Effective Strategies to Counter Science Denialism in Public

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Prof. Dr. Cornelia Betsch
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Weitere Personen waren an der geistigen Herstellung der vorliegenden Arbeit nicht beteiligt. Insbesondere habe ich nicht die Hilfe einer Promotionsberaterin bzw. eines Promotionsberaters in Anspruch genommen. Dritte haben von mir weder unmittelbar noch mittelbar geldwerte Leistungen für Arbeiten erhalten, die im Zusammenhang mit dem Inhalt der vorgelegten Dissertation stehen.

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Zusammenfassung [German Summary]

Zusammenfassung

Die vorliegende Dissertation beschreibt die Konzeption und empirische Evaluation von Strategien im Umgang mit Wissenschaftsleugnern in öffentlichen Diskussionen. Ziel der Wissenschaftsleugnung (*science denialism*; Diethelm & McKee, 2009; Hansson, 2017; Lewandowsky, Mann, Brown, & Friedman, 2016) ist die Ablehnung eines wissenschaftlichen Konsens um finanzielle, politische oder psychologische Eigeninteressen durchzusetzen (Collomb, 2014; Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016; Oreskes & Conway, 2011). So verbreitete beispielsweise die Tabakindustrie systematisch Falschinformationen, um den wissenschaftlichen Konsens über die tödlichen Folgen des Rauchens in Frage zu stellen und um den Zigarettenkonsum in der Bevölkerung zu sichern (Bates & Rowell, 2004; Bero, 2005; Brandt, 2012; Landman & Glantz, 2009; Ong & Glantz, 2000; Ong & Glantz, 2001; Oreskes & Conway, 2011; Proctor, 2012a, 2012b). Die historische Aufarbeitung des Vorgehens der Tabakindustrie gewährt wesentliche Einblicke über Motivationen, Strukturen und Strategien von Wissenschaftsleugnern im Allgemeinen (Proctor, 2012a; Hansson, 2017). Doch diese Einblicke allein können den Schutz der breiten Öffentlichkeit vor Wissenschaftsleugnern und ihren Falschinformationen nicht sicherstellen. Es bedarf Kommunikationsstrategien, die Fachwissen laienverständlich aufarbeiten und die menschliche Informationssuche, -verarbeitung und -integration berücksichtigen, um die Verbreitung von Falschinformationen zu mindern (Betsch, 2017; Iyengar & Massey, 2019; Lewandowsky, Ecker, & Cook, 2017). In einer Zeit in der die Gesellschaft für deutsche Sprache „postfaktisch“ zum Wort des Jahres 2016 gewählt hat (GfdS, 2016), in einer Zeit in der der amtierende US Präsident die Sinnhaftigkeit von Impfungen und die Notwendigkeit von Maßnahmen zur Klimawandelbekämpfung in Frage stellt (Dyer, 2016; Mann, 2019; Tollefson, 2016), und in einer Zeit in der Wissenschaft in Medien zu bloßen Meinung degradiert wird (Dixon & Clarke, 2013; Petersen, Vincent, & Westerling, 2019), wird die Notwendigkeit solcher Kommunikationsstrategien immer deutlicher (Betsch, 2017; Iyengar & Massey, 2019; Lewandowsky, Ecker, & Cook, 2017; van der Linden, Maibach, Cook, Leiserowitz, & Lewandowsky, 2017). Eine Wissenschaft, die solche Kommunikationsstrategien gestaltet und empirisch evaluiert ist die Psychologie.

Bisherige psychologische Strategien zielen darauf ab, entweder die Öffentlichkeit vor Falschinformation zu warnen und Individuen mit Gegenargumenten auszurüsten bevor die Falschinformation Schaden anrichten kann (*inoculation*: McGuire, 1961a, 1961b; van der Linden et al., 2017), oder die Falschinformation zu korrigieren nachdem sie sich bereits als

Überzeugung in den Köpfen der Öffentlichkeit manifestiert hat (*debunking*: Chan, Jones, Hall Jamieson, & Albarracín, 2017; Cook & Lewandowsky, 2011; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). Debunking-Strategien sind effektive Interventionen zur Bekämpfung von Falschinformationen (Chan et al., 2017), die jedoch aufwendig konzipierte Informationsmaterialien benötigen, denn Individuen neigen dazu ihre Überzeugungen nicht leichtfertig aufzugeben, selbst wenn diese sich als fehlerhaft erweisen (Cook & Lewandowsky, 2011). Zudem können unbedachte Debunking-Strategien im schlimmsten Fall die Falschinformation sogar verstärken, anstatt sie zu eliminieren (Nyhan & Reifler, 2010; Schwarz, Sanna, Skurnik, & Yoon, 2007).

Inoculation Strategien sind effektive Präventionsmaßnahmen zur Bekämpfung von Falschinformationen (Banas & Rains, 2010), die jedoch an zwei praktische Bedingungen gebunden sind. Erstens, die sogenannten Impfungen gegen *fake-news* können nur effektiv gestaltet werden, wenn vorab bekannt ist, gegen welche Falschinformation geimpft werden soll, das heißt, welche Falschinformation zukünftig eine Bedrohung für die Bevölkerung darstellt (Roozenbeek & van der Linden, 2019). Fehlt dieses Wissen, dann bergen Inoculation-Strategien das Risiko mehr Schaden anzurichten als abzuwenden, denn im schlimmsten Fall ist die Impfung selbst der einzige Berührungspunkt der Bevölkerung mit der Falschinformation. Zweitens, Präventionsmaßnahmen müssen die Öffentlichkeit vor dem Virus, das heißt, vor der Falschinformation, erreichen, um ihre Schutzfunktion zu entfalten. Um dies sicherzustellen wurden Inoculation-Strategien bereits in Schulprogramme integriert (Nsangi et al., 2017) oder ansprechend gestaltete Spiele konzipiert, die die Öffentlichkeit anregen soll sich mit den Inhalten von Inoculation-Strategien zu beschäftigen (Roozenbeek & van der Linden, 2019). Dennoch, der flächendeckende Zugang zu Impfungen gegen fake-news bleibt eine Herausforderung für die effektive Implementierung von Inoculation.

Die vorliegende Dissertation beschreibt die Konzipierung und Evaluation einer dritten Möglichkeit dem Problem der Wissenschaftsleugnung zu begegnen. Die dritte Möglichkeit, das sogenannte *rebuttal* (Schmid & Betsch, 2019), basiert auf der Idee Falschinformationen genau in dem Moment als irreführend zu entlarven in dem sie im Begriff sind eine breite Öffentlichkeit zu erreichen. Rebuttal bedeutet, dass Fürsprecher von Wissenschaft den Wissenschaftsleugnern in öffentlichen Diskussionsformaten entgegentreten und im optimalen Fall von Journalisten durch flankierende Strategien (*weight-of-evidence strategies*; Schmid, Schwarzer & Betsch, 2019) unterstützt werden. Im Gegensatz zu Debunking-Strategien widerlegen Fürsprecher von Wissenschaft mit Rebuttal-Strategien Falschinformationen bevor diese sich als Überzeugung manifestieren. Im Gegensatz zu Inoculation-Strategien, erreicht ein Fürsprecher von Wissenschaft mit Rebuttal-Strategien die Öffentlichkeit immer dann, wenn sie auch mit der Falschinformation konfrontiert wird und risikobehaftete Spekulationen über den nächsten möglichen Mythos entfallen. Während zahlreiche empirische Evaluationsstudien und Handreichungen zum Einsatz von Debunking- und Inoculation-Strategien publiziert wurden (Chan et al., 2017; Cook & Lewandowsky, 2011; Cook, Maibach, van der Linden, & Lewandowsky, 2018; Lewandowsky et al., 2012; van der Linden et al., 2017), waren evidenzbasierte Ansätze zu Rebuttal-Strategien, bisher rar (Betsch, 2017; WHO, 2016).

Folglich befasst sich diese Dissertation mit der Konzeption und empirischen Evaluation von Strategien zum Umgang mit Wissenschaftsleugnern in öffentlichen Diskussionen. Dies beinhaltet sowohl die Konzeption und Evaluation des Rebuttal-Ansatzes als auch möglicher flankierender Strategien (*weight-of-evidence strategies*; Schmid, Schwarzer & Betsch, 2019).

Rebuttal und Weight-of-Evidence Strategien sind dabei kein Ersatz für Debunking und Inoculation Strategien, sondern vielmehr ein ergänzendes Element, oder eine „second-order line of defense“ (van der Linden, 2019, p. 890) im Kampf gegen Falschinformation.

Die Dissertation ist in drei Forschungsartikel unterteilt. Die Artikel geben die Entwicklung und Evaluation von Strategien im Umgang mit Wissenschaftsleugnern in öffentlichen Diskussionen wie folgt wieder:

Artikel 1: Strategiekonzeption zum Umgang mit Wissenschaftsleugnern in öffentlichen Diskussionen.

Artikel 2: Empirische Evaluation der Rebuttal-Strategien aus Artikel 1.

Artikel 3: Konzeption und empirische Evaluation von flankierenden Strategien für Rebuttal.

Artikel 1: Kommentar zum Leitfaden der Weltgesundheitsorganisation „How to respond to vocal vaccine deniers in public".

Schmid, P., MacDonald, N. E., Habersaat, K., & Butler, R. (2018). Commentary to: How to respond to vocal vaccine deniers in public. *Vaccine*, 36, 196-198. doi: 10.1016/j.vaccine.2016.09.065

Der erste Artikel legt die Entwicklung und Struktur des Leitliniendokuments „How to respond to vocal vaccine deniers in public" der Weltgesundheitsorganisation (WHO, 2016) dar. Das Leitliniendokument wurde von Prof. Dr. Noni Macdonald, Katrine Habersaat, Robb Butler und mir unter der Schirmherrschaft der WHO verfasst, um Sprecher von Gesundheitsbehörden im Umgang mit Impfgegnern in der Öffentlichkeit zu unterstützen. Das Leitliniendokument beschreibt erstmalig die Widerlegung (eng. rebuttal) von Wissenschaftsleugnern in öffentlichen Diskussionen als Zweikomponentenstrategie.
In öffentlichen Debatten werden Botschaften von Wissenschaftsleugnern oft durch Rechtfertigungen untermauert. Das heißt, aus der bloßen Falschinformation (Komponente 1) wird durch Hinzunahme von rhetorischen Techniken (Komponente 2) ein irreführendes Argument. Folglich basiert die Zweikomponentenstrategie auf der Idee falsche Fakteninformation zu korrigieren (Komponente 1: *topic rebuttal*) und zudem irreführende rhetorische Techniken der Argumente offenzulegen (Komponente 2: *technique rebuttal*). Durch die Zweikomponentenstrategie werden mehrere Schwachpunkte in der Argumentation von Wissenschaftsleugnern erkennbar und zum Schutz der Öffentlichkeit aufgedeckt. Gerade das *technique rebuttal* birgt für Wissenschaftskommunikation enorme ökonomische Vorteile, da Wissenschaftsleugner unabhängig von der inhaltlichen Domäne (bspw. das Leugnen der Effektivität von Impfungen, das Leugnen des menschengemachten Klimawandels) auf ein und dasselbe Arsenal an rhetorischen Mitteln zurückgreifen. Diese Mittel sind: Falsche Experten zitieren, Verschwörungstheorien postulieren, nicht-repräsentative Befunde selektieren, Fakten und Zitate verfälschen und unmögliche Erwartungen an die Wissenschaft stellen (Diethelm & McKee, 2009). Durch das Erkennen und Offenlegen dieser fünf rhetorischen Techniken erlernen Fürsprechern von Wissenschaft das Handwerk universell auf Wissenschaftsleugner in öffentlichen Diskussionen reagieren zu können.

Das Leitliniendokument basiert auf Erkenntnissen von Literaturrecherchen und Experteninterviews aus den Bereichen Psychologie, Public-Health, Impfstoffentwicklung und Kommunikationswissenschaften. Die Zweikomponentenstrategie wurde von den Mitgliedern der Europäischen Fachgruppe für technische Beratung im Bereich Immunisierung (ETAGE) auf ihrer Jahrestagung (2015; Kopenhagen, Dänemark) und von Teilnehmern des

Europäischen WHO-Regionaltreffens von Managern nationaler Immunisierungsprogramme von 53 WHO-Mitgliedsstaaten (2015; Antwerpen, Belgien) begutachtet. Darüber hinaus wurde die Praktikabilität der Strategie von Impfmanagern aus 17 verschiedenen Mitgliedstaaten in fünf technischen Konsultationen zum Umgang mit Impfgegnern in der Öffentlichkeit erprobt und diskutiert (2016: Belgrad, Serbien; 2016: Kopenhagen, Dänemark; 2017: Kopenhagen, Dänemark; 2017: Stuttgart, Deutschland; 2018: Berlin, Deutschland).

Der Kommentar zum Leitliniendokument fasst die wesentlichen Aspekte der Zweikomponentenstrategie zusammen und gilt als konzeptuelle Vorarbeit für die empirischen Evaluationsstudien der folgenden zwei Artikel.

Der Kommentar ist im wissenschaftlichen Fachjournal *Vaccine* erschienen. Das zugehörige Leitliniendokument ist öffentlich zugänglich (Abbildung 1).

Abbildung 1: QR-Code zur WHO Leitlinie (WHO, 2016).

Artikel 2: Wirksame Strategien zur Widerlegung von Wissenschaftsleugnung in öffentlichen Diskussionen.

