Science Communication
Scientific uncertainty and trust in science

Rui Mata, HS 2024

Version: October 10, 2024

Course structure

Session information

Sessions take place Thursdays, 8.15-9.45, Biozentrum, Hörsaal U1.131.

#	Date	Topic	Instructor(s)	Slides
1	19.09.2024	What is science communication?	Mata	pdf
2	03.10.2024	Models and elements of science communication	Mata	pdf
3	10.10.2024	Scientific uncertainty and trust in science	Mata	pdf
4	17.10.2024	Guidelines for science communication	Mata	pdf
5	24.10.2024	Science communication gone wrong	Mata	pdf
6	31.10.2024	Practical: Knowledge and Data Visualization	Hil/Lachenmeier	pdf
7	07.11.2024	Practical: Modular Information Design	Hil/Lachenmeier	pdf
8	14.11.2024	Practical: Modular Information Design	Hil/Lachenmeier	pdf
9	21.11.2024	Practical: Modular Information Design	Hil/Lachenmeier	pdf
10	28.11.2024	Practical: Modular Information Design	Hil/Lachenmeier	pdf
11	05.12.2024	Practical: Modular Information Design	Hil/Lachenmeier	pdf
12	12.12.2024	Practical: Modular Information Design	Hil/Lachenmeier	pdf
13	19.12.2024	Exam		

Recap of last session

- Get an overview of the history, models, and elements of science communication

- Identify stakeholders and audiences (public segmentation) of science communication

- Discuss rationale and practices of evaluation of science communication


WHO'S GOT THE ANSWER?

The second half of the 20th century has seen important changes in the ecology of science communication, including…
[Select all the correct answers]

- A: the rise of specialized higher-education programs.
- B: the rise of social media and decline of print media.
- C: the founding of the first institution solely dedicated to science communication.
- D: a generalized disinterest in science communication.

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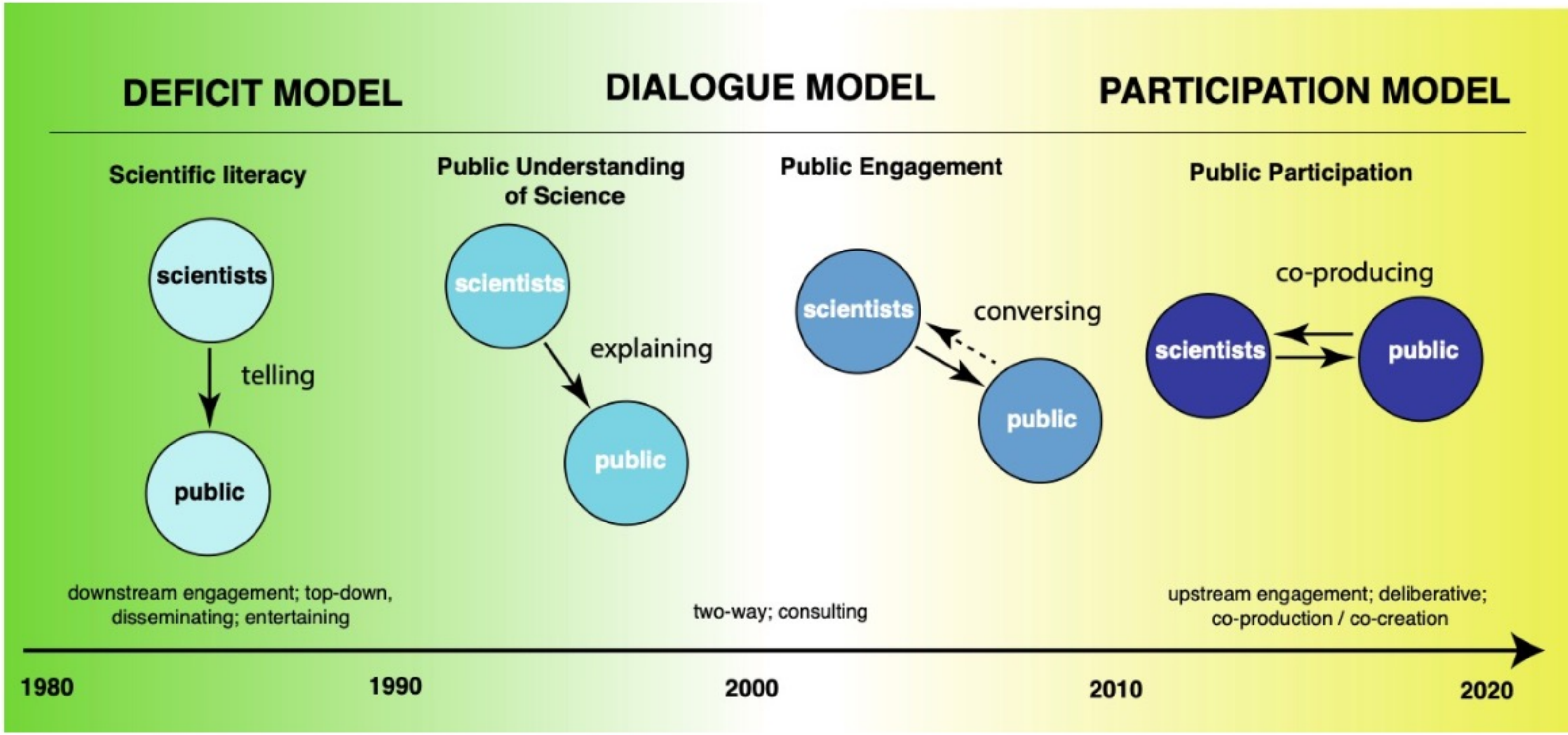
- D: has limited scalability.



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- B: prioritizing behavioral change over media attention.
- C: not consistently applying pre-post evaluation designs.
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Goals for today

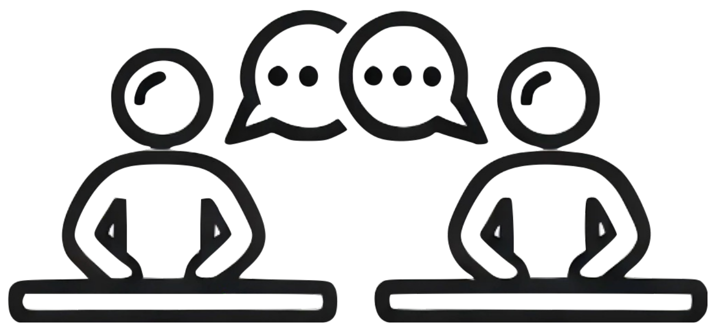
- Become familiar with the concept of scientific evidence and be able to distinguish different levels/quality of evidence

- Become familiar with the concept of uncertainty, be able to distinguish different types of uncertainty, and become familiar with several factors influencing the role of uncertainty on communication

- Discuss reasons for trust in science and scientists; become familiar with overall trends in trust in science, understand its measurement, and discuss its importance for public health and well-being

WHAT IS SCIENTIFIC EVIDENCE?

and is all evidence created equal?



Scientific evidence

Scientific evidence refers to **information or data that justifies belief** in a hypothesis or theory by making it reasonable to hold certain conclusions. It serves as a rational guide to truth by providing a reliable basis for distinguishing between true and false claims. Scientific evidence is often empirical, arising from observation or experimentation, and is used to confirm or disconfirm theories. Scientific evidence can be seen as a neutral arbiter in resolving theoretical disputes, and it is expected to be objective, public, and intersubjective, meaning that it can be assessed and confirmed by others, leading to consensus.

https://plato.stanford.edu/entries/evidence/

Levels of evidence

GRADE (Grading of Recommendations, Assessment, Development, and Evaluations)

Table 5.1: Quality of Evidence Grades

Grade	Definition
High	We are very confident that the true effect lies close to that of the estimate of the effect.
Moderate	We are moderately confident in the effect estimate: The true effect is likely to be close to the estimate of the effect, but there is a possibility that it is substantially different
Low	Our confidence in the effect estimate is limited: The true effect may be substantially different from the estimate of the effect.
Very Low	We have very little confidence in the effect estimate: The true effect is likely to be substantially different from the estimate of effect

Quality of evidence is a continuum; any discrete categorisation involves some degree of arbitrariness. Nevertheless, advantages of simplicity, transparency, and vividness outweigh these limitations.

