not wish to sign. Thirdly, the response rate

was reasonable (29%) for this type of single communication survey, but it is likely that responders are different to non-responders. It is not clear in what direction this would bias the results. For example, it is unknown whether signatories who were very much in favour of the positions of the Nature commentary would be more likely to complete the survey (to testify their fervent enthusiasm) or less likely to complete it (feeling that the survey is causing unnecessary questioning). Thirdly, this is a single case study of signature collection, and thus, inferences may not necessarily extend to other petitions that may have higher or lower agreement between signatories in the positions expressed. Petitions that recruit signatories may also differ on whether single, simple positions are expressed, or many statements are incorporated that may attract different degrees of enthusiasm. Nevertheless, we feel that given the scientific importance of the matter addressed in this specific situation and the great attention it received, any insights obtained from this case will be useful. Finally, these data may bear on the utility of the petition, but do not directly pertain to the merits of the scientific arguments to retire statistical significance, which have been debated elsewhere.[17-20]

In conclusion, we are grateful to all colleagues who shared their insights about their participation in the Nature petition and their perspectives about the hot topic of retiring statistical significance. If and/or how petitions should be used in scientific argumentation remains an open question; however, we hope that the insights obtained in this exercise might provide the foundations for an informed debate. We have invited and received extensive insightful comments from the authors of the Nature commentary and we have revised our Perspective paper accordingly. The original version and revised version are available at https://doi.org/10.31222/osf.io/73xm5. We hope the current paper will stimulate further debate.

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We are grateful to all the scientists who responded to our questions and who have contributed constructively on the ongoing debate about statistical significance. Many thanks to the authors of the Nature commentary for their insightful comments and criticisms on an earlier version of this Perspective.

CONFLICT OF INTEREST

John PA Ioannidis is editor-in-chief of the European Journal of Clinical Investigation, and the opinions expressed in this perspective are those of the authors and not of any institution. John Ioannidis has previously taken a stance on issues of what statistical inference methods should be used and how and his positions can be seen in the references that he has authored or co-authored which are cited in this Perspective. His expressed comments of the Nature commentary content and process can also be seen in the highly popular blog of Andrew Gelman. Tom E. Hardwicke declares no competing interests.

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DATA AVAILABILITY STATEMENT

The study protocol was pre-registered on 4 April 2019 and is available at https://osf.io/hbkj3/. The protocol was hidden under embargo for the duration of the survey to avoid contamination of participant responses. The introductory text of this report is largely based on the text of the pre-registered document. All procedural deviations from the pre-registered protocol are explicitly acknowledged in this article. All data exclusions and measures conducted during this study are reported in this article. Data, materials and analysis scripts related to this study are publicly available at https://osf.io/8aenp/. To facilitate reproducibility, the analysis script is available in a Code Ocean container (https://doi.org/10.24433/CO.3912558.v1) which re-creates the software environment in which the original analyses were performed.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section at the end of the article.

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