Schmid, P., Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nat Hum Behav*, 3, 931–939. doi:10.1038/s41562-019-0632-4

Der zweite Artikel beschreibt die Ergebnisse von sechs psychologischen Experimenten, mit denen die Effektivität der Zweikomponentenstrategie des ersten Artikels empirisch überprüft wurde. Die insgesamt 1.773 Teilnehmer lasen oder hörten in den Experimenten eine fiktive öffentliche Diskussion zwischen Wissenschaftsleugnern und Fürsprechern von Wissenschaft. Thema der Diskussion war in jedem Experiment die Sinnhaftigkeit einer wissenschaftlich fundierten Maßnahme (bspw. Impfungen). Die Teilnehmer wurden zufällig einer von vier Experimentalbedingungen zugeteilt. Entweder lasen oder hörten die Teilnehmer nur die Argumente der Wissenschaftsleugner (Bedingung 1), oder zusätzlich Gegenargumente der Fürsprecher von Wissenschaft im Sinne des topic rebuttal (Bedingung 2), des technique rebuttal (Bedingung 3) oder einer Kombination aus beiden Ansätzen (Bedingung 4). Die Teilnehmer gaben vor und nach der Diskussion ihre Einstellung gegenüber der wissenschaftlich fundierten Maßnahme (bspw. Impfungen) und ihre Bereitschaft die Maßnahme durchzuführen an (bspw. Bereitschaft sich impfen zu lassen). Die mittlere Änderung der Einstellung und Handlungsbereitschaft der Teilnehmer ermöglichte die Ermittlung des Einflusses der Wissenschaftsleugner. Der Unterschied im Einfluss der Wissenschaftsleugner zwischen den vier Bedingungen ermöglichte die Ermittlung der Effektivität der Zweikomponentenstrategie im Kampf gegen Falschinformationen. Die Resultate zeigen:

Resultat 1: Öffentliche Diskussionen mit Wissenschaftsleugnern mindern positive Einstellungen gegenüber wissenschaftlich-fundierten Maßnahmen (bspw. Impfungen) und senken die Bereitschaft diese Maßnahmen auszuführen.

Resultat 2: Beide Komponenten der Zweikomponentenstrategie können den Einfluss von Wissenschaftsleugnern in öffentlichen Diskussionen reduzieren. Das heißt auch, dass der Wissenschaftsleugner den größten Einfluss hat, wenn kein Fürsprecher von Wissenschaft an der öffentlichen Diskussion teilnimmt.

Resultat 3: Die Experimente zeigen nicht, dass der Einsatz der Kombination der zwei Komponenten den Einfluss der Wissenschaftsleugner stärker minimiert als der Einsatz der jeweiligen Einzelkomponenten. Das heißt auch, dass effektive Gegenmaßnahmen nicht notwendigerweise komplex sein müssen.

Resultat 4: Die Experimente zeigen nicht, dass die Zweikomponentenstrategie bei Individuen mit besonderer Anfälligkeit für Wissenschaftsleugnung (bspw. U.S. Republikaner, Individuen mit geringerem Grundvertrauen in Impfungen) zu Abwehrreaktionen führt. Das heißt auch, dass Rebuttal-Strategien universell einsetzbar sind.

Der Forschungsartikel ist der erste empirische Test für die Wirksamkeit des Zweikomponentenansatzes im Kampf gegen Wissenschaftsleugnung und Falschinformation. Der Forschungsartikel ist im wissenschaftlichen Fachjournal *Nature Human Behaviour* erschienen.

Artikel 3: Weight-of-Evidence Strategien zur Widerlegung von Wissenschaftsleugnung in öffentlichen Diskussionen.

Schmid, P., Schwarzer, M. Betsch, C. (2019). Weight-of-Evidence Strategies to Counter Science Denialism in Public Discussions. *Manuscript submitted for publication.*

Die Öffentlichkeit in Europa und Amerika ist der Auffassung, dass Journalisten dafür verantwortlich sind, die Verbreitung von Falschinformationen in einem postfaktischen Zeitalter zu bekämpfen (EC, 2018; PRC, 2019). Angesichts der Rolle der Medien als Mitverantwortliche dieses Zeitalters (Dixon & Clarke, 2013; Petersen, Vincent, & Westerling, 2019) erscheint die öffentliche Erwartungshaltung an Journalisten wenig überraschend. In Bezug auf Rebuttal-Strategien stellt sich folglich die Frage was Journalisten tun können, um Fürsprecher von Wissenschaft in öffentlichen Diskussionen mit Wissenschaftsleugnern zu unterstützen.

Der dritte Artikel beschreibt die Konzeption und empirische Evaluation von flankierenden psychologischen Strategien, die von Journalisten in öffentlichen Diskussionen implementiert werden können. Ziel dieser Strategien ist es den Einfluss der Wissenschaftsleugner zu minimieren indem Journalisten jeder Position in der öffentlichen Diskussion eine Gewichtung zuweisen, die der Menge der Evidenz entspricht, die diese Position tatsächlich stützt (*weight-of-evidence strategies*: Dunwoody, 2005; Kohl et al., 2016). Diese weight-of-evidence Strategien stehen in direktem Kontrast zu den häufig irreführend ausgeglichenen Medienformaten (*false-balance*: Dixon & Clarke, 2013; Petersen, Vincent, & Westerling, 2019), bei denen Wissenschaftsleugner und Fürsprecher von Wissenschaft wie gleichwertige Kontrahenten dargestellt werden, deren Positionen durch ein gleiches Maß an Evidenz gestützt zu sein scheint. Journalisten können diese verzerrten Darstellungen mit Gewichtungen durchbrechen, indem sie beispielsweise zu öffentlichen

Diskussionen mehr Fürsprecher von Wissenschaft als Wissenschaftsleugner einladen (*outnumbering*), oder sie können Warnungen implementieren, die darauf hinweisen, dass die relative Anzahl der Diskussionsteilnehmer kein Maß der tatsächlichen Evidenzlange ist (*forewarning*). Beide Strategien bewahren die Freiheit, gegensätzliche Meinungen und widersprüchliche wissenschaftliche Ansichten in öffentlichen Diskussionen zu teilen, das heißt, sie bewahren den demokratischen Diskurs.

Der dritte Artikel umfasst neben der Konzeption dieser zwei flankierenden Strategien drei psychologischen Experimente, mit denen die Effektivität von outnumbering und forewarning empirisch überprüft wurde. Die insgesamt 887 Teilnehmer hörten in den Experimenten eine fiktive öffentliche Diskussion zwischen Wissenschaftsleugnern und Fürsprechern von Wissenschaft. Thema der Diskussion war in jedem Experiment die Sinnhaftigkeit einer empfohlenen Impfung. Die Teilnehmer wurden zufällig entweder den jeweiligen Kontrollbedingungen (kein outnumbering, kein forewarning) oder den jeweiligen Experimentalbedingungen (outnumbering, forewarning) zugeordnet. Die Teilnehmer gaben vor und nach der Diskussion ihre Einstellung gegenüber der Impfung und ihre Bereitschaft sich impfen zu lassen an. Die mittlere Änderung der Einstellung und Handlungsbereitschaft der Teilnehmer ermöglichte die Ermittlung des Einflusses der Wissenschaftsleugner. Der Unterschied im Einfluss der Wissenschaftsleugner zwischen den Kontrollbedingungen und den Experimentalbedingungen ermöglichte die Ermittlung der Effektivität der weight-of-evidence Strategien im Kampf gegen Falschinformationen. Die Resultate zeigen:

Resultat 1: Öffentliche Diskussionen mit Wissenschaftsleugnern mindern positive Einstellungen gegenüber wissenschaftlich-fundierten Maßnahmen (bspw. Impfungen) und senken die Bereitschaft diese Maßnahmen auszuführen.

Resultat 2: Der Einsatz von Vorabwarnungen (forewarning) über verzerrte Berichterstattungen in öffentlichen Diskussionen kann den Einfluss von Wissenschaftsleugnern reduzieren.

Resultat 3: Es gibt keine Evidenz, dass das Einladen von mehr Fürsprechern als Wissenschaftsleugner (outnumbering) den Einfluss von Wissenschaftsleugnern in öffentlichen Diskussionen reduziert.

Der Forschungsartikel ist der erste empirische Test für die Wirksamkeit von Weight-of-Evidence Strategien im Kampf gegen Falschinformation in öffentlichen Diskussionen mit Wissenschaftsleugnern. Der Forschungsartikel ist zur wissenschaftlichen Publikation vorbereitet und befindet sich zur Zeit im Bewertungsprozess (peer-review).

Literaturverzeichnis

Banas, J. A., & Rains, S. A. (2010). A meta-analysis of research on inoculation theory. *Communication Monographs*, *77*(3), 281–311. https://doi.org/10.1080/03637751003758193

Bates, C., & Rowell, A. (2004). *Tobacco Explained - The truth about the tobacco industry...in its own words*. UC San Francisco. Retrieved from https://www.who.int/tobacco/media/en/TobaccoExplained.pdf

Bero, L. A. (2005). Tobacco industry manipulation of research. *Public Health Reports*, *120*(2), 200–208. https://doi.org/10.1177/003335490512000215

Betsch, C. (2017). Advocating for vaccination in a climate of science denial. *Nature Microbiology*, *2*. https://doi.org/10.1038/nmicrobiol.2017.106

Brandt, A. M. (2012, January). Inventing conflicts of interest: A history of Tobacco industry tactics. *American Journal of Public Health*. American Public Health Association. https://doi.org/10.2105/AJPH.2011.300292

Chan, M. pui S., Jones, C. R., Hall Jamieson, K., & Albarracín, D. (2017). Debunking: A Meta-Analysis of the Psychological Efficacy of Messages Countering Misinformation. *Psychological Science*. https://doi.org/10.1177/0956797617714579

Collomb, J.D. (2014). The Ideology of Climate Change Denial in the United States. *European Journal of American Studies*, *9*(1). https://doi.org/10.4000/ejas.10305

Cook, J., & Lewandowsky, S. (2011). *The debunking handbook*. https://doi.org/10.1017/CBO9781107415324.004

Cook, J., Maibach, E., van der Linden, S., & Lewandowsky, S. (2018). *The Consensus Handbook climate change is important*. https://doi.org/10.1016/j.vacuum.2008.03.035

Diethelm, P., & McKee, M. (2009, October 16). Denialism: What is it and how should scientists respond? *European Journal of Public Health*. Oxford University Press. https://doi.org/10.1093/eurpub/ckn139

Dixon, G. N., & Clarke, C. E. (2013). Heightening Uncertainty Around Certain Science: Media Coverage, False Balance, and the Autism-Vaccine Controversy. *Science Communication*, *35*(3), 358–382. https://doi.org/10.1177/1075547012458290

Dunwoody, S. (2005). Weight-of-Evidence Reporting: What Is It? Why Use It? *Nieman Reports*, *59*(4), 89–91. Retrieved from https://niemanreports.org/articles/weight-of-evidence-reporting-what-is-it-why-use-it/

Dyer, O. (2016, December 5). Andrew Wakefield calls Trump “on our side” over vaccines after meeting. *BMJ (Clinical Research Ed.)*. British Medical Journal Publishing Group. https://doi.org/10.1136/bmj.i6545

European Commission. (2018). *Eurobarometer on fake news and online disinformation*. Available online: https://ec.europa.eu/digital-single-market/en/news/final-results-eurobarometer-fake-news-and-online-disinformation

Gesellschaft für deutsche Sprache. (2016). GfdS wählt postfaktisch zum Wort des Jahres 2016. Retrieved from https://gfds.de/wort-des-jahres-2016/

Hansson, S. O. (2017). Science denial as a form of pseudoscience. *Studies in History and Philosophy of Science Part A*, *63*, 39–47. https://doi.org/10.1016/j.shpsa.2017.05.002

Hornsey, M. J., & Fielding, K. S. (2017). Attitude roots and jiu jitsu persuasion: Understanding and overcoming the motivated rejection of science. *American Psychologist*, *72*(5), 459–473. https://doi.org/10.1037/a0040437

Iyengar, S., & Massey, D. S. (2019). Scientific communication in a post-truth society. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(16), 7656–7661. https://doi.org/10.1073/pnas.1805868115

Kohl, P. A., Kim, S. Y., Peng, Y., Akin, H., Koh, E. J., Howell, A., & Dunwoody, S. (2016). The influence of weight-of-evidence strategies on audience perceptions of (un)certainty when media cover contested science. *Public Understanding of Science*, *25*(8), 976–991. https://doi.org/10.1177/0963662515615087

Landman, A., & Glantz, S. A. (2009). Tobacco industry efforts to undermine policy-relevant research. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.2007.130740

Lewandowsky, S., Ecker, U. K. H., & Cook, J. (2017). Beyond Misinformation: Understanding and Coping with the “Post-Truth” Era. *Journal of Applied Research in Memory and Cognition*, *6*(4), 353–369. https://doi.org/10.1016/j.jarmac.2017.07.008

Lewandowsky, S., Ecker, U. K. H., Seifert, C. M., Schwarz, N., & Cook, J. (2012). Misinformation and Its Correction: Continued Influence and Successful Debiasing. *Psychological Science in the Public Interest, Supplement*, *13*(3), 106–131. https://doi.org/10.1177/1529100612451018

Lewandowsky, S., Mann, M. E., Brown, N. J. L., & Friedman, H. (2016). Science and the public: Debate, denial, and skepticism. *Journal of Social and Political Psychology*, *4*(2), 537–553. https://doi.org/10.5964/jspp.v4i2.604

Lewandowsky, S., & Oberauer, K. (2016). Motivated Rejection of Science. *Current Directions in Psychological Science*, *25*(4), 217–222. https://doi.org/10.1177/0963721416654436

Mann, B. W. (2019). Autism Narratives in Media Coverage of the MMR Vaccine-Autism Controversy under a Crip Futurism Framework. *Health Communication*, *34*(9), 984–990. https://doi.org/10.1080/10410236.2018.1449071

McGuire, W. J. (1961a). Resistance to persuasion conferred by active and passive prior refutation of the same and alternative counterarguments. *Journal of Abnormal and Social Psychology*, *63*(2), 326–332. https://doi.org/10.1037/h0048344

McGuire, W. J. (1961b). The Effectiveness of Supportive and Refutational Defenses in Immunizing and Restoring Beliefs Against Persuasion. *Sociometry*, *24*(2), 184. https://doi.org/10.2307/2786067

Nsangi, A., Semakula, D., Oxman, A. D., Austvoll-Dahlgren, A., Oxman, M., Rosenbaum, S., … Sewankambo, N. K. (2017). Effects of the Informed Health Choices primary school intervention on the ability of children in Uganda to assess the reliability of claims about treatment effects: a cluster-randomised controlled trial. *The Lancet*, *390*(10092), 374–388. https://doi.org/10.1016/S0140-6736(17)31226-6

Nyhan, B., & Reifler, J. (2010). When corrections fail: The persistence of political misperceptions. *Political Behavior*, *32*(2), 303–330. https://doi.org/10.1007/s11109-010-9112-2

Ong, E., & Glantz, S. (2000). Tobacco Industry Effort Subverting the International Agency for Research on Cancer’s Secondhand Smoke Study. *Lancet*, *355*, 1253–1259. Retrieved from https://www.sciencedirect.com/science/article/pii/S0140673600020985

Ong, E., & Glantz, S. A. (2001, November). Constructing “sound science” and “good epidemiology”: Tobacco, lawyers, and public relations firms. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.91.11.1749

Oreskes, N., & Conway, E. (2011). Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming.