SUMMARY POINTS

A guideline's formulation should include a clear question with specification of all outcomes of importance to patients

GRADE offers four levels of evidence quality: high, moderate, low, and very low

Randomised trials begin as high quality evidence and observational studies as low quality evidence

Quality may be downgraded as a result of limitations in study design or implementation, imprecision of estimates (wide confidence intervals), variability in results, indirectness of evidence, or publication bias

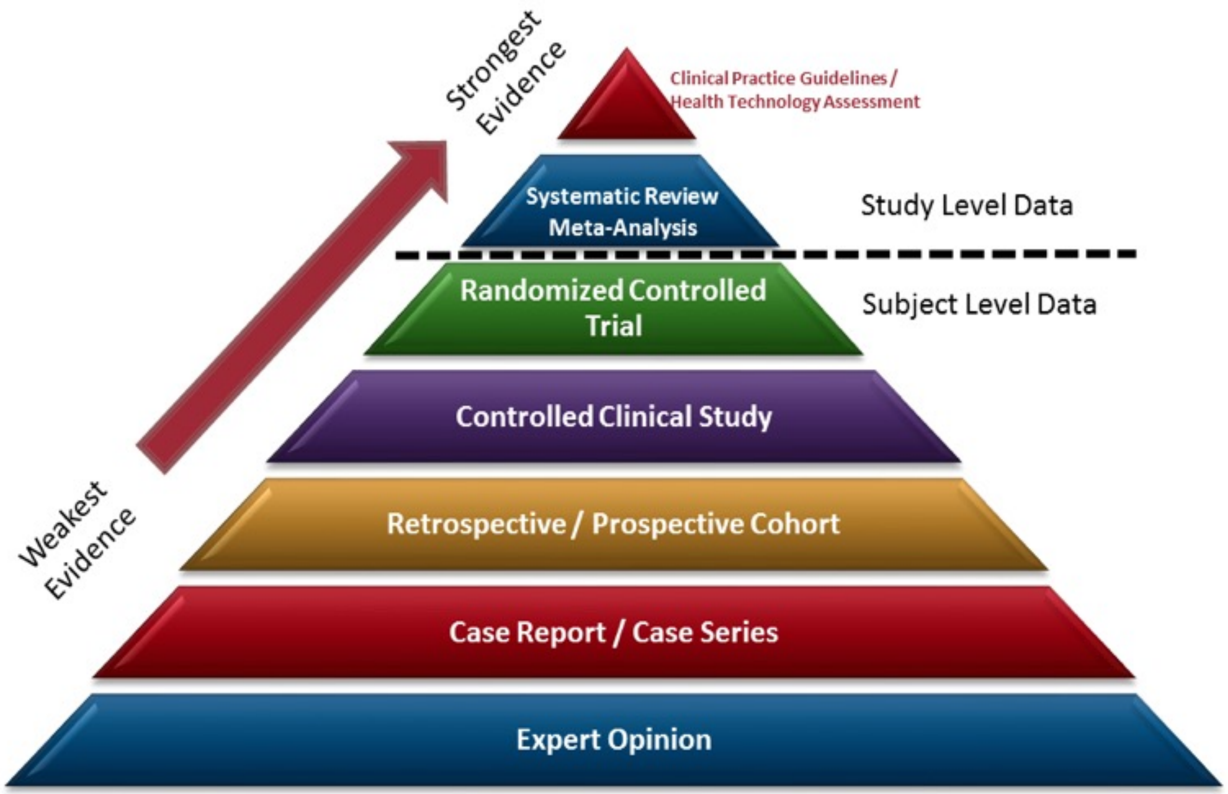
Quality may be upgraded because of a very large magnitude of effect, a dose-response gradient, and if all plausible biases would reduce an apparent treatment effect

Critical outcomes determine the overall quality of evidence

Evidence profiles provide simple, transparent summaries

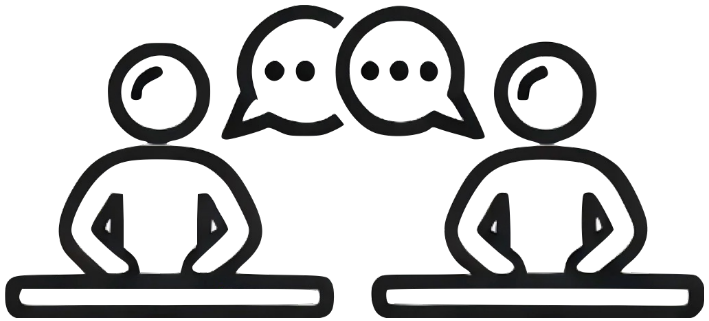
Guyatt, G. H., Oxman, A. D., Kunz, R., Vist, G. E., Falck-Ytter, Y., & Schünemann, H. J. (2008). What is "quality of evidence" and why is it important to clinicians? BMJ, 336(7651), 995–998. https://doi.org/10.1136/bmj.39490.551019.BE

Levels of evidence



https://en.wikipedia.org/wiki/Hierarchy_of_evidence

WHAT IS SCIENTIFIC UNCERTAINTY?