Petersen, A. M., Vincent, E. M., & Westerling, A. L. (2019). Discrepancy in scientific authority and media visibility of climate change scientists and contrarians. *Nature Communications*, *10*(1), 3502. https://doi.org/10.1038/s41467-019-09959-4

Pew Research Centre. (2019). *Many Americans Say Made-Up News Is a Critical Problem That Needs To Be Fixed*. Available online: https://www.journalism.org/2019/06/05/many-americans-say-made-up-news-is-a-critical-problem-that-needs-to-be-fixed/

Proctor, R. N. (2012a). *Golden holocaust: Origins of the cigarette catastrophe and the case for abolition*. *Golden Holocaust: Origins of the Cigarette Catastrophe and the Case for Abolition*. University of California Press. https://doi.org/10.1136/medhum-2012-010202

Proctor, R. N. (2012b). The history of the discovery of the cigaretteelung cancer link: Evidentiary traditions, corporate denial, global toll. *Tobacco Control*, *21*(2), 87–91. https://doi.org/10.1136/tobaccocontrol-2011-050338

Roozenbeek, J., & van der Linden, S. (2019). Fake news game confers psychological resistance against online misinformation. *Palgrave Communications*, *5(1)*(12). Retrieved from https://www.nature.com/articles/s41599-019-0279-9

Schwarz, N., Sanna, L. J., Skurnik, I., & Yoon, C. (2007). Metacognitive Experiences and the Intricacies of Setting People Straight: Implications for Debiasing and Public Information Campaigns. *Advances in Experimental Social Psychology*. https://doi.org/10.1016/S0065-2601(06)39003-X

Tollefson, J. (2016, July 26). Trump vs Clinton: Worlds apart on science. *Nature*. https://doi.org/10.1038/535473a

van der Linden, S. (2019). Countering science denial. *Nature Human Behaviour*. https://doi.org/10.1038/s41562-019-0631-5

van der Linden, S., Maibach, E., Cook, J., Leiserowitz, A., & Lewandowsky, S. (2017). Inoculating against misinformation. *Science*, *358*(6367), 1141.2-1142. https://doi.org/10.1126/science.aar4533

World Health Organization. (2016). *Best practice guidance: How to respond to vocal vaccine deniers in public*. Copenhagen: World Health Organization,. Retrieved from http://www.euro.who.int/de/health-topics/disease-prevention/vaccines-and-immunization/publications/2016/best-practice-guidance-how-to-respond-to-vocal-vaccine-deniers-in-public-2016

Overview

Overview

This dissertation introduces and then evaluates effective strategies for countering science denialism in the public sphere. The dissertation is separated into three consecutive research articles.

Article 1

Schmid, P., MacDonald, N. E., Habersaat, K., & Butler, R. (2018). Commentary to: How to respond to vocal vaccine deniers in public. *Vaccine*, *36*, 196–198. doi:10.1016/j.vaccine.2016.09.065

Article 1 presents a commentary that explains the structure and development of a best practice guidance document that Prof. Dr Noni Macdonald, Katrine Habersaat, Robb Butler and I developed under the auspices of the World Health Organization Regional Office for Europe; the goal of the document is to support health authority spokespersons in preparing for public discussions with vaccine deniers. Furthermore, the commentary introduces the guidance document's key element, that is, a new approach for how to respond to science denialism messages in public.

The initial approach was reviewed and discussed by the members of the European Technical Advisory Group of Experts on Immunization (ETAGE) at their annual meeting (2015; Copenhagen, Denmark) and by the participants of the WHO European Regional Meeting of National Immunization Programme Managers (2015; Antwerp, Belgium), which included the immunisation programme managers of the 53 member states of the WHO European Region. Furthermore, its practicability was evaluated by national immunisation managers of 17 different member states during five technical consultations on addressing vaccination opposition (2016: Belgrade, Serbia; 2016: Copenhagen, Denmark; 2017: Copenhagen, Denmark; 2017: Stuttgart, Germany; 2018: Berlin, Germany). The commentary was published in the scientific journal *Vaccine*.

Key Findings

- Advocates for science should inform the general public by providing their messages and should not aim to convince the vaccine denier in public discussions.

- Advocates for science should rebut arguments of vaccination denialism by correcting the misinformation content (i.e., topic rebuttal) and by unmasking the techniques used by vaccine deniers (i.e., technique rebuttal).

Article 2

Schmid, P., & Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nature Human Behaviour*, *3*, 931–939. doi:10.1038/s41562-019-0632-4

Article 2 presents the first empirical evaluation of the newly introduced rebuttal approach (see Article 1) on how to respond to science denialism messages in public. Thus, in this article, we evaluated whether correcting the misinformation content (i.e., topic rebuttal) or unmasking the techniques used by science deniers (i.e., technique rebuttal) can mitigate the damage of denialism and whether a combination of both rebuttals are more effective than single strategies alone. Furthermore, we explored whether rebuttal backfires in groups vulnerable to messages of denialism (e.g., US conservatives). We conducted six preregistered online experiments that focused specifically on vaccination and climate change denialism. The results of the experiments were presented and discussed at the International Meeting of the Psychonomic Society (2018; Amsterdam, Netherlands), the Risk and Uncertainty Conference (RUC, 2018; Amsterdam, Netherlands), the Congress of the Germany Psychological Society (2018; Frankfurt, Germany) and the Congress of Health Psychology (2017; Siegen, Germany). The experiments were published as a research article in the scientific journal *Nature Human Behaviour*.

Key Findings

- Science deniers can damage an audience's attitude towards behaviours favoured by science and the intentions to perform these behaviours. The damage is maximised when no advocate for science is present.
- Topic rebuttal or technique rebuttal can mitigate the damage from denialism.
- We found no evidence that the combination of topic and technique rebuttals is more effective than single strategies alone.
- We found no evidence that topic and technique rebuttals will backfire when used for vulnerable groups (e.g., US conservatives).

Article 3

Schmid, P., Schwarzer, M., & Betsch, C. (2019). Weight-of-evidence strategies to counter science denialism in public discussions. *Manuscript submitted for publication.*

Article 3 introduces and evaluates strategies that journalists can use to mitigate damage from science denialism in public discussions. In public discussions, journalists can support advocates of science by inviting more advocates than science deniers (i.e., outnumbering), or they can use warnings about the false-balance effect prior to the discussion (i.e., forewarning). The effectiveness of the strategies was tested in three preregistered laboratory experiments that focused specifically on vaccination denialism. The study's results were presented and discussed at the Conference of the European Health Psychology Society (2019; Dubrovnik, Croatia) and at the Conference of the European Cognitive Psychology Society (2019; Tenerife, Canary Islands). The experiments have been prepared for publication and are currently under review.

Key Findings

- We found no evidence that inviting more advocates for science than science deniers mitigates damage from denialism.
- Forewarnings about the false-balance effect can mitigate the damage from denialism.

Research Approach

Article 2 and Article 3 of the current dissertation present quantitative experimental research that aimed at empirically evaluating the effectiveness of strategies to counter science denialism in public discussions. All experiments were randomised control trials. That is, all the participants were randomly allocated to different experimental groups, and the effectiveness of the different strategies in countering science denialism (treatment) was assessed compared with a control group (no treatment). The experiments were either conducted online (Experiments 1–6; Table 1) or in laboratory facilities at the University of Erfurt and the RWTH Aachen (Experiments 7–9; Table 1). All experiments measured the same classic primary outcome of persuasion research, that is, participants' change in attitude towards a behaviour and participants' change in intention to perform the behaviour after they encountered a persuasive attempt. A basic premise of all the experiments is that science denialism messages have a persuasive, damaging effect on individuals' attitudes towards a behaviour favoured by science and the intention to perform this behaviour (e.g., vaccination).

The different strategies used to counter science denialism were thus evaluated based on their effectiveness to mitigate the damage from science denialism messages. Several psychological variables of the participants were measured, along with the primary outcomes. Individuals' age, gender, education, domain specific knowledge and relevance of different information sources, were measured in all the experiments. In addition, potential psychological moderators (e.g., individuals' issue involvement) and mediators (e.g., individuals' perceived argument strength) of the effectiveness of the strategies to counter science denialism were assessed.

Samples

In sum, nine experiments with 2,660 human adult participants were conducted in accordance with the German Psychological Association's guidelines. All participants provided written informed consent to use and share their data for scientific purposes. Their identities were anonymised. The research was negligible-risk research, with no foreseeable risk of harm or discomfort other than potential inconvenience. All participants were free to quit the experiments at any time without any consequences.

Article 2 introduces a new communication approach to counter science denialism. Thus, to test the robustness of findings, we replicated the initial Experiment 1 in samples with varying demographic characteristics (student samples and general public), with varying political ideologies (US Republican and Democrats) and with varying languages (German and English). Moreover, we varied the subject domain of the experiments (vaccination and climate change; Table 1).

Table 1. Overview of experiments included in the dissertation. The details reveal the type of experiment, a short description of the samples, their sizes and the reason for the sample selection.

	Experiment Nr.	Type	Research sample	Reason for sample selection	Sample size N
	1	Online: quantitative experimental	University of Erfurt undergraduates	Pilot experiment	112
	2	Online: quantitative experimental	Participants from panel survey company	Replication in a more heterogeneous, nonstudent sample	164
	3	Online: quantitative experimental	Participants from a panel survey company	Replication in a more heterogeneous, nonstudent sample	201
Article 2	4	Online: quantitative experimental	Amazon Mechanical Turk workers	Replication in a heterogeneous, English- speaking sample	227
	5	Online: quantitative experimental	University of Erfurt undergraduates	Replication of Experiment 1 in a similar sample but different subject domain	148
	6	Online: quantitative experimental	Amazon Mechanical Turk workers	Replication in a sample of US residents	921
	7	Laboratory: quantitative experimental	University of Erfurt undergraduates	Pilot experiment	101
Article 3	8	Laboratory: quantitative experimental	University of Erfurt undergraduates	Replication with increased statistical power	390
	9	Laboratory: quantitative experimental	University of Erfurt and RWTH Aachen undergraduates	Replication with increased statistical power	396

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Contributions

Article 1. All authors substantially contributed to this article. P.S., N.M., K.H. and R.B. wrote the Article. The article was supported by the World Health Organization, Regional Office for Europe, Copenhagen, Denmark.

Article 2. Both authors substantially contributed to this article. P.S. and C.B. developed and designed the study, conducted the analyses and wrote the Article and Supplementary Information. P.S. visualized and curated the data. C.B. secured the funding.

Article 3. All authors substantially contributed to this article. P.S., M.S. and C.B. developed and designed the study, conducted the analyses and wrote the Article and Supplementary Information. P.S. visualized and curated the data. C.B. secured the funding.

Additional Achievements

During the development of this dissertation I published several additional research articles and presented the results at scientific conferences. These additional contributions to the research communities are not subject of this dissertation but highlight the development of my research profile. Thus, a full list of my publications and talks is provided below.

Under Review

Schmid, P., Schwarzer, M., Betsch, C. (2019). Weight-of-Evidence Strategies to Counter Science Denialism in Public Discussions. *Manuscript submitted for publication.*

Published in Peer-Reviewed Journals

Haase, N., **Schmid, P.**, & Betsch C. (2019): Impact of disease risk on the narrative bias in vaccination risk perceptions, *Psychology & Health*. https://doi.org/10.1080/08870446.2019.1630561

Schmid, P., Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nat Hum Behav*, 3, 931–939. doi:10.1038/s41562-019-0632-4

Betsch, C., Böhm, R., **Schmid, P.**, Korn, L., Steinmeyer, L., Heinemeier, D., Eitze, S. & Küpke, N.K. (2019). Impfverhalten psychologisch erklären, messen und verändern. *Bundesgesundheitsblatt*, 1-10. https://doi.org/10.1007/s00103-019-02900-6

Betsch, C., **Schmid, P.**, Heinemeier, D., Korn, L., Holtmann, C., Böhm, R. (2018). Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. *PLoS ONE* 13(12): e0208601. https://doi.org/10.1371/journal.pone.0208601

Betsch, C., Rossmann, C., Pletz, M.W., Vollmar, H.C., Freytag, A., Wichmann, O., Hanke, R., Hanke, W., Heinemeier, D., **Schmid, P.**, Eitze, S., Weber, W., Reinhardt, A., Küpke, N.K., Forstner, C., Fleischmann-Struzek, C., Mikolajetz, A., Römhild, J., Neufeind, J., Rieck, T., Suchecka, K., Reinhart, K. (2018). Increasing influenza and pneumococcal vaccine uptake in the elderly: Study protocol for the multi-methods prospective intervention study Vaccination60+. *BMC Public Health*, 18(1), 885. doi: 10.1186/s12889-018-5787-9

Betsch, C., Bödeker, B., **Schmid, P.**, & Wichmann, O. (2018). How baby's first shot determines the development of maternal attitudes towards vaccination. *Vaccine*, 36(21), 3018-3026.

Schmid, P., MacDonald, N. E., Habersaat, K., & Butler, R. (2018). Commentary to: How to respond to vocal vaccine deniers in public. *Vaccine*, 36, 196-198. doi: https://doi.org/10.1016/j.vaccine.2016.09.065

Schmid, P., Rauber, D., Betsch, C,. Lidolt, G., Denker, M. L. (2017). Barriers of Influenza Vaccination Intention and Behavior – A Systematic Review of Influenza Vaccine Hesitancy, 2005 – 2016. *PLoS ONE* 12(1): e0170550.

Betsch, C., Haase, N., Renkewitz, F. & **Schmid, P.** (2015). The narrative bias revisited: What drives the biasing influence of narrative information on risk perceptions? *Judgement and Decision Making*, 10, 241-264.

Betsch, C. & **Schmid, P.** (2012). Angst essen Impfbereitschaft auf? Der Einfluss kognitiver und affektiver Faktoren auf die Risikowahrnehmung im Ausbruchsgeschehen. [The influence of cognitive and affective aspects of risk perception during outbreaks.] *Bundesgesundheitsblatt*, 56, 124-130.

Book Chapters and Reports

Betsch, C., **Schmid, P.**, Holtmann, C., Heinemeier, D. & Korn, L. (2018). *Erklärung und Veränderung von Präventionsverhalten.* In: Kohlmann, C.-W., Salewski, C., Wirtz, M. A. (Hrsg.) (2018). Psychologie in der Gesundheitsförderung. Bern: Hogrefe.

World Health Organization, Regional Office for Europe (2017). *Vaccination and trust – How concerns arise and the role of communication in mitigating crises.* Authored by Cornelia Betsch, Constanze Rossmann, Katrine Bach-Habersaat, **Philipp Schmid**, Cindy Holtmann, Lars Korn, Jascha Wiehn, Linda Mummer.

World Health Organization, Regional Office for Europe (2016). *Best practice guidance: How to respond to vocal vaccine deniers in public*. Authored by **Philipp Schmid**, Noni MacDonald, Katrine Habersaat, Robb Butler.

Talks

Schmid, P., (2019). *Fake-News zum Thema Impfungen bekämpfen – eine psychologische Perspektive*. Turnusärztekongress, Vorarlberg (Austria).

Schmid, P., (2019). *Rebutting fake news around vaccination – A psychological perspective*. XVI International Update Seminar On Vaccines – Balmis Instituto, Almeria (Spain).

Schmid, P., Betsch, C., (2019). *Advocating for science: How to rebut science denialism in public discussions.* 21st Conference of the European Society for Cognitive Psychology, Tenerife (Spain).

Schmid, P., Schwarzer, M., Betsch, C., (2019). *Neutralizing the false-balance effect – How media can support rebuttal of misinformation about vaccination*. European Health Psychology Society Annual Conference, Dubrovnik (Croatia).

Schmid, P., (2019). *Health communication in a post-truth era.* Keynote Behavioural Insights Summer School, Erfurt (Germany).

Schmid, P., (2019). *FakeNews und Mythen im Impfwesen entkräften –was funktioniert? Ein psychologischer Blick*. Impfgespräche aks Gesundheit Vorarlberg, Bregenz (Austria).

Schmid, P., (2019). *Fake News – Rhetorische Fallen erkennen und vermeiden*. Nationale Impfkonferenz, Hamburg (Germany).

Schmid, P., Betsch, C., (2018). *How to respond to persuasive messages of vaccine deniers in public debates.* The Risk and Uncertainty Conference (RUC), Amsterdam (Netherlands).

Schmid, P., Betsch, C., (2018). *How to respond to persuasive messages of vaccine deniers – Experimental verification of a two-dimensional debunking strategy.* International Meeting of the Psychonomic Society, Amsterdam (Netherlands).

Schmid, P., Betsch, C., (2018). *Debunking of persuasive messages of vaccine denial; An empirical verification of a two dimensional debunking strategy [Persuasive Botschaften von Impfgegnern entkräften; Experimentelle Überprüfung einer zweidimensionalen Debunking Strategie] Update 2.* Kongress der Deutschen Gesellschaft für Psychologie (DGPS), Frankfurt (Germany).

Schmid, P., Betsch, C., (2018). *Fake news und Mythen im Gesundheitsbereich entkräften. Was funktioniert? Ein psychologischer Blick.* Herbstsymposium Institut für Qualität und Wirtschaftlichkeit im Gesundheitswesen. (IQWiG), Köln (Germany).

Schmid, P., Betsch, C., (2018). *How to respond to vocal vaccine deniers in public.* Fondation Merieux: Strategies to Increase Vaccine Acceptance and Uptake, Annecy (France).

Schmid, P., Betsch, C., (2017). *Debunking of persuasive messages of vaccine denial; An empirical verification of a two dimensional debunking strategy [Persuasive Botschaften von Impfgegnern entkräften; Experimentelle Überprüfung einer zweidimensionalen Debunking Strategie] Update 1.* 2.Jahrestagung der DGPuK – Fachgruppe Gesundheitskommunikation, Erfurt (Germany).

Schmid, P., Betsch, C., (2017). *Debunking of persuasive messages of vaccine denial; An empirical verification of a two dimensional debunking strategy [Persuasive Botschaften von Impfgegnern entkräften; Experimentelle Überprüfung einer zweidimensionalen Debunking Strategie].* Kongress für Gesundheitspsychologie (DGPS), Siegen (Germany).

Schmid, P., Betsch, C., (2017). *Impfcompliance – Psychologische Erklärungs- und Interventionsansätze.* 31. Freiburger Symposium Arbeitsmedizin im Gesundheitsdienst, Freiburg (Germany).

Schmid, P., Betsch, C., (2017). *Vaccination; A social decision. [Impfen als soziale Entscheidung].* 25. Jahrestagung der Deutschen Gesellschaft für Pädiatrische Infektiologie e. V. (DGPI), Dresden (Germany).

Schmid, P., Betsch, C., (2016). *Vaccine Scepticism, Vaccine Criticism, Vaccine Hesitancy, [Impfskepsis, Impfkritik, Impfmüdigkeit].* Workshop des ÄKBV Ärztlicher Kreis- und Bezirksverband München, München (Germany).

Schmid, P., Betsch, C., (2016). *The Four Reasons of Vaccine Refusal – Development of a Measurement Tool. [Die 4 Gründe von Impfverweigerung – Entwicklung und Validierung eines Messinstruments].* Kongress der Deutschen Gesellschaft für Psychologie (DGPS), Leipzig (Germany).

Schmid, P., Betsch, C., (2016). *Hesitancy Issues for Influenza Vaccination: A Literature Review.* Third WHO Consultation on Global Action Plan for Influenza Vaccines (GAP III). Geneva (Switzerland).

Schmid, P., Betsch, C., (2016). *Psychology of Vaccine Decision Making [Die Psychologie der Impfentscheidung]* in *Vaccination in Austria – Status Quo and Quo Vadis.* Forum Alpbach, Alpbach (Austria).

General Introduction

Science Denialism

In the year 1604, King James VI of Scotland and I of England claimed that smoking tobacco is a vice ‘dangerous to the Lungs, and in the blacke stinking fume thereof, nearest resembling the horrible Stigian smoke of the pit that is bottomelesse’ (Stuart, 1672, p. 12). However, the fact that a highly influential reigning monarch compared smoking with the crossing into hell did not stop the global rise of tobacco use, which according to current statistics, kills an estimated eight million people every year (WHO, 2019a). In fact, once the English Crown identified tobacco as a source of tax revenue and economic development, much of the early antipathy towards smoking faded (Best, 1979).

Only some 360 years later, the UK Royal College of Physicians report and the US Surgeon General report reviewed the scientific evidence from animal experimentation, clinical studies and human population studies, uncovering the emerging scientific consensus that smoking tobacco is indeed ‘dangerous to the lungs’ (Stuart, 1672, p. 12) and that it causes lethal diseases such as lung cancer (RCP, 1962; USPHS, 1964). The reports were a turning point for global public health because knowing that millions of premature deaths are tobacco related also implied that future deaths could be preventable (Bode & Dong, 2009). However, scientific knowledge did not immediately translate into common knowledge (Proctor, 2012a, 2012b; HHS, 2014). For example, US polls in 1966 found that about one-third of participants agreed that ‘science had not yet determined the relation between smoking and lung cancer’ (Saad, 1998, p. 3). Moreover, it was only in 2005 that 168 countries signed the World Health Organization Framework Convention on Tobacco Control, which includes universal standards for limiting the use of tobacco (WHO, 2005).

A major reason why the public’s knowledge about the health risks of smoking only slowly adjusted to the scientific knowledge and why even policy makers remained hesitant to take immediate actions was the implementation of disinformation campaigns by the tobacco industry (Proctor, 2012b; HHS, 2014). The tobacco industry systematically spread doubt about the health risks of smoking to silence the scientific consensus and ensure cigarette consumption (Bates & Rowell, 2004; Bero, 2005; Brandt, 2012; Landman & Glantz, 2009; Ong & Glantz, 2000; Ong & Glantz, 2001; Oreskes & Conway, 2011; Proctor, 2012a, 2012b). More specifically, the industry discredited government reports (Bero, 2005; Ong & Glantz, 2000; Ong & Glantz, 2001), supressed studies that confirmed the damage of tobacco (Bero, 2005; Muggli, Ebbert, Robertson, & Hurt, 2008; Proctor, 2012b) and funded new studies ‘not for purposes of research and development but, rather, to undo what was now known’ (Brandt, 2012, p. 64). This undermining of the scientific consensus was accompanied by large investments in persuasive advertisements. For example, the tobacco industry spent an estimated 250 billion dollars between 1940 and 2005 for product advertisement in the US alone (NCI, 2008). The goal of many of the advertisement messages was to reduce the public's perceived risk perception towards tobacco (Cummings & Proctor, 2014) and to frame smoking as part of a healthy lifestyle (NCI, 2008). In fact, the tobacco industry even claimed that tobacco 'renews and restores bodily energy' (Bates & Rowell, 2004, p. 42).

The outlined reactions of the tobacco industry towards the emerging scientific consensus on the causal link between smoking and cancer cannot simply be defined as nonscientific (Hansson, 2017). In fact, tobacco corporations even pretended to act scientifically themselves, claiming to produce reliable scientific data (Bero, 2005; Oreskes & Conway, 2011; Proctor, 2012a). This mimicry of scientific methods with the goal of rejecting a proposition on which a scientific consensus exists is a type of pseudoscience known as *science denialism* (Diethelm & McKee, 2009; Hansson, 2017; Kalichman, 2014; Lewandowsky, Mann, Brown, & Friedman, 2016; Liu, 2012). In contrast to pseudoscientific theorising (e.g., astrology), science denialism does not necessarily promote an alternative belief system but merely aims to undermine the prevalent scientific consensus (Hansson, 2017) or in the words of the tobacco industry, 'Doubt is our product since it is the best means of competing with the "body of fact" that exists in the mind of the general public' (Brown & Williamson Tobacco Corporation, 1969, p. 1).

Tobacco disease denialism is specifically well studied because of its devastating damage to the general public's health but also because the tobacco industry has produced an unprecedented amount of material that provides insights into the motivations, strategies and impact of science deniers (Proctor, 2012a). However, other scientific consensuses exist that are challenged by domain-specific forms of science denialism, such as vaccination denialism (i.e., denying the health benefits of vaccination), holocaust denialism (i.e., denying that the holocaust happened), climate change denialism (i.e., denying human made climate change), HIV denialism (i.e., denying the link between HIV and AIDS), evolution theory denialism (i.e., denying the existence of biological evolution), globe denialism (i.e., denying that the earth is round) and relativity theory denialism (i.e., denying the relativity of time; Hansson, 2017). Among these, tobacco disease denialism and climate change denialism are specifically promoted by political and economic institutions; that is, they are examples of institutionally organised denial (Lewandowsky & Oberauer, 2016; Oreskes & Conway, 2011).

However, previous research reveals that not only the vested interests of organisations, but also the psychological processes of single individuals, can promote science denialism

(Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016). Individuals may reject scientific consensuses because they express their personal identities by doing so, they wish to follow social norms, they have high levels of a conspiratory mentality, they believe in paranormal activities, they fear the behaviour favoured by science, or they endorse political, religious or moral worldviews that conflict with the scientific consensus (Amin et al., 2017; Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016; Lobato, Mendoza, Sims, & Chin, 2014). For example, some individuals reject the scientific consensus on climate change because they endorse a free market ideology and perceive state-regulated restrictions on CO_2 emission as politically motivated actions that conflict with their own political worldview (Häkkinen & Akrami, 2014). Others deny climate change because they live in social environments where the rejection of alternatives to fossil fuels is the prevalent social norm (Tvinnereim & Ivarsflaten, 2016). Others express their general belief in secret governmental plots by claiming that climate change is a hoax (Lewandowsky, Oberauer, & Gignac, 2013). Independent of whether science denialism is expressed on an organisational or individual level, it aims to defend the economic, political or psychological interests of the denier; thus, science denialism is a *motivated rejection of science* rather than mere ignorance or a lack of education (Hamilton, Hartter, Lemcke-Stampone, Moore, & Safford, 2015; Kahan et al., 2012; Lewandowsky & Oberauer, 2016; Sobo, 2015).

Being a motivated rejection, science denialism also differs from scientific *scepticism* (Kemp, Milne, & Reay, 2010; Lewandowsky et al., 2016; Weart, 2011). A science denier tends to search, integrate and share evidence that serves their economic, political or psychological interests and dismisses evidence that threatens their view (Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016; McKee & Diethelm, 2010). In turn, this can trigger biased risk assessments (e.g., it would be riskier to stop than to continue smoking, thus I smoke), the use of oversimplified decision heuristics (e.g., I know a sports trainer who smokes every day, thus I do it too) and irrational judgements (e.g., smoking renews and restores bodily energy, thus I smoke) among science deniers (Lewandowsky & Oberauer, 2016). In contrast, scientific *sceptics* constantly update prior beliefs as new scientific evidence comes in – independent of whether the new evidence confirms or disconfirms their prior beliefs (Schmid & Betsch, 2019). This data-driven updating is a crucial element of critical thinking because it enables unbiased analyses and judgements (Gorard, 2002; Stirling, 2011). As a consequence, many social movements and nongovernmental organisations that address the spread of pseudoscientific sentiments and support scientific communities describe themselves as sceptics (e.g., Germany: Society for the Scientific Investigation of Parascience;

United States: Skeptical Science; Australia: Australian Skeptics). Another difference between deniers and sceptics is the way that they deal with people who disagree with their worldview. In contrast to sceptics, science deniers do not refrain from personal attacks against advocates for science (Lewandowsky et al., 2016; Weart, 2011). For example, advocates for science repeatedly receive abusive mail from science deniers or are openly insulted on social media (Lewandowsky et al., 2016).

Thus, because of the fundamentally different approaches regarding how science denier and sceptics deal with unpleasant evidence or people, they should not be confused with each other (Björnberg, Karlsson, Gilek, & Hansson, 2017; Dunlap, 2013; Lewandowsky et al., 2016). Quite the opposite, individuals in a state of science denial reject 'well-established scientific results for reasons that are not scientifically grounded' (Lewandowsky, Oberauer, et al., 2013, p. 623), while sceptics aim to endorse scientifically grounded critical thinking (Gorard, 2002; Stirling, 2011). In line with this, research suggests that teaching critical thinking decreases – rather than increases – the tendency to adapt beliefs that foster science denialism (Cook, Ellerton, & Kinkead, 2018; McLaughlin & McGill, 2017; Swami, Voracek, Stieger, Tran, & Furnham, 2014; Wilson, 2018).