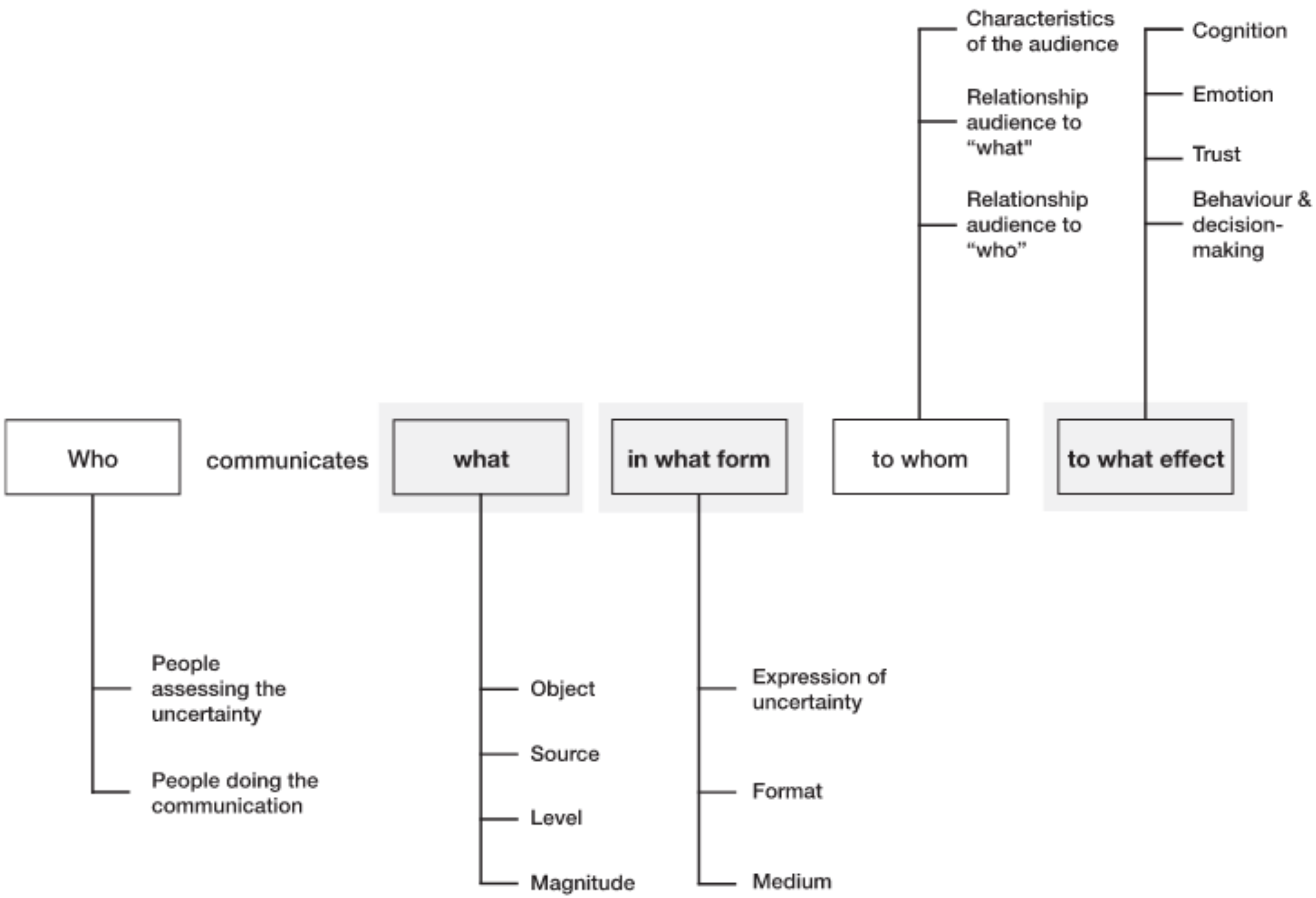


Types of (scientific) uncertainty

Uncertainty	Description	Examples
Aleatory	Refers to uncertainty due to fundamental indeterminacy or randomness in the world. Often associated with unpredictable future events, luck, or chance.	Communicating the inherent unpredictability of future events like economic forecasts or climate change models
Epistemic	Refers to uncertainty due to limited knowledge or ignorance, often concerning past or present phenomena that could potentially be known with more data.	Reporting uncertainty in scientific estimates, e.g., “The current estimate for the number of tigers in India ranges from 2,500 to 3,000 due to sampling error.”

van der Bles, A. M., van der Linden, S., Freeman, A. L. J., Mitchell, J., Galvao, A. B., Zaval, L., & Spiegelhalter, D. J. (2019). Communicating uncertainty about facts, numbers and science. Royal Society Open Science, 6(5), 181870. https://doi.org/10.1098/rsos.181870

A framework for communicating uncertainty



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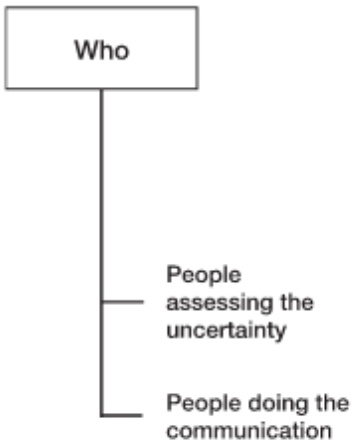

Table 2. Summary of Effect Sizes and Test for Publication Bias.

	Effect size				Heterogeneity test		Test for publication bias			
Aggregated factors	k	N	Weighted-mean ES	95%CI	Q statistic	I^2 (%)	z	p	Fail-safe N	Trim-and-fill adjusted estimates
Source factors										
Source credibility	14	5,475	.42***	[.26, .57]	357.84***	96.23	.21	.84	4,472	–
Source congruency	8	5,540	.12*	[.03, .19]	108.70***	95.91	.03	.97	206	–
Source expertise	12	7,825	.26***	[.14, .38]	321.79***	92.84	−1.42	.16	1,518	–
Social Endorsement (Number of sources)	20	10,284	.13***	[.02, .23]	238.78***	93.77	1.07	.28	1,472	–
Content factors										
Argument quality	12	4,103	.47***	[.25,.69]	367.51***	96.41	1.25	.21	3,343	–
Content fluency	13	2,432	.33***	[.16, .50]	124.33***	89.87	−.00	.99	994	–
Content congruency	7	6,119	.20*	[.01, .39]	102.73***	96.97	2.21*	.03	679	.22*
Channel factors										
Media interactivity	10	2,866	.11*	[.05, .17]	22.83**	62.82	1.76	.08	151	–
Media modality (Textual vs. visual)	15	5,910	.09***	[.05, .16]	24.90*	42.05	1.77	.08	257	–
Receiver factors										
Topical knowledge	9	7,668	.06	[−.09, .21]	215.27***	96.52	−.04	.97	70	–
Issue involvement	15	6,362	.27***	[.11, .43]	290.65***	96.62	1.04	.30	2,843	–
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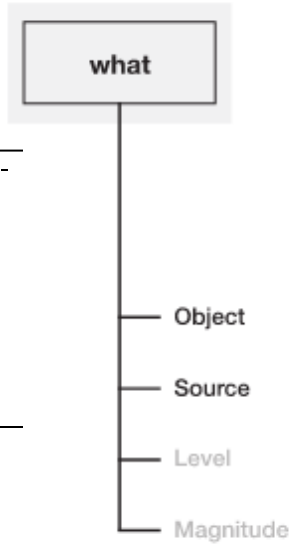
Note. k = number of studies; N = total sample size for all studies combined; ES = effect size; 95%CI = lower and upper limits of 95% confidence interval for effect size; Q, I^2 = measure of homogeneity; Fail-safe N = statistics for fail-safe N test; For trim-and-fill adjusted estimates, only relations having statistically significant publication bias were examined.
$^*p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Credibility and expertise of the source have the strong effects on information credibility…

Ou, M., & Ho, S. S. (2024). Factors associated with information credibility perceptions: A meta-analysis. Journalism & Mass Communication Quarterly, 101(2), 346–372. https://doi.org/10.1177/10776990231222556

A framework for communicating uncertainty

Object	Examples
Facts: Categorical variables that are theoretically verifiable. These facts can be verified as true or false	- Water is liquid at room temperature
Numbers: Continuous variables describing the world. They can be directly observable or theoretical constructs used as parameters in models	- The number of tigers in India - GDP growth
Hypotheses: Theories or models about how the world works, expressed as structural relationships between variables. These hypotheses often involve uncertainty about the adequacy of models or assumptions.	- What is the dose-response function between ionizing radiation and harm?



Source	Examples
Variability in the sample: Uncertainty due to natural variation within a population or repeated measures, often leading to statistical margins of error.	- Confidence intervals
Computational or Systematic Inadequacies: Uncertainty arising from limitations in measurement methods, computational models, or systematic errors in data collection.	-Acknowledging potential measurement errors
Limited knowledge: Uncertainty due to incomplete knowledge or ignorance about underlying processes or phenomena..	- Expressing uncertainty by acknowledging gaps in knowledge (e.g., interactions between variables)
Expert disagreement: Uncertainty stemming from differences in opinions or interpretations among experts in a field.	Communicating differing expert views

van der Bles, A. M., van der Linden, S., Freeman, A. L. J., Mitchell, J., Galvao, A. B., Zaval, L., & Spiegelhalter, D. J. (2019). Communicating uncertainty about facts, numbers and science. Royal Society Open Science, 6(5), 181870. https://doi.org/10.1098/rsos.181870

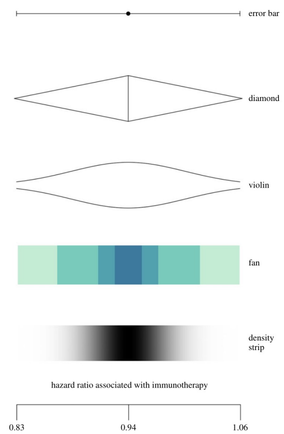
A framework for communicating uncertainty

Decreasing precision

i. A full explicit probability distribution
ii. A summary of a distribution
iii. A rounded number, range or an order-of-magnitude assessment
iv. A predefined categorisation of uncertainty
v. A qualifying verbal statement
vi. A list of possibilities or scenarios
vii. Informally mentioning the existence of uncertainty
viii. No mention of uncertainty
ix. Explicit denial that uncertainty exists

Expression of uncertainty	Examples
Direct - absolute: Direct expressions of uncertainty that are precise and often quantifiable, applying to facts, numbers, or scientific hypotheses. The precision decreases as uncertainty increases.	- “There is a 95% confidence interval that the hazard ratio (HR) is between 0.83 and 1.06."
Direct - relative: Relative comparisons between competing hypotheses or values, often using verbal comparisons, likelihood ratios, or measures of model adequacy.	- "The likelihood function suggests that this model provides a better fit for the data compared to the alternative."
Indirect – quality of evidence: Summarizes subjective confidence in a claim based on the quality of underlying evidence. Communicated using qualitative caveats or ordered categories.	- "The evidence for this medical intervention is high quality (GRADE: 4+).”

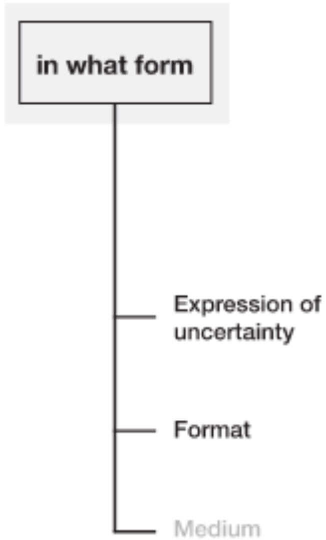
Visual



Numerical

Verbal

cf. next slide



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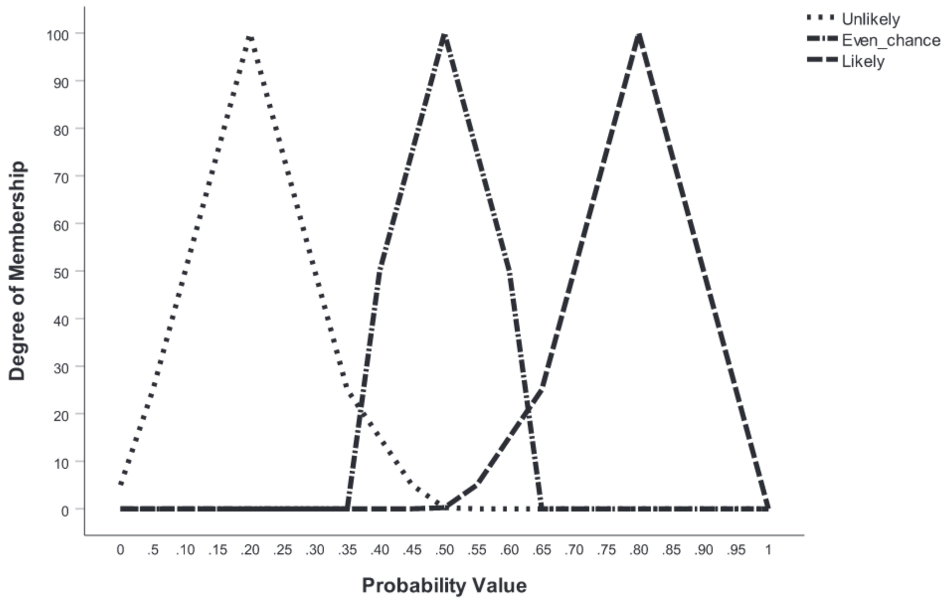

Figure 1. Hypothetical membership functions for three probability terms. Participants are asked to determine how well they think each numeric probability value (e.g., 0, 0.5, 0.10,…1) represents a specific term (e.g., *likely*). Responses are provided by marking a point on a scale (from 0 to 100) for each probability value. This yields several measures, such as the 'minimum', 'maximum', and 'peak' numeric values that the term represents, as well as the 'spread' (i.e., maximum minus the minimum) of values.

Highlights

The (positive and negative) directionality of verbal probabilities enables them to convey more than uncertainty. Probability terms can communicate uncertainty in a face-saving manner and implicitly shape receivers' cognitions and behavior.

Verbal probabilities preclude fine-grained uncertainty communication. Assigning numeric probability ranges to words does not eliminate their imprecise and variable meaning, but can have unintended effects on judgment and decision-making.

Senders are misplaced in their belief that verbal expressions of uncertainty are especially helpful for those with lower numeracy and in thinking that these individuals cannot benefit from numeric probability information.

The benefits of precise numeric expressions of uncertainty, coupled with receivers' preference for numeric information when it really matters, suggests that senders ought to embrace numeric precision over vague words if they wish to communicate uncertainty clearly.

Dhami, M. K., & Mandel, D. R. (2022). Communicating uncertainty using words and numbers. *Trends in Cognitive Sciences*, S1364661322000602. https://doi.org/10.1016/j.tics.2022.03.002

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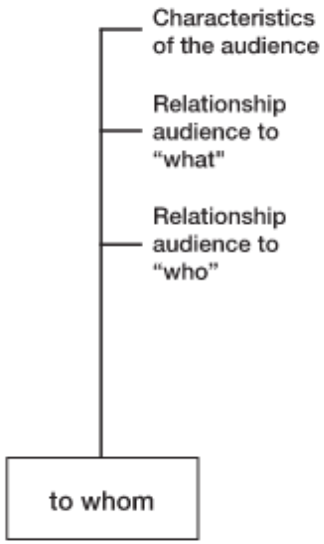

Receiver factors have effects on perceived credibility…

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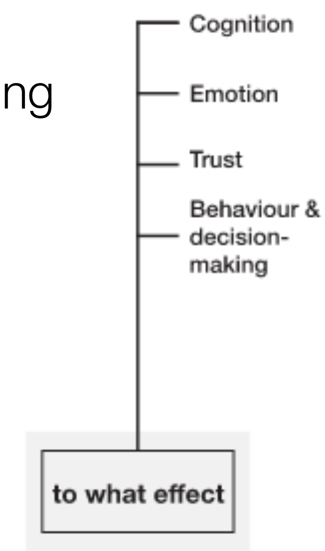
A framework for communicating uncertainty

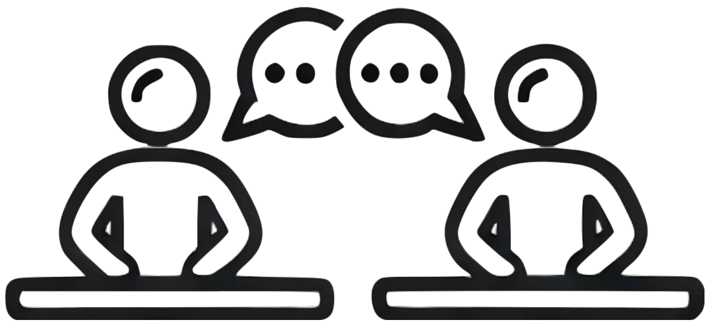
"Uncertainty is inherent to science and science communication. However, the evidence appears mixed regarding whether portraying uncertainty in science communication has positive or negative effects. We review a diverse range of experimental literature (k = 48), summarize the extant findings, and observe how the effects vary across four different types of communicated uncertainty (**deficient**, **technical**, **scientific**, and **consensus** uncertainty). The results indicate that most findings of negative effects (such as reduced credibility and beliefs) are from experiments that operationalized uncertainty as disagreement or conflict in science (consensus uncertainty). In this review, consensus uncertainty was never found to have positive effects. In contrast, uncertainty in the form of quantified error ranges and probabilities (technical uncertainty) in these studies has had only positive or null effects, not negative effects."