Science denialism: A form of pseudoscience that aims to reject a proposition on which a scientific consensus exists (Diethelm & McKee, 2009; Hansson, 2017). Science denialism is driven by economic, political or psychological interests that trigger biased belief updating (Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016; McKee & Diethelm, 2010).

Science denialism is especially threatening when it affects the decisions that can have lethal consequences for the decision maker. For example, science deniers can prevent individuals from getting treatments (e.g., HIV treatment) and prevention measures (e.g., vaccinations) that would increase the individuals’ life expectancies (Andre et al., 2008; Bor, Herbst, Newell, & Bärnighausen, 2013). Science deniers can affect individuals’ decision making in two ways. First, if in power, science deniers have the potential to use force or policies that restrict individuals’ choices and prevent them from performing behaviours favoured by science. For example, the former president of the Republic of South Africa (RSA) Mbeki influenced the health policies of the RSA in a way so that AIDS patients could not get life-saving treatments, even if they were willing to (Chigwedere & Essex, 2010; Chigwedere, Seage, Gruskin, Lee, & Essex, 2008). Second, science deniers can influence individuals’ behaviours via persuasive science denialism messages. The current dissertation focuses specifically on how to counter the latter case, that is, how to counter science denialism messages such as ‘tobacco renews and restores bodily energy’ (Bates & Rowell, 2004, p. 42). Thus, it is now necessary to explore what constitutes science denialism messages.

Science Denialism Messages

Science denialism messages are originally spread to cast doubt on ‘a proposition on which a scientific consensus exists’ (Diethelm & McKee, 2009, p. 2); they contain information that is not scientifically grounded and that is inaccurate relative to the prevalent scientific consensus. For example, the claim that ‘tobacco renews and restores bodily energy’ (Bates & Rowell, 2004, p. 42) contrasts the scientific consensus on the lethal health consequences of smoking (WHO, 2019a). Although the terms *misinformation* and *disinformation* are both used in research on science denialism to describe this form of inaccurate information, it has been argued that these terms differ in their meaning (Lewandowsky, Stritzke, Freund, Oberauer, & Krueger, 2013; MacKenzie & Bhatt, 2018; Roozenbeek & van der Linden, 2019; Southwell, Thorson, & Sheble, 2018). Misinformation is defined by the Oxford Dictionary as ‘false or inaccurate information, especially that which is deliberately intended to deceive’ (OUP, 2019a) and disinformation as ‘false information which is intended to mislead, especially propaganda issued by a government organisation to a rival power or the media’ (OUP, 2019b). Following these definitions and in line with Southwell, Thorson and Sheble (2018), disinformation can be interpreted as a special type of misinformation that is intentionally spread to deceive an audience, despite the sender having better knowledge. Disinformation is spread systematically to disseminate the sender's ideological position and eliminate opposing positions (Lanoszka, 2019; Lewandowsky, Stritzke et al., 2013). In contrast, the umbrella term misinformation includes disinformation but also inaccurate information that is spread because the sender her-/himself believes it to be true (Lewandowsky, Stritzke et al., 2013). Thus, using terms from the ancient Greek philosopher Plato, disinformation is a fraudulent *lie,* while misinformation also incorporates innocent *errors* (see Arendt, 1961).

When the tobacco industry spread messages such as 'smoking tobacco renews and restores bodily energy', they certainly did not commit an innocent error; indeed, these messages were rather intentionally spread to deceive an audience and defend the interests of the sender (Bates & Rowell, 2004; Bero, 2005; Brandt, 2012; Landman & Glantz, 2009; Ong & Glantz, 2000; Ong & Glantz, 2001; Oreskes & Conway, 2011; Proctor, 2012a, 2012b). Thus, based on their origin, science denialism messages are a type of disinformation that undermines the propositions on which a scientific consensus exists (Diethelm & McKee, 2009; Roozenbeek & van der Linden, 2019; Southwell et al., 2018). However, these messages can also be multiplied by other entities that either believe the false information to be true (i.e., misinformed individuals) or are even incapable of forming such an intention (e.g., mechanical algorithms; Iyengar & Massey, 2019). In these cases, science denialism messages indeed become errors. Thus, labelling science denialism messages as misinformation avoids the risk of false allegations (Southwell et al., 2018) because not everyone who shares science denialism messages is necessarily a science denier.

Irrespective of whether science denialism messages are spread by a science denier or shared by misinformed individuals, they can decrease positive attitudes towards the behaviours favoured by science and hence decrease the willingness to perform these behaviours (e.g., refuse vaccinations, refuse HIV treatments, continue smoking, etc.); that is, science denialism messages are persuasive messages (Schmid & Betsch, 2019).

Science denialism messages: Mis- or disinformation that undermines propositions on which a scientific consensus exists. Science denialism messages are persuasive in nature; that is, they can damage the receivers' attitudes towards the behaviours favoured by science and the willingness to perform these behaviours (Schmid & Betsch, 2019).

In its simplest form, science denialism messages provide information that is incompatible with the prevalent scientific consensus. The number of different science denialism messages that ‘give the appearance of a legitimate debate where there is none’ (Diethelm & McKee, 2009, p. 2) are tremendous and vary by domain. For example, the nongovernmental organisation Skeptical Science provides a list of different science denialism messages that contain 197 entries for climate change alone (Skeptical Science, 2019). Thus, to reduce complexity and identify commonalities, previous research has aimed to categorise different science denialism messages (Cook, 2019; Kalichman, 2014; Mazo, 2013). Article 1 in the current dissertation provides a categorisation of the topics repeatedly addressed by vaccine deniers.

However, when science denialism messages are challenged or when science deniers want to increase the persuasiveness of their messages, they often provide additional rhetorical justifications for their claims (Cook, 2019; Diethelm & McKee, 2009); that is, the initial message becomes an argument. Previous research has identified the following five rhetorical techniques that science deniers repeatedly use as justifications for their claims: *fake experts*, *conspiracy theories*, *selectivity*, *impossible expectations* and *misrepresentation* (Cook, 2019; Diethelm & McKee, 2009; McKee & Diethelm, 2010). These techniques are weak justifications in relation to the body of evidence supporting the scientific consensuses, and they are often fallacious (Cook et al., 2018; Cook, Lewandowsky, & Ecker, 2017; Kaufman & Kaufman, 2018); that is, they commonly lead to errors in reasoning because of their deceptive nature (Bennett, 2015). Despite their weaknesses, these techniques are still persuasive. In fact, the results provided in Chapters 2 and 3 reveal that science denialism messages based on these justifications can indeed damage the public’s understanding of science. The characteristics of the five techniques and potential reasons for why their weaknesses are difficult to spot for a lay audience are explored in detail below.

Fake Experts. Fake experts communicate about scientific issues and ‘appear to have relevant expertise but in fact rarely do’ (Cook, Lewandowsky, & Ecker, 2017, p. 3). Fake experts do not qualify as relevant experts because they either lack training in the specific domain under discussion or because they are biased in their judgements because of substantial conflicts of interest (Diethelm & McKee, 2009). Science deniers quote fake experts to increase the perceived credibility of their message. By doing this, they conduct a logical fallacy commonly known as an *appeal to false authority*. The logical form of this fallacy is presented in Table 1.

Table 1. Fake experts as a fallacy – appeal to false authority. The letter *p* represents a proposition such as 'tobacco renews and restores bodily energy'. The logical form of the appeal to the false authority fallacy is adapted from Bennett (2015).

Fake Expert	*Logical form*	*Example*
Justification	Person A (who is either biased or not an expert in judging whether proposition *p* is true) says *p*	An employer of the tobacco industry said that tobacco renews and restores bodily energy.
Conclusion	Thus, proposition *p* is true	Thus, tobacco renews and restores bodily energy.

The fake expert technique may be specifically persuasive because it is difficult for a layperson to evaluate the expertise of the source making a judgement about whether *p* (Table 1) is true or not (Goldman, 2001). In fact, studies have revealed that individuals have difficulty evaluating whether they themselves are knowledgeable in a specific domain (Kruger & Dunning, 1999). The evaluation of expertise is aggravated when fake experts mimic the essential features of trusted experts. For example, simply wearing a white coat, which is associated with medical expertise, can increase the perceived trustworthiness of an individual (Petrilli et al., 2018). In the worst case, science deniers simply pay actual experts to make a false judgement about whether *p* is true or not. For example, under the codename *Project Whitecoat*, the tobacco industry paid medical personnel and scientists to promote smoking and misused their trustworthiness to create a web of fake experts (Barnoya & Glantz, 2006; Drope & Chapman, 2001; Landman & Glantz, 2009). This web was in turn used to justify advertisement slogans such as 'Philip Morris – a cigarette recognised by eminent medical authorities for its advantages to the nose and throat' (Bates & Rowell, 2004, p. 41).

Conspiracy Theories. Conspiracy theories can be defined as 'attempts to explain the ultimate causes of significant social and political events and circumstances with claims of secret plots by two or more powerful actors' (Douglas et al., 2019, p. 4). Conspiracy theories undermine trust in science by proposing that scientific findings or consensuses are the result of a hidden agenda (Lewandowsky, Oberauer, et al., 2013; van der Linden, 2015). There is no doubt that conspiracies do exist, but their possibility does not mean that they are probable (Wagner-Egger, Bronner, Delouvée, Dieguez, & Gauvrit, 2019). In fact, research has suggested that the claim that scientific consensuses are the result of secret conspiracies is rather unlikely (Grimes, 2016). Moreover, the way science deniers use conspiracy theories is often irrational because it violates the principles of scientific reasoning (Grimes, 2016;

Wagner-Egger et al., 2019). For example, conspiratory accusations are often backed up by no or uncompelling evidence such as ambiguous pictures and videos; that is, they violate the *burden of proof* principle (Cargile, 1997; Dentith, 2014; Wagner-Egger et al., 2019). In the most extreme form of this violation, science deniers use the *absence of evidence* as proof for their claim. The logical form of this fallacy is presented in Table 2.

Table 2. Conspiracy theories as a fallacy – absence of evidence. The letter *p* represents a proposition such as 'tobacco renews and restores bodily energy'. The logical form of the absence of evidence fallacy is adapted from Bennett (2015).

Conspiracy theories	*Logical form*	*Example*
Justification	Proposition *p* is true	Tobacco renews and restores bodily energy.
	A conspiracy hides the evidence for proposition *p*	We know that socialists are hiding the real data on whether 'tobacco renews and restores bodily energy' to damage champions of the free market.
Conclusion	Thus, proposition *p* is true	Thus, tobacco renews and restores bodily energy.

Conspiracy theories may be specifically effective in promoting science denialism messages for two reasons. First, science deniers often immunise these theories against potential falsifications. Whenever an advocate for science produces evidence against a conspiracy theory, science deniers can accuse that advocate of being part of the conspiracy him/herself (Douglas, Sutton, & Cichocka, 2017). The fact that adding more and more individuals to the conspiracy often violates the *parsimony principle* of scientific reasoning and makes the conspiracy less likely is thereby ignored (Grimes, 2016; Wagner-Egger et al., 2019). Second, individuals who feel powerless are specifically prone to believe in conspiracy theories (Leman & Cinnirella, 2013; Whitson & Galinsky, 2008). Unfortunately, the issues addressed by denialism, such as HIV and climate change, trigger this feeling of powerlessness – and even fatalism – because their scope and severity often exceeds the individuals' perceived behavioural control (Clayton, Manning, Krygsman, & Speiser, 2017; Gifford, 2011; Meyer-Weitz, 2005). Thus, when dealing with these large-scale issues, conspiracy theories may be more appealing for the public compared with the official version because 'the conspiratorial worldview offers us the comfort of knowing that while tragic events occur, they at least occur for a reason' (Keeley, 1999, p. 124), while the official version leaves the individual with the impression that 'not God, not us, not even some of us – is in control' (Keeley, 1999, p. 124).

Selectivity. Selectivity or cherry picking can be defined as 'the activity of presenting an explanation that uses evidence that has been specifically selected from a wider pool of evidence to make a candidate explanation look warranted when it otherwise might not be' (Dentith, 2014, p. 125). In line with this definition, the science denier makes their messages look warranted by cherry picking isolated scientific studies and single narratives while ignoring the overwhelming evidence that contradicts their messages (Diethelm & McKee, 2009; Hansson, 2017). A common use of cherry picking is to select extraordinary single narratives or personal experiences as justification of a claim while ignoring the more common narratives and experiences. In this case, the science denier conducts a logical fallacy commonly known as *incomplete evidence*. The logical form of this fallacy is presented in Table 3.

Table 3. Selectivity as a fallacy – incomplete evidence. The letter p represents a proposition such as 'tobacco renews and restores bodily energy'. $\neg p$ represents a proposition that contradicts proposition p. The letter A represents a person who argues in favour of p. The logical form of the incomplete evidence fallacy is adapted from Bennett (2015).

Selectivity	*Logical form*	*Example*
Justification	Evidence for proposition p and proposition $\neg p$ is available	Studies show that smoking tobacco reduces life expectancy, but former chancellor Helmut Schmidt was a smoker, and he was 96 years old.
	Evidence for proposition p confirms the assumptions made by person A	Helmut Schmidt fits the 'tobacco renews and restores bodily energy' slogan.
Conclusion	Thus, only evidence for proposition p is presented by person A	Thus, Helmut Schmidt is presented as a typical smoker.

As part of a disinformation campaign, science deniers have repeatedly cherry-picked data for their messages (McGarity & Wagner, 2008; Ricciardi & Ryan, 2018). However, even without the intention to deceive, individuals generally tend to search for and select evidence that confirms their own prior beliefs while tending to ignore disconfirming evidence (Nickerson, 1998). This so-called *confirmation bias* makes any individual – even advocates for science (Lee, Sugimoto, Zhang, & Cronin, 2013; Murphy & Aguinis, 2019) – prone to accept cherry-picked evidence if that evidence confirms what the individual already thought was true. The general problem of cherry picking has gained particular attention in the Internet era, where Internet users are often communicating within social media environments (e.g., Facebook, Twitter) that rarely challenge the users' prior beliefs; that is, users are locked into so-called *echo chambers* (Del Vicario et al., 2016; Quattrociocchi, Scala, & Sunstein, 2018).