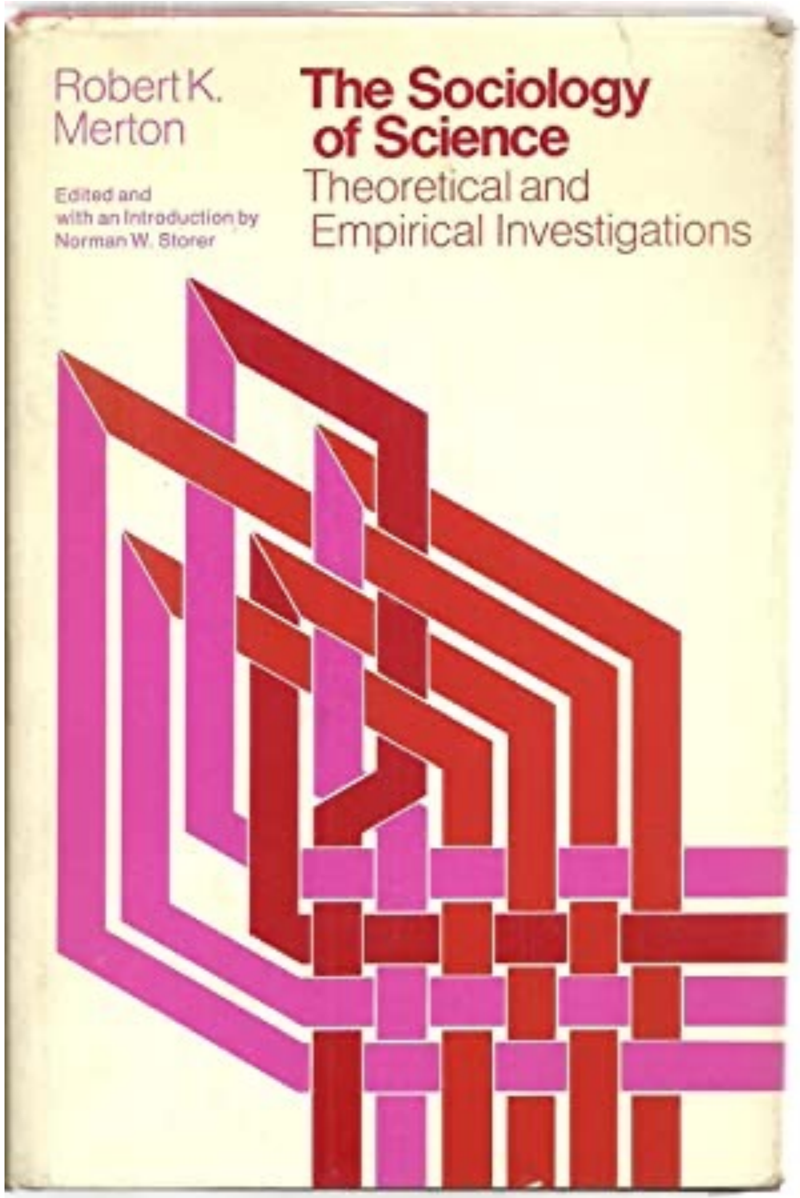


Gustafson, A., & Rice, R. E. (2020). A review of the effects of uncertainty in public science communication. Public Understanding of Science, 29(6), 614–633. https://doi.org/10.1177/0963662520942122

WHY TRUST SCIENCE?

AND SCIENTISTS?

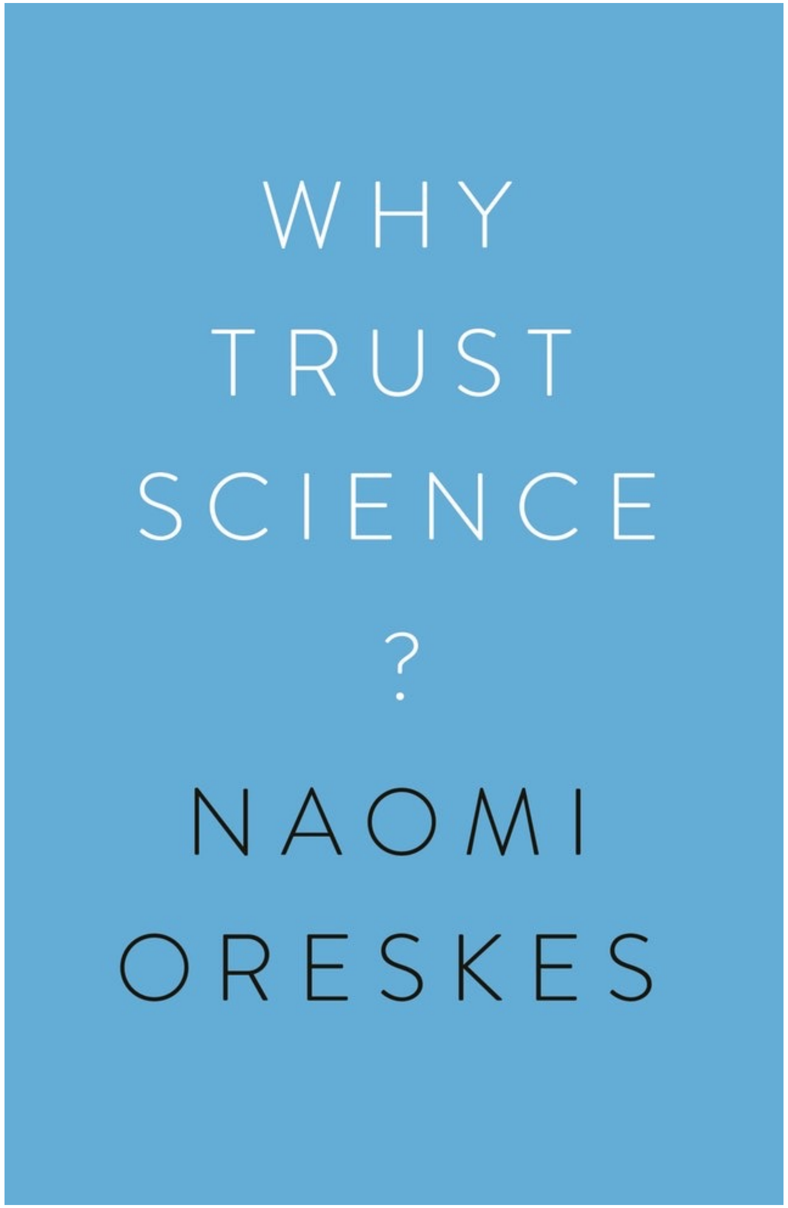




The Ethos of Science (aka, the Mertonian norms):

- Universalism: it's not about who is doing the science
- Communism/Communality: scientists share!
- Disinterestedness: scientists don't have egos or financial interests, only thirst for knowledge
- Organized skepticism: no claim is accepted at face value…

https://en.wikipedia.org/wiki/Mertonian_norms



Trust in science is **not** warranted because there is a singular scientific method that is objective and infallible; science consists of communities of people, making decisions for reasons that are both altruistic and self-interested, using diverse methods.

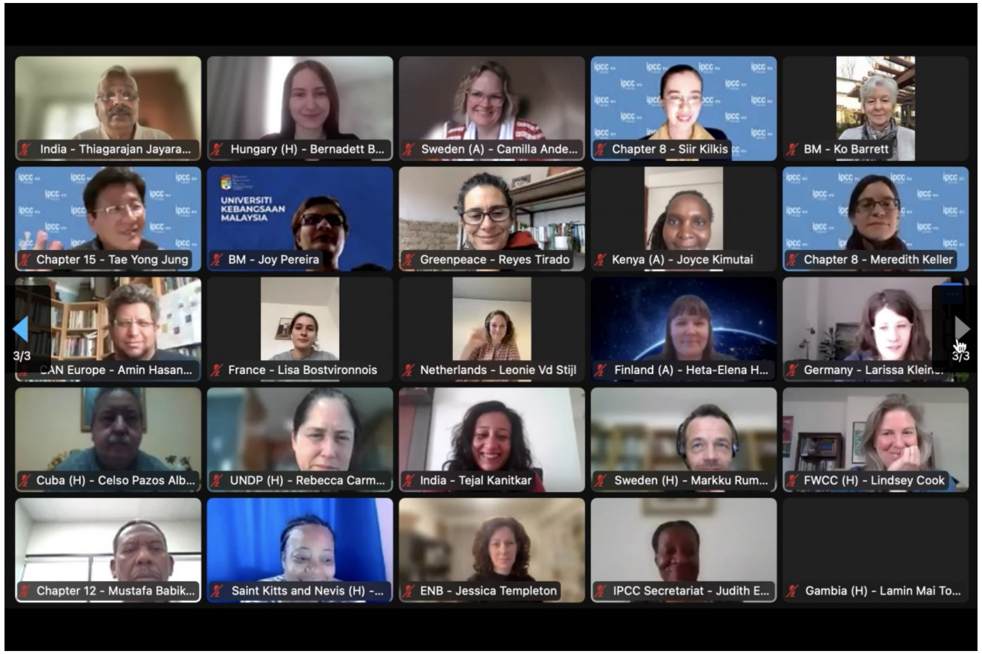
There are however some reasons to **trust** science, specifically:

- its sustained engagement with testable empirical phenomena;
- its social and organized character – a form of **organized skepticism** that tends to self-correction in the long run.

https://www.ted.com/talks/naomi_oreskes_why_we_should_trust_scientists

INTERGOVERNMENTAL PANEL ON climate change

WMO UNEP

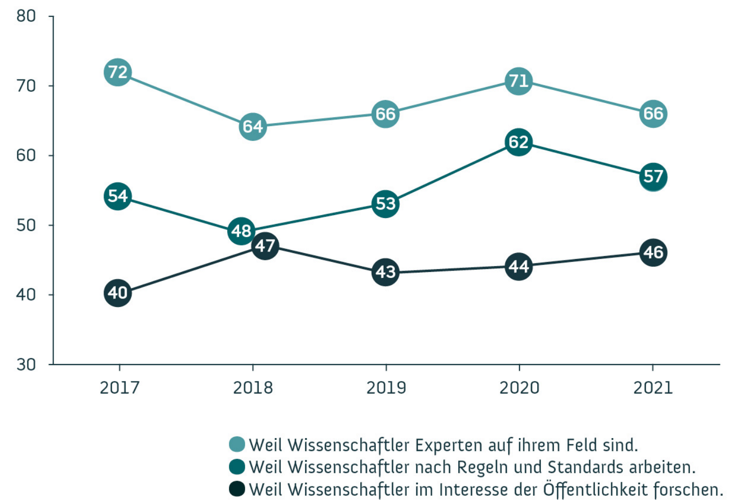


https://www.ipcc.ch

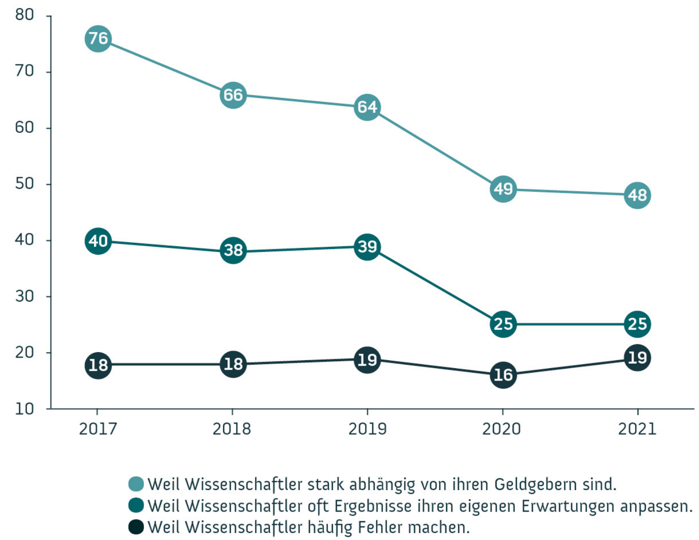
How is trust measured?

“The results show that surveys rarely measure distrust in science, and instead focus on trust in science – mainly at the macro-level – rather than trust in scientists (micro-level) or scientific organisations (meso-level). Benevolence is the dimension of trust considered most frequently; the media is predominantly included as a general type of contact with science without a direct link to (dis)trust. Hence, representative surveys cover a number of different aspects of public (dis)trust in science. However, there is room for improvement.”