Cherry picking may be specifically persuasive because the confirmation bias, echo chambers and a simple lack of expertise make it difficult for laypeople to identify whether a study is indeed isolated or representing a consensus. Moreover, human decision making is influenced by the emotional content of single narratives (Rakow, Heard, & Newell, 2015; Winterbottom, Bekker, Conner, & Mooney, 2008). Several studies have revealed the damaging effect of single narratives on individuals' risk perceptions and intentions to perform behaviours favoured by science despite the provision of statistical summaries that put the narrative into perspective (Betsch, Haase, Renkewitz, & Schmid, 2015; Betsch, Renkewitz, & Haase, 2013; Haase, Betsch, & Renkewitz, 2015). Single misleading narratives have been exploited repeatedly by science deniers in tailored advertisements. For example, the tobacco industry used personalised narratives of women with varying versions of the quote 'to keep a slender figure I reach for a Lucky instead of a sweet' to detract from the lethal health consequences of tobacco consumption (Beard & Klyueva, 2010).

Impossible Expectations. Impossible expectations aim to 'set unrealistic standards for data that invalidate an entire body of research' (Liu, 2012, p. 130). Science deniers use impossible expectations to highlight the limits of scientific research and thereby falsely conclude the impotence of science when it comes to recommending specific behaviours, for example, abandoning tobacco products (Ong & Glantz, 2001). As a variation of this technique, science deniers set unrealistic quality standards for evidence, which they give as proof that scientific results cannot meet these criteria and thus discount the results (e.g., *vaccines should be 100% safe*; Kata, 2012; *studies on risks of smoking need to present an odds ratio above two*; Ong & Glantz, 2001). By doing this, they conduct a logical fallacy commonly known as the *nirvana fallacy*. The logical form of this fallacy is presented in Table 4.

Table 4. Impossible expectation as a fallacy – nirvana fallacy. The letter *b* represents the available scientific evidence at a given point in time. The letter *c* represents evidence that would meet an impossible standard. The logical form of the nirvana fallacy is adapted from Bennett (2015).

Impossible expectation	*Logical form*	*Example*
Justification	Evidence *b* is what science can offer	The risks of vaccination outweigh the risks of vaccine-preventable disease.
	Evidence *c* would meet the impossible standard	Only a vaccination that is 100% safe is acceptable.
Conclusion	Thus, evidence *b* is not good enough	Thus, the current safety profile of vaccination is not good enough.

Science deniers conduct a second form of impossible expectations if they ask for specific impossible evidence that would be sufficient but is not necessary to justify the scientific standpoint. For example, science deniers often ask for randomised placebo-controlled trials comparing unvaccinated and vaccinated children and reject vaccination in general if these studies cannot be provided (Najera, 2019). This type of evidence is sometimes impossible to provide for an advocate for science because it is ethically unacceptable to deny the unvaccinated study group the benefits of being vaccinated 'when a highly efficacious and safe vaccine exists and is currently accessible in the public health system' (Rid et al., 2014, p. 4709). However, in most of these cases, the existing evidence about the effectiveness and safety of vaccinations from other types of studies is deemed sufficient by the majority of experts to conclude that vaccinations are indeed beneficial (Najera, 2019). Thus, randomised placebo-controlled trials are not deemed necessary, and by insisting on these trials, science deniers conduct a logical fallacy known as *denying the antecedents*. The logical form of this fallacy is presented in Table 5.

Table 5. Impossible expectation as a fallacy – denying the antecedents. The letter *b* represents impossible evidence. The letter *c* represents a conclusion that can be drawn from *b* but also from other forms of evidence. The logical form of the fallacy is adapted from Bennett (2015).

Impossible expectation	*Logical form*	*Example*
Justification	If evidence *b* is provided, then proposition *c* is true	If randomised placebo-controlled trials of vaccine A show that vaccinated children are healthier than unvaccinated children, then vaccine A is beneficial.
	Evidence *b* is not provided	Randomised placebo-controlled trials do not exist for vaccine A.
Conclusion	Thus, proposition c is rejected	Thus, vaccine A is not beneficial.

The technique of impossible expectations may be specifically persuasive because it reduces the complexity of a scientific issue into two options: one that everyone would prefer and the scientific option.

Misrepresentation. Misrepresentation can be defined as an 'offence of giving a false or misleading account of the nature of something' (OUP, 2019c). Science deniers repeatedly misrepresent facts from the past to create counter-evidence against scientific studies (Oreskes & Conway, 2011; Proctor, 2012b). For example, the slogan 'tobacco renews and restores bodily energy' was scientifically unfounded and was declared false and deceptive by the US Federal Trade Commission (Bates & Rowell, 2004). However, misrepresentations can also be more subtle. Science deniers take quotes from well-trusted sources out of context to give the quotes new meanings – meanings that are in line with the deniers' conclusion. For example, evolution deniers repeatedly used the quote 'I am quite conscious that my speculations run quite beyond the bounds of true science' (Darwin Correspondence Project, 2006) by Charles Darwin as proof that he had doubted his own theories. However, the original statement was part of a letter correspondence in which Darwin admitted his lack of evidence for a very specific hypothesis, that is, he was not talking about the general theory of evolution (Darwin Correspondence Project, 2016). This so-called *quote mining* (Hansson, 2017) is used by a number of science deniers across domains (tobacco disease denialism; Ernster & Burns, 1984; climate change denialism; Reay, 2010). When taking quotes out of context, science deniers conduct a logical fallacy also known as *contextomy*. The logical form of this fallacy is presented in Table 6.

Table 6. Misrepresentation as a fallacy – contextomy. The letter *b* represents a proposition. The letters *a* and *c* represent the interpretations of the meaning of *b*. The logical form of the fallacy is adapted from Bennett (2015).

Misrepresentation	*Logical form*	*Example*
Justification	Proposition *b* has meaning *a* in context	The quote 'I am quite conscious that my speculations run quite beyond the bounds of true science' reveals Darwin's problem in dealing with a specific hypothesis.
	Proposition *b* has meaning *c* when taken out of context	The quote 'I am quite conscious that my speculations run quite beyond the bounds of true science' reveals that Darwin doubted his own theory if the context is ignored.
Conclusion	Thus, proposition *b* means *c*	Thus, Darwin himself knew the theory of evolution is beyond true science.

Another common fallacious application of misrepresentation is to repeat a strong scientific proposition with minor changes to it – changes that make the initial proposition prone to refutation (McKee & Diethelm, 2010). By doing this, science deniers conduct a logical fallacy commonly known as the *strawman*. The logical form of this fallacy is presented in Table 7.

Table 7. Misrepresentation as a fallacy – strawman. The letter *b* represents a proposition. The letters *a* and *c* represent the interpretations of the meaning of *b*. The logical form of the fallacy is adapted from Bennett (2015).

Misrepresentation	*Logical form*	*Example*
Justification	Person A states proposition b	Advocate for science: Smoking tobacco can cause cancer!
	Person B restates b with minor changes	Science denier: Well, the advocate just said that smoking is always causing cancer.
	Person B proofs the changed version of b to be false	I would like to present to you the smoker Mr. Schmidt. He turned 96 years without any signs of cancer! The advocate is obviously not telling the truth.
Conclusion	Thus, $\neg b$	Thus, smoking does not cause cancer.

The technique of misrepresentation may be specifically persuasive because laypeople can rarely judge whether the presented numbers or arguments are being misrepresented, not to mention identifying made-up evidence. In the Internet era, this difficulty has largely been increased by the deliberate design of fake news (Waisbord, 2018), fake videos (Maras & Alexandrou, 2019) and fake accounts on social media (Gurajala, White, Hudson, Voter, & Matthews, 2016), that is, the mimicry of trusted outlets.

It is important to note that none of the outlined strategies are exclusively conducted by science deniers. For example, advocates for science themselves have misrepresented or cherry-picked data (Boutron & Ravaud, 2018; Murphy & Aguinis, 2019) and have cited experts in domains unrelated to their studies (Lehmkuhl & Leidecker-Sandmann, 2019). Thus, identifying weak or even fallacious arguments in science denialism messages also provides the opportunity to train advocates for science to avoid such pitfalls in their own reasoning.

Science Denialism and the Post-truth Era

The potential damage that arises from science denialism messages and their often faulty reasoning varies by domain and context. For example, tobacco consumption is still a leading global health threat, but the burden of tobacco disease denialism messages has decreased in recent years because of the enforcement of comprehensive bans on tobacco advertisements in 48 countries (WHO, 2019a). Furthermore, some other science denialism messages, such as ‘the earth is flat’, are not considered highly persuasive and thus give little reason for concern (Landrum, Olshansky, & Richards, 2019). In contrast, vaccine and climate change denialism have gained serious media attention in recent years (Petersen, Vincent, & Westerling, 2019; Ward, Peretti-Watel, Bocquier, Seror, & Verger, 2019), and medical experts agree that they pose a threat to the future of healthcare (Marzouk & Choi, 2019; WHO, 2019b). The concerns from expert communities are reinforced by the fact that a considerable number of individuals resonate with vaccine and climate change denialism messages. For example, a representative survey of US citizens revealed that 20% of respondents agreed that ‘Doctors and the government still want to vaccinate children even though they know these vaccines cause autism and other psychological disorders’ (Oliver & Wood, 2014, p. 817); the Wellcome Global Monitor survey revealed that between 20% and 33% of Frenchmen, Austrians, Belgians and Swiss disagree that vaccines are safe (Gallup, 2019); and a Pew Research Centre survey revealed that only 18% of Chinese consider global climate change a very serious problem (PRC, 2015). Neither vaccination denialism nor climate change denialism are new phenomena (Oreskes & Conway, 2011; Poland & Jacobson, 2011). However, the increased politisation of vaccination and climate change denial in recent years and the rise of new technical achievements (e.g., the Internet) have intensified the threat of science denialism and have contributed to the perception that we live in a *post-truth era* (Lewandowsky, Ecker, & Cook, 2017).

The increased politisation of science and science denialism in the post-truth era became particularly apparent after the 2016 US election. According to the *Washington Post*, the forty-fifth president of the United States of America spread misinformation on average nearly 13 times per day in about two and a half years in office (The Washington Post, 2019). Among these pieces of false information, he repeatedly challenged the existence of human-caused climate change and the safety of vaccinations (Dyer, 2016; Mann, 2019; Tollefson, 2016). Unfortunately, spreading these science denialism messages for political agendas is by no means exclusively conducted by Donald Trump. Other political elites have repeatedly opposed vaccinations and actions against climate change to represent various political interests (Charo, 2007; Dryzek, Norgaard, & Schlosberg, 2012; Fielding, Head, Laffan, Western, & Hoegh-Guldberg, 2012; Kennedy, 2019; Lockwood, 2018). The spread of science denialism messages by political elites is particularly problematic for three reasons. First, political elites are opinion leaders, and thus, individuals use their messages as guidance on how to deal with complex issues such as vaccination and climate change (Carmichael & Brulle, 2017; Gilens & Murakawa, 2002). Second, when vaccination and actions against climate change are accepted by one political party but rejected by another, the decision to adapt these behaviours will be influenced by political partisanship (Fielding et al., 2012; Gollust, Attanasio, Dempsey, Benson, & Fowler, 2013). In this case, supporting a science denier is not necessarily an expression of irrationality but merely an expression of political identity (Lewandowsky & Oberauer, 2016; Nisbet, Cooper, & Garrett, 2015). Third, when issues become politicised, journalists often present the different political positions in a balanced fashion in mass media (Gollust et al., 2013; Petersen et al., 2019). This balancing of the positions is conducted to eliminate journalists' subjective interpretations of political opinions and thus promote objective journalism (Boudana, 2016; Schudson, 2001). However, when balancing is applied in contexts where one position is supported by an overwhelming scientific consensus and the other position lacks scientific evidence, balancing becomes a bias known as *false-balance* (Brüggemann & Engesser, 2017; Dixon & Clarke, 2013; Koehler, 2016). This false-balance can distort individuals' attitudes towards vaccination and reduce the willingness to engage in actions against climate change (Corbett & Durfee, 2004; Dixon & Clarke, 2013).

But this is not all: as noted above, the rise of the post-truth era is also the product of new technical achievements – primarily the Internet – that promote the spread of misinformation (Lewandowsky et al., 2017). The increased threat of science denialism in the Internet era is particularly highlighted by the widespread dissemination of misinformation about vaccination and climate change online (Davies, Chapman, & Leask, 2002; Hoffman et al., 2019; Petersen et al., 2019; Schmidt, Zollo, Scala, Betsch, & Quattrociocchi, 2018; Scullard, Peacock, & Davies, 2010; Vicario et al., 2016). For example, Davies, Chapman and Leask (2002) entered 'immunisation' and 'vaccination' in seven search engines and found that 43% of the first 10 web pages promoted vaccination denialism viewpoints. Moreover, Scullard, Peacock and Davies (2010) entered 'MMR autism' in Google UK and found that 56% of the first 100 webpages presented a false or inappropriate answer to the question of whether vaccines can cause autism. In addition, experimental research revealed that 5–10 minutes of viewing such misinforming webpages can increase the individual's risk perception towards vaccination and decrease the intention to get vaccinated (Betsch, Renkewitz, Betsch, & Ulshöfer, 2010).

The issue of science denialism messages online is aggravated by the use of social media applications, in which misinformation spreads faster than normal information (Vosoughi, Roy, & Aral, 2018). Moreover, the algorithms of social media applications tend to provide users with (mis)information that confirms the users' prior beliefs. This creates environments – so-called *echo chambers* – in which social media users only read, hear or listen to propositions they already believed to be true and in which they rarely encounter information that challenges their worldviews (Del Vicario et al., 2016; Zollo et al., 2017). Thus, the more a social media user is already misinformed about climate change and vaccination, the more difficult it will be for the individual to circumvent further misinforming content online.

The actual scope of the damage of online science denialism is difficult to assess. However, country reports by WHO member states provide insights into some alarming experiences. For example, in Denmark, vaccine deniers spread science denialism messages via videos and testimonials on social media, claiming that young girls have been harmed by the human papillomavirus (HPV) vaccination. This misinformation is discussed as a major reason why national immunisation rates in Denmark have dropped from 90% to an alarming 20% in only five years' time (Larson, 2018).

Resistance to Science Denialism

The alarming trends in recent years have intensified the threat of science denialism but have also triggered the development of promising interventions to resist the structural, technical and content-related challenges of science denialism messages. On the structural level, political changes that contributed to the post-truth era are opposed by proscientific social movements (Durnová, 2019), institutionalised policies to fight misinformation (EC, 2019) and school-based programmes that teach future voters to detect fake news (Nygren, 2017). Moreover, the technical changes that have contributed to the post-truth era are being tackled by tools to monitor the spread of fake news (Allcott, Gentzkow, & Yu, 2019) and by a growing number of fact-checkers (Hameleers & van der Meer, 2019; Schäfer, 2011). On the content level, researchers have started to investigate effective communication interventions as a response to science denialism messages. Among the most promising communication approaches are inoculation (Roozenbeek & van der Linden, 2019), debunking (Cook & Lewandowsky, 2011) and rebuttal interventions (Schmid & Betsch, 2019). The latter is described and evaluated in detail in Articles 1–3 in the current dissertation.

All three approaches can equip science advocates with the tools to defend the general public against misinformation in general and science denialism messages in particular. For example, if science advocates knew that the tobacco industry plans to run a campaign that includes science denialism messages such as 'tobacco renews and restores bodily energy', then they could try to make the general public resistant against this persuasive message before it reaches them (Figure 1). Guidance on how to design such proactive interventions against misinformation is provided by 'the grandparent theory of resistance to attitude change' (Eagly & Chaiken, 1993, p. 561), that is, the inoculation theory (McGuire, 1961a, 1961b).

Inoculation Interventions. According to the inoculation theory, inoculation interventions increase resistance to change via two primary mechanisms: threat induction and refutational preemption (Figure 1; Banas & Rains, 2010; Compton, Jackson, & Dimmock, 2016; McGuire, 1961a, 1961b). Threat induction aims to make the individual aware of the vulnerability of her/his current attitudinal beliefs and to increase the individual's motivation to resist a persuasive attempt (Banas & Rains, 2010; Compton, 2013). Threat induction is commonly induced by using explicit forewarnings (Compton & Ivanov, 2012; McGuire & Papageorgis, 1962). For example, in the case of an approaching tobacco campaign, health authorities could warn the general public that the tobacco industry is going to spread highly persuasive and deceptive messages to promote cigarette consumption. According to the theory, the receiver of this warning would then be aware of being a potential target of an inappropriate persuasive attempt and thus be motivated to defend her/his current attitudinal beliefs (Compton, 2013).

However, being motivated alone does not necessarily mean that the individual will be equipped with the necessary resources to resist the persuasive attempt. For example, a forewarned individual who faces the message 'tobacco renews and restores bodily energy' may still lack knowledge about an appropriate counter-argument and thus be incapable of defending her/his current attitudinal beliefs, despite being motivated to do so. To address this issue, inoculation interventions usually contain persuasive messages that mirror the actual upcoming persuasive attempt together with a refutation of these messages, that is, *refutational preemption* (Banas & Rains, 2010; Compton, 2013; Compton & Ivanov, 2012). For example, in the case of an approaching tobacco campaign, health authorities could state that messages such as 'tobacco renews and restores bodily energy' are deceptive because, in fact, tobacco kills an estimated eight million people every year (Figure 1). In this specific example, the persuasive message and its refutation would be provided by the designer of the inoculation intervention, that is, *passive refutation* (Compton, 2013). In contrast, *active refutation* asks the receiver of the intervention to generate the persuasive message or the refutations him/herself (Figure 1; Banas & Rains, 2010; Roozenbeek & van der Linden, 2019). Either way, refutational preemption provides access to external or internal resources that effectively facilitate resistance to change (Pfau et al., 1997). In sum, an individual is fully inoculated against a persuasive message if she/he is motivated to resist change and is equipped with the appropriate counter-arguments (Banas & Rains, 2010; Compton, Jackson, & Dimmock, 2016; McGuire, 1961a, 1961b).

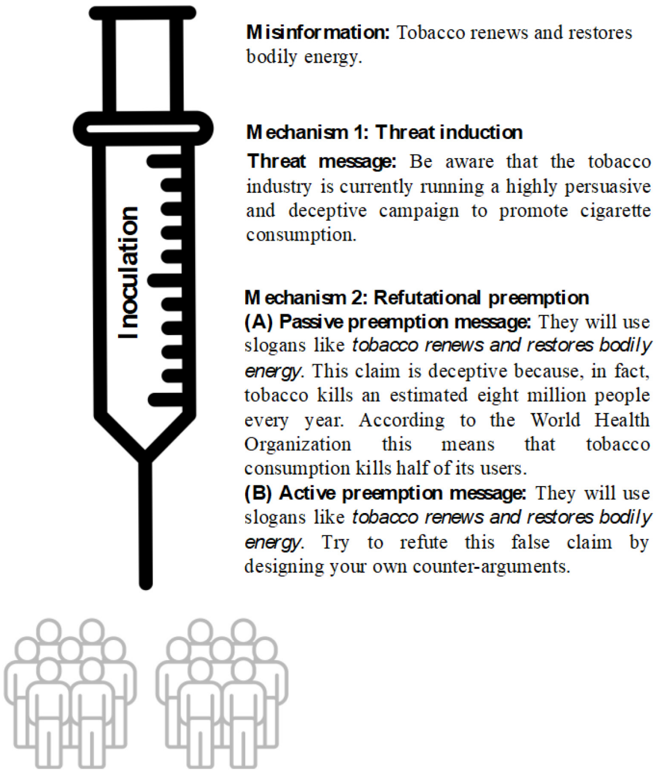

Figure 1: Example of an inoculation intervention to counter science denialism messages. In this example, the two primary mechanisms (threat induction and refutational preemption) of inoculation interventions are applied to the misinformation that tobacco renews and restores bodily energy.

The two outlined mechanisms of inoculation interventions were originally compared with the mechanisms of a biological vaccination —an analogy that gave the theory its name but also revealed important potential pitfalls for the designers of inoculation interventions (Banas & Rains, 2010; Compton, 2013). Biological vaccinations contain a weakened version of a virus that is just strong enough to trigger an immune response but not strong enough to cause the disease. In this analogy, inoculation interventions should contain persuasive messages that challenge the individual's attitudinal beliefs to facilitate resistance, but these messages should not be so strong that they induce the attitude change one sought to prevent (Compton, 2013). Moreover, a biological vaccination against a disease is considered disproportional if the population is not threatened by the disease. In this analogy, inoculating individuals against the misinformation that 'the HPV vaccine can cause cancer' (Bazilchuk, 2018) may raise unnecessary concerns about this highly recommended vaccination if the intervention itself remains the only source of this misinformation. Thus, before applying a biological or psychological vaccination, it is important to assess whether the risk of the vaccination outweighs the risk of the disease that it aims to prevent (Roozenbeek & van der Linden, 2019).

With the rise of the post-truth era, there was little doubt about the high risk for the general public to encounter misinformation (Iyengar & Massey, 2019; Lewandowsky et al., 2017; Vicario et al., 2016), and the concept of a *vaccine against fake news* seemed highly promising (van der Linden, Maibach, Cook, Leiserowitz, & Lewandowsky, 2017). Thus, researchers developed renewed interest for the inoculation theory and designed effective inoculation interventions that could increase resistance against specific messages of science denialism (van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017; Wong, 2016). The inoculation interventions of the post-truth era are based on the same mechanisms that McGuire described 50 years ago (McGuire, 1961a, 1961b). However, the design of inoculation interventions and the areas of application have experienced substantial changes (Banas & Rains, 2010). Interventions based on the inoculation theory were originally meant to induce resistance against attitudes that are widely accepted. McGuire argued that these so-called *cultural truisms* (e.g., vaccinations prevent diseases) are specifically prone to persuasive attacks because individuals would not expect an attack and would thus be unprepared to counter the persuasive message (Banas & Rains, 2010; McGuire, 1964). However, since then, inoculation interventions have been effectively applied to protect cultural truisms (e.g., vaccinations prevent diseases; Wong, 2016) just as well as more controversial beliefs (e.g., legalising marijuana; Pfau et al., 2009) and are now considered a universal approach to counter misinformation (Banas & Rains, 2010; Compton, 2013; Roozenbeek & van der Linden, 2019; van der Linden, Maibach, et al., 2017).

Inoculation: Psychological vaccines aim to make individuals resilient against the influence of misinformation prior to a persuasive attempt (Roozenbeek & van der Linden, 2019; van der Linden, Maibach et al., 2017). An individual is fully inoculated if she/he is motivated to resist change and equipped with appropriate counter-arguments against misinformation (Banas & Rains, 2010; Compton, Jackson, & Dimmock, 2016; McGuire, 1961a, 1961b).

Debunking Interventions. The inoculation theory informs on how to prebunk interventions (van der Linden, Leiserowitz et al., 2017). This means that health authorities will correct misinformation before the public even encounters it. But what if misinformation such as 'tobacco renews and restores bodily energy*'* is already circulating, and large parts of the general public tend to agree? Then, science advocates could try to correct this misinformation after its spread. That is, science advocates could try to debunk rather than prebunk misinformation (Chan, Jones, Hall Jamieson, & Albarracín, 2017). Guidance on how to design such reactive interventions is provided by the debunking approach from Cook and Lewandowsky (2011; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). Unlike inoculation interventions, debunking is not based on a single psychological theory but rather on the translation of isolated effects into best practices on how to correct misinformation.

According to the debunking approach, the designers of corrections should primarily comply with five recommendations from studies in the area of cognitive psychology: do not unnecessarily repeat misinformation but highlight the facts, include visualisations to support the facts, use explicit warnings to introduce the misinformation, avoid terms and statements that unnecessarily challenge individuals' worldviews and fill the gap that is created by the correction with alternative explanations (Figure 2; Cook & Lewandowsky, 2011). The latter recommendation is backed up by studies that have revealed an increased effectiveness of corrections 'through the provision of an alternative account that explains *why* the information was incorrect' (Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012, p. 117).The other four recommendations result from studies that have suggested that attempts to debunk misinformation 'can inadvertently reinforce the very myths one seeks to correct' (Cook & Lewandowsky, 2011, p. 1). Thus, in the worst case, trying to correct misinformation such as 'tobacco renews and restores bodily energy*'* may ironically increase the individual's belief in the healthiness of smoking. These unintended effects are widely referred to as *backfire effects* (Lewandowsky et al., 2012; Nyhan & Reifler, 2015; Schwarz, Sanna, Skurnik, & Yoon, 2007; Skurnik, Yoon, Park, & Schwarz, 2005). Thus, the first four recommendations of the debunking approach primarily seek to circumvent backfire effects, that are of particular relevance for the correction of misinformation. These are the *familiarity backfire effect* (Skurnik et al., 2005), the *overkill backfire effect* (Schwarz et al., 2007) and the *worldview backfire effect* (Nyhan & Reifler, 2010, 2015). The specific backfire effects are explained in detail below.

The familiarity backfire effect describes the finding that an individual's belief in misinformation can increase with increased repetition of the misinformation in a debunking attempt (Swire, Ecker, & Lewandowsky, 2017). Researchers have argued that this effect may be based on two primary cognitive processes, that is, the feeling of familiarity and the decay of negations (Peter & Koch, 2016; Swire et al., 2017). First, if individuals lack explicit knowledge about whether a statement is true or false, then these individuals tend to judge the truth of a message based on the ease with which the message comes to mind, that is, based on a feeling of familiarity (Begg, Anas, & Farinacci, 1992). Second, negations of messages are considered prone to decay (Swire et al., 2017). Thus, if a correction repeats misinformation (e.g., tobacco does *not* renew and restore bodily energy) then the misinformation (tobacco does … renew and restore bodily energy) can become more familiar, while the negation (…*not*…) is easily forgotten. As a consequence, the debunking approach recommends avoiding unnecessary repetitions of the misinformation that the science advocate aims to correct. For example, if a science advocate wants to debunk the science denialism message 'tobacco renews and restores bodily energy', then she/he should highlight the facts instead of the misinformation and should mention the misinformation only after an explicit warning of its falsehood (Figure 2; Cook & Lewandowsky, 2011).

The familiarity backfire effect is based on the fact that individuals often use shortcuts, so-called *heuristics*, to judge the truth of a message (Lewandowsky et al., 2012). However, familiarity is not the only heuristic used for such truth judgements. Individuals also tend to judge the truth of a message based on whether the message confirms or disconfirms with the individual's worldviews (Nyhan & Reifler, 2010). When individuals receive a debunking message that disconfirms their worldviews, they tend to protect their worldview and recollect counterarguments against the debunking (Cook & Lewandowsky, 2011). In the worst case, the debunking message triggers so many counterarguments that individuals are more convinced of their initial worldviews after receiving the debunking (Nyhan & Reifler, 2010). This unintended effect is known as the worldview backfire effect (Cook & Lewandowsky, 2011; Nyhan & Reifler, 2010, 2015). As a consequence, the debunking approach recommends avoiding terms and statements that unnecessarily challenge individuals' worldviews (Cook & Lewandowsky, 2011). For example, antismoking campaigns that are perceived to interfere with an individual's freedom of choice can in fact trigger unintended responses such as, 'All the ''truth'' campaign does is convince me that I should go outside and light up another cigarette' (Wolburg, 2006, p. 294). Thus, following the debunking approach, if a science advocate tries to correct 'tobacco renews and restores bodily energy', she/he should avoid authoritarian messages that talk down to smokers and should rather focus on facts and opportunities that help the individual quit smoking (Figure 2; Cook & Lewandowsky, 2011; Cortland, Shapiro, Guzman, & Ray, 2019).