Trust



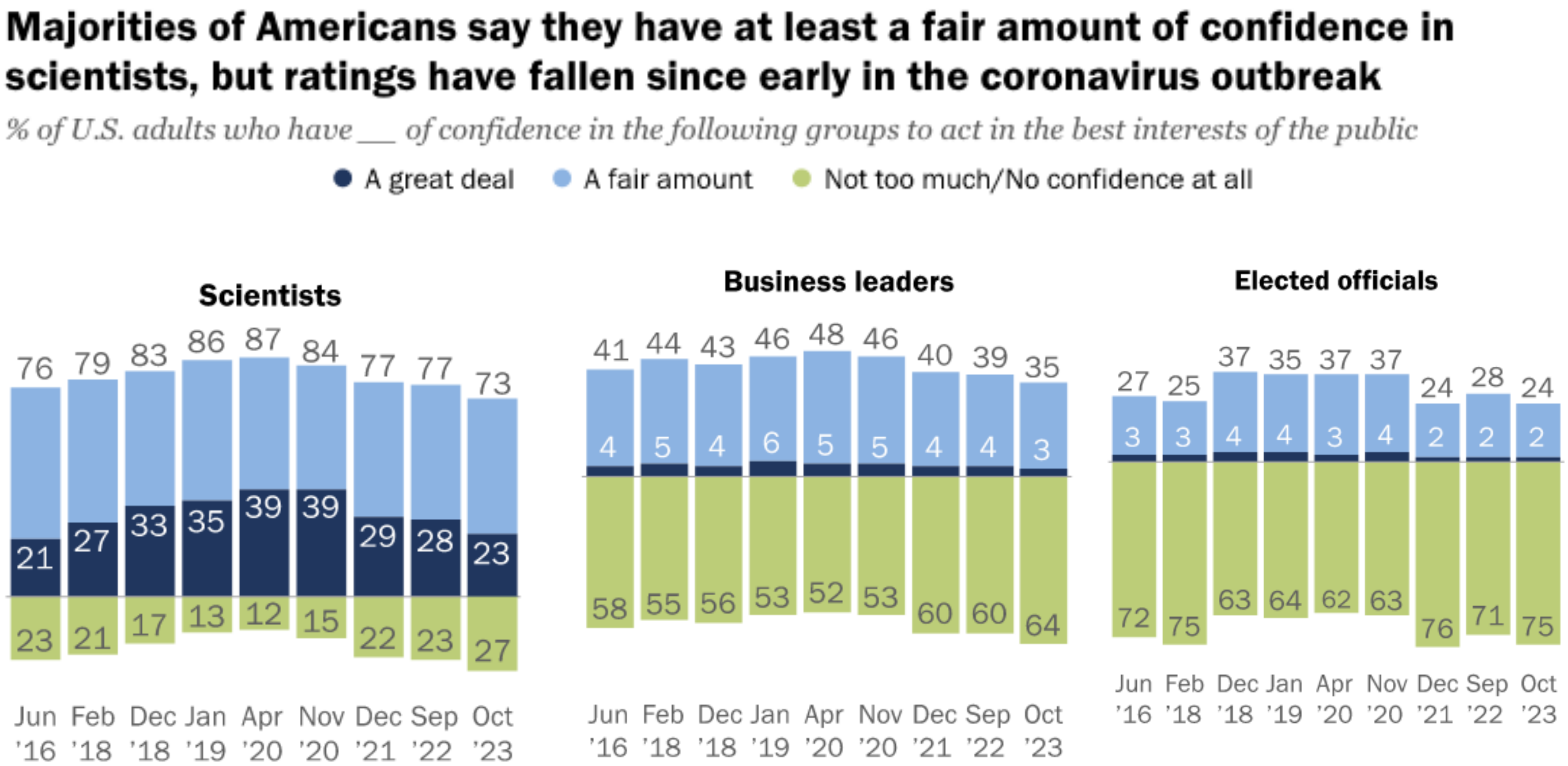
Distrust



Wissenschaftsbarometer – Wissenschaft im Dialog/Kantar

Reif, A., & Guenther, L. (2021). How representative surveys measure public (dis)trust in science: A systematisation and analysis of survey items and open-ended questions. Journal of Trust Research, 11(2), 94–118. https://doi.org/10.1080/21515581.2022.2075373

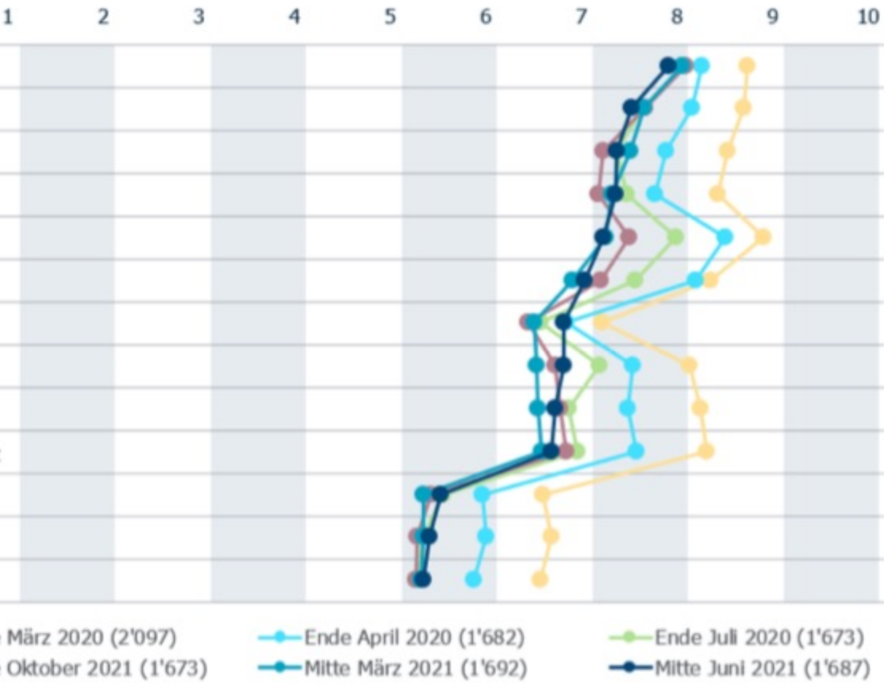
Trends in trust in science



Lupia, A., Allison, D. B., Jamieson, K. H., Heimberg, J., Skipper, M., & Wolf, S. M. (2024). Trends in US public confidence in science and opportunities for progress. Proceedings of the National Academy of Sciences, 121(11), e2319488121. https://doi.org/10.1073/pnas.2319488121

SOTOMO

Abb. 21 Wie hoch ist Ihr Vertrauen in folgende Organisationen und Personengruppen hinsichtlich Informationen zum Coronavirus?



	Mittelwerte					
	Ende März 2020	Ende April 2020	Ende Juli 2020	Ende Oktober 2020	Mitte März 2021	Mitte Juni 2021
Hausärztin/Hausarzt	8.7	8.3	8.1	8.1	8.1	7.9
Pflegefachfrau/-mann	8.7	8.2	7.6	7.7	7.7	7.5
Wissenschaftler/-innen / Forscher/-innen	8.5	7.9	7.4	7.2	7.5	7.4
Apothekerin/Apotheker	8.4	7.8	7.5	7.2	7.3	7.4
Bundesamt für Gesundheit BAG	8.9	8.5	8.0	7.5	7.3	7.2
Bundesrat	8.6	8.2	7.6	7.2	6.9	7.0
Personen aus meinem persönlichen Umfeld	7.2	6.8	6.6	6.4	6.5	6.8
Kanton / kantonale Behörden	8.1	7.5	7.2	6.7	6.5	6.8
Öffentlich-rechtliches Radio der Schweiz	8.2	7.5	6.9	6.8	6.6	6.7
Öffentlich-rechtliche Fernsehsender der Schweiz	8.3	7.6	7.0	6.8	6.6	6.7
Zeitungen, Zeitschriften	6.6	6.0	5.6	5.4	5.4	5.5
Andere Fernsehsender (inkl. Ausland)	6.7	6.0	5.3	5.3	5.4	5.4
Andere Radiosender (inkl. Ausland)	6.6	5.9	5.3	5.3	5.3	5.3

Basis: Anzahl Befragte in Klammern / Skala von «1» (= «Sehr geringes Vertrauen») bis «10» (= «Sehr hohes Vertrauen»)

https://sotomo.ch/site/wp-content/uploads/2021/07/Bericht-Wirkungsmessung-BAG-Juni.pdf

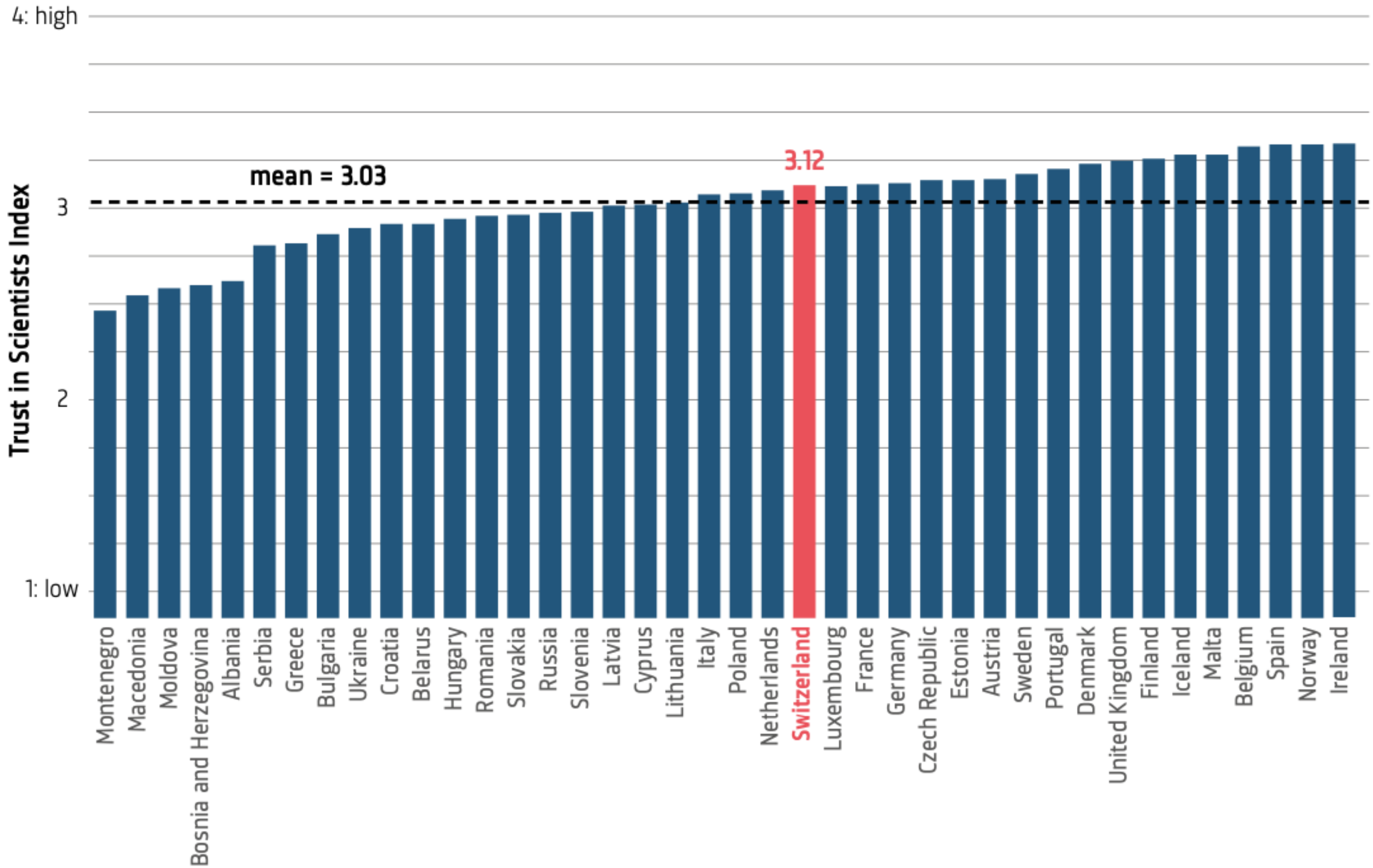


Figure 2: Index of five variables measuring trust in scientists in 40 European countries, showing the average level of trust indicated by survey respondents between 1 ="low" and 4 = "high". Switzerland ranks 18th, above average, among the surveyed countries (Gallup, 2019)

Stewart, I. S. (2024). Advancing disaster risk communications. Earth-Science Reviews, 249, 104677. https://doi.org/10.1016/j.earscirev.2024.104677

Does trust matter?

The meta-analysis by Cologna and Siegrist (2020) examines the association between trust and climate change mitigation and adaptation behaviors.

The results suggest that trust in environmental groups shows the strongest correlation with climate-friendly actions. Trust in scientists also has a significant positive impact, particularly influencing public support for climate policies, though it is somewhat less impactful on individual behavioral changes compared to environmental groups (results not shown). Trust in industry shows the lowest correlation with climate action, likely reflecting public skepticism toward industries that are major contributors to greenhouse gas emissions. Lastly, general and unspecific trust measures show modest correlations, indicating that they have a lesser influence compared to trust in specific groups.

These findings suggest that targeted communication strategies could leverage trusted sources, particularly environmental organizations and scientists, to effectively engage the public in climate mitigation efforts.

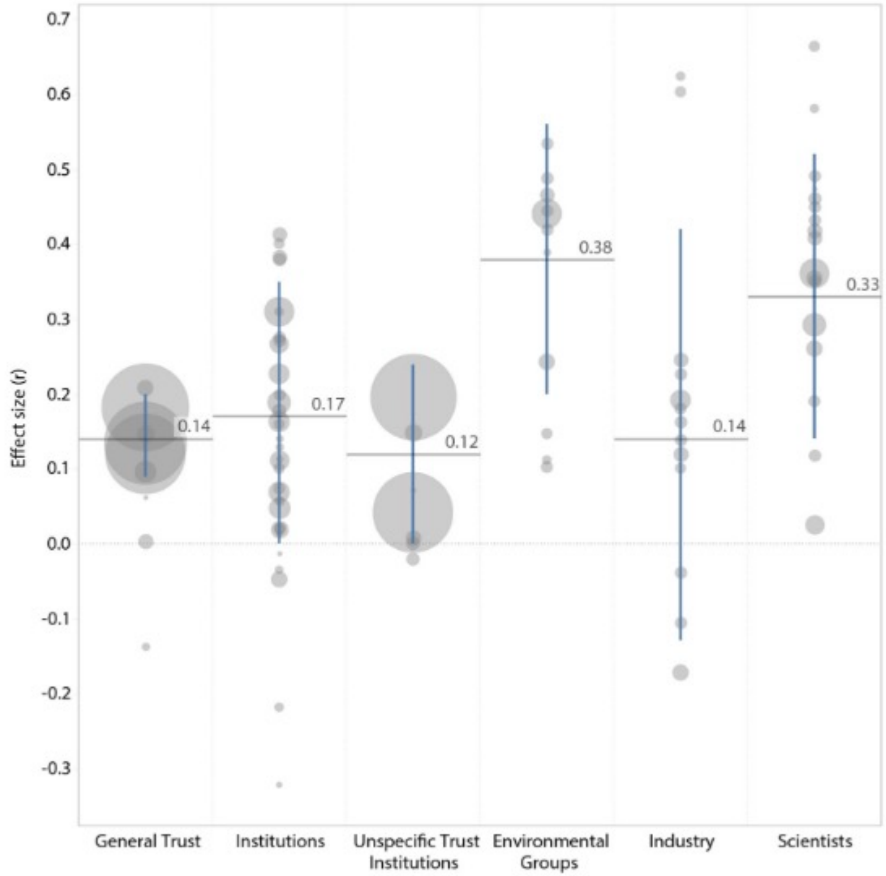


Fig. 2. Mean effect sizes for different trust measures. Forest plot of composite correlation coefficients for trust and climate-friendly behaviours. Error bars represent the 80% credibility intervals of the effect size. Grey circles represent the effect size for included studies. The size of the circle indicates the study sample size.

Cologna, V., & Siegrist, M. (2020). The role of trust for climate change mitigation and adaptation behaviour: A meta-analysis. Journal of Environmental Psychology, 69, 101428. https://doi.org/10.1016/j.jenvp.2020.101428

Summary

- **Scientific Evidence:** Scientific evidence serves as a guide to distinguish true from false claims, and is typically empirical, arising from observation or experimentation. Ideally, evidence is objective, public, and intersubjective, allowing consensus building. Different levels of evidence exist, with a hierarchy from expert opinion to systematic reviews and meta-analyses.

- **Uncertainty**: aleatory uncertainty refers to randomness or unpredictability in the world (e.g., forecasts), epistemic uncertainty arises from limited knowledge or incomplete data (e.g., sampling errors in population estimates); Effective communication of uncertainty involves expressing it clearly, either through direct expressions (quantifiable measures like confidence intervals or verbal likelihoods), or indirect expressions (quality of evidence, such as subjective confidence in a claim). Tools like visual aids, numerical ranges, and verbal explanations can enhance understanding.

- **Trust:** Trust in science is based on its empirical nature and its social, organized structure, which fosters self-correction through skepticism and peer review. The Mertonian norms (universalism, communalism, disinterestedness, organized skepticism) remain key in ensuring that scientific knowledge is shared openly, subjected to critical review, leading to trust. Surveys measuring public trust in science often focus on the macro-level (trust in science as a whole) but overlook micro-level (individual scientists) and meso-level (scientific institutions) aspects. Overall trust in science and scientists is high and remains so, however, there have been recent changes due to societal challenges.