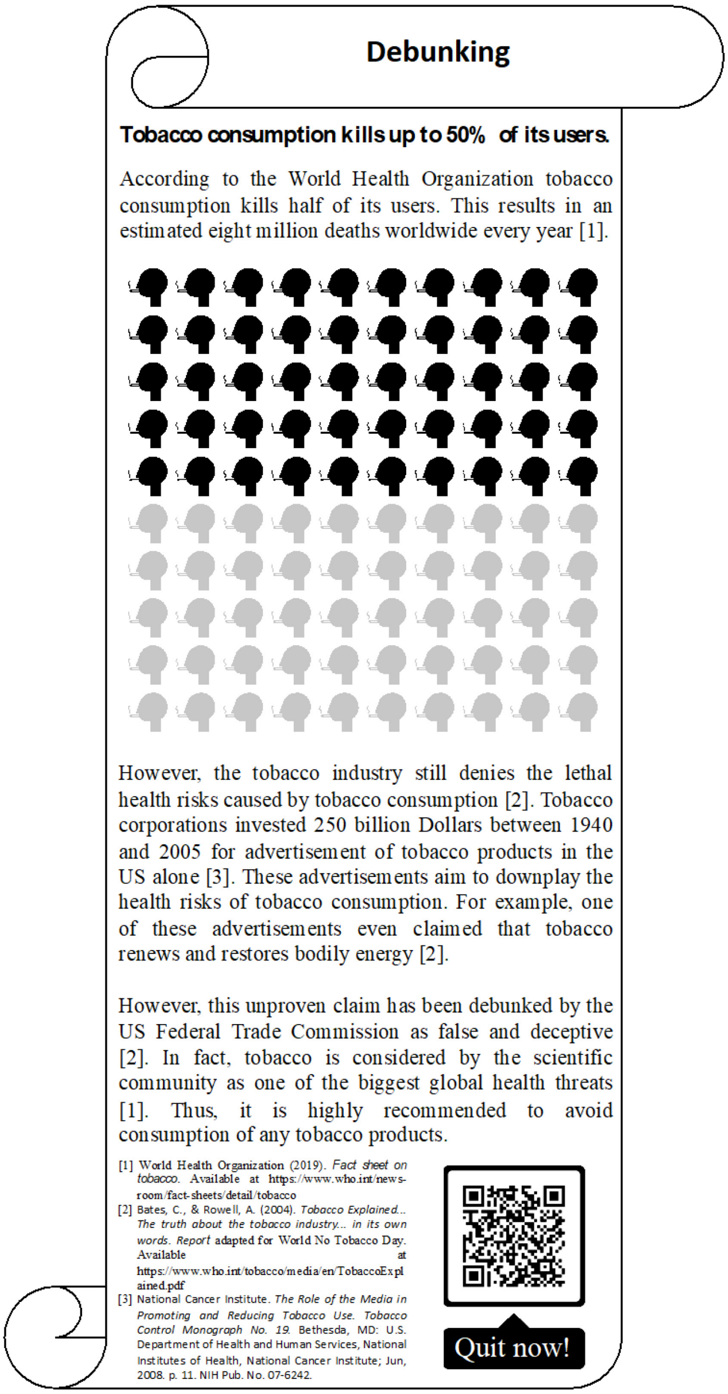

Figure 2: Example of a debunking intervention to counter science denialism messages. This example follows the guideline by Cook and Lewandowsky (2011), that is, do not unnecessarily repeat misinformation but highlights the facts, includes visualisations to support the facts, uses explicit warnings to introduce the misinformation and fills the gap created by the correction with alternative explanations. The guideline is applied to the misinformation that tobacco renews and restores bodily energy.

Research on the familiarity backfire effect and the worldview backfire effect have resulted in a recommendation to focus on the facts. It is thus tempting to believe that the more facts that are delivered, the more effective the correction will be (Ecker, Lewandowsky, Jayawardana, & Mladenovic, 2019). However, a study by Schwarz et al. (2007) revealed that the persuasiveness of messages can in fact increase when generating less rather than more arguments. This could imply that debunking approaches are less effective when the science advocate uses too many counterarguments compared with a concise debunking. This potential overkill backfire effect may occur because individuals prefer simple over complex information and thus neglect corrections if their complexity exceeds a certain threshold (Lewandowsky et al., 2012). Thus, the debunking approach recommends that corrections should follow a concise structure that reduces complexity and focuses on the most relevant facts rather than unreasonably containing everything an advocate knows about the issue (Cook & Lewandowsky, 2011). According to Cook and Lewandowsky (2011), the conciseness of a debunking can also be promoted by adding visuals that highlight the key facts and thus further reduce complexity (Figure 2).

Debunking interventions are generally considered an effective measure to counter misinformation (Chan et al., 2017). However, recent research has challenged whether the different backfire effects are actually a common threat when designing debunking interventions. In fact, given the new results on the familiarity (Ecker, Hogan, & Lewandowsky, 2017; Swire et al., 2017) worldview (Haglin, 2017; Wood & Porter, 2019) and overkill backfire effects (Ecker et al., 2019), the risk of unintended effects in science communication may be lower than previously thought. Future studies are needed to analyse under which conditions backfire effects are to be expected and if complex debunking interventions are always necessary. Until then, the debunking approach by Cook and Lewandowsky (2011) can still be considered the most concise and evidence-based approach on debunking available.

Debunking: The systematic correction of misinformation when individuals are already exposed to misinformation. Debunking interventions are in line with psychological best practices if they highlight the facts instead of the misinformation, provide explicit warnings about the misinformation, explain why the misinformation is incorrect in the first place and avoid terms and statements that unnecessarily challenge individuals' worldviews (Cook & Lewandowsky, 2011).

Outlook – Rebuttal Interventions. Inoculation and debunking interventions deal with misinformation before individuals encounter it and after its dissemination. But what if a science advocate has the opportunity to correct misinformation such as 'tobacco renews and restores bodily energy' in the very moment it is being spread, for example, in a live TV debate or in a discussion in social media? Then, science advocates could try to rebut misinformation. Advice on how to rebut science denialism messages and how to support rebuttal as a journalist (i.e., weight-of-evidence strategies) is outlined in the following articles that constitute the current dissertation. Figure 3 provides an outlook on how to apply the rebuttal approach when aiming to counter the misinformation that tobacco renews and restores bodily energy. Articles 1–3 focus on applying rebuttal and weight-of-evidence strategies to counter vaccination denialism and climate change denialism. As outlined above, these forms of denialism are specifically relevant because of their role in the post-truth era.

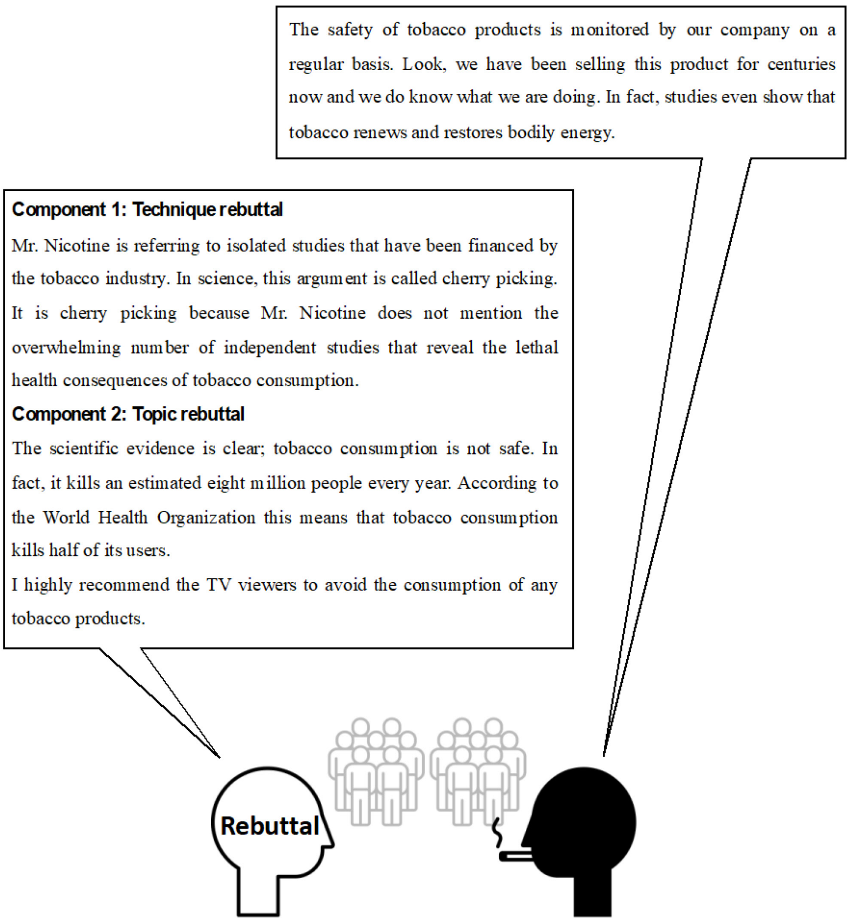

Figure 3: Example of a rebuttal intervention to counter science denialism messages. This example follows the WHO guideline on how to respond to vocal vaccine deniers (WHO, 2016), that is, unmask the technique the science denier is using (Component 1) and correct the content the science denier is addressing (Component 2). The guideline is applied to the misinformation that tobacco renews and restores bodily energy.

References

Allcott, H., Gentzkow, M., & Yu, C. (2019). Trends in the diffusion of misinformation on social media. *Research and Politics*. https://doi.org/10.1177/2053168019848554

Amin, A. B., Bednarczyk, R. A., Ray, C. E., Melchiori, K. J., Graham, J., Huntsinger, J. R., & Omer, S. B. (2017). Association of moral values with vaccine hesitancy. *Nature Human Behaviour*, *1*(12), 873–880. https://doi.org/10.1038/s41562-017-0256-5

Andre, F. E., Booy, R., Bock, H. L., Clemens, J., Datta, S. K., John, T. J., … Schmitt, H. J. (2008). Vaccination greatly reduces disease, disability, death and inequity worldwide. *Bulletin of the World Health Organization*, *86*(2), 140–146.

Arendt, H. (1961). Truth and Politics. In *Between Past and Future*. New York: The Viking Press.

Banas, J. A., & Rains, S. A. (2010). A meta-analysis of research on inoculation theory. *Communication Monographs*, *77*(3), 281–311. https://doi.org/10.1080/03637751003758193

Barnoya, J., & Glantz, S. A. (2006). The tobacco industry's worldwide ETS consultants project: European and Asian components. *European Journal of Public Health*, *16*(1), 69–77. https://doi.org/10.1093/eurpub/cki044

Bates, C., & Rowell, A. (2004). *Tobacco Explained - The truth about the tobacco industry...in its own words*. UC San Francisco. Retrieved from https://www.who.int/tobacco/media/en/TobaccoExplained.pdf

Bazilchuk, N. (2018, June 6). Fake researcher fabricated finding that HPV vaccine causes cervical cancer. *ScienceNordic*.

Beard, F., & Klyueva, A. (2010). George Washington Hill and the "Reach for a Lucky … " campaign. *Journal of Historical Research in Marketing*, *2*(2), 148–165. https://doi.org/10.1108/17557501011042524

Begg, I. M., Anas, A., & Farinacci, S. (1992). Dissociation of Processes in Belief: Source Recollection, Statement Familiarity, and the Illusion of Truth. *Journal of Experimental Psychology: General*. https://doi.org/10.1037/0096-3445.121.4.446

Bennett, P. B. (2015). *Logically Fallacious: The Ultimate Collection of Over 300 Logical Fallacies (Academic Edition)*. Retrieved from https://books.google.com/books?hl=en&lr=&id=WFvhN9lSm5gC&oi=fnd&pg=PT13&dq=bo+300+fallacies&ots=Sz1drpT8sy&sig=1LdzgRmLXCCiYxUG84wufpAeQCw

Bero, L. A. (2005). Tobacco industry manipulation of research. *Public Health Reports*, *120*(2), 200–208. https://doi.org/10.1177/003335490512000215

Best, J. (1979). Economic Interests and the Vindication of Deviance: Tobacco in Seventeenth Century Europe. *Sociological Quarterly*, *20*(2), 171–182. https://doi.org/10.1111/j.1533-8525.1979.tb01207.x

Betsch, C., Haase, N., Renkewitz, F., & Schmid, P. (2015). The narrative bias revisited: What drives the biasing influence of narrative information on risk perceptions? *Judgment and Decision Making*, *10*(3), 241–264.

Betsch, C., Renkewitz, F., Betsch, T., & Ulshöfer, C. (2010). The influence of vaccine-critical websites on perceiving vaccination risks. *Journal of Health Psychology*. https://doi.org/10.1177/1359105309353647

Betsch, C., Renkewitz, F., & Haase, N. (2013). Effect of narrative reports about vaccine adverse events and bias-awareness disclaimers on vaccine decisions: A simulation of an online patient social Network. *Medical Decision Making*, *33*(1), 14–25. https://doi.org/10.1177/0272989X12452342

Björnberg, K. E., Karlsson, M., Gilek, M., & Hansson, S. O. (2017). Climate and environmental science denial: A review of the scientific literature published in 1990–2015. *Journal of Cleaner Production*, *167*, 229–

241. https://doi.org/10.1016/J.JCLEPRO.2017.08.066

Bode, A. M., & Dong, Z. (2009, July). Cancer prevention research then and now. *Nature Reviews Cancer*. NIH Public Access. https://doi.org/10.1038/nrc2646

Bor, J., Herbst, A. J., Newell, M. L., & Bärnighausen, T. (2013). Increases in adult life expectancy in rural South Africa: Valuing the scale-up of HIV treatment. *Science*, *339*(6122), 961–965. https://doi.org/10.1126/science.1230413

Boudana, S. (2016). Impartiality is not fair: Toward an alternative approach to the evaluation of content bias in news stories. *Journalism*, *17*(5), 600–618. https://doi.org/10.1177/1464884915571295

Boutron, I., & Ravaud, P. (2018). Misrepresentation and distortion of research in biomedical literature. *Proceedings of the National Academy of Sciences of the United States of America*, *115*(11), 2613–2619. https://doi.org/10.1073/pnas.1710755115

Brandt, A. M. (2012, January). Inventing conflicts of interest: A history of Tobacco industry tactics. *American Journal of Public Health*. American Public Health Association. https://doi.org/10.2105/AJPH.2011.300292

Brown & Williamson Tobacco Corporation. (1969). Internal Memo. Retrieved from https://www.industrydocuments.ucsf.edu/docs/xqkd0134

Brüggemann, M., & Engesser, S. (2017). Beyond false balance: How interpretive journalism shapes media coverage of climate change. *Global Environmental Change*, *42*, 58–67. https://doi.org/10.1016/j.gloenvcha.2016.11.004

Cargile, J. (1997). On the burden of proof. *Philosophy*, *72*(279), 59–83. https://doi.org/10.1017/S0031819100056655

Carmichael, J. T., & Brulle, R. J. (2017). Elite cues, media coverage, and public concern: an integrated path analysis of public opinion on climate change, 2001–2013. *Environmental Politics*, *26*(2), 232–252. https://doi.org/10.1080/09644016.2016.1263433

Chan, M. pui S., Jones, C. R., Hall Jamieson, K., & Albarracín, D. (2017). Debunking: A Meta-Analysis of the Psychological Efficacy of Messages Countering Misinformation. *Psychological Science*. https://doi.org/10.1177/0956797617714579

Charo, R. A. (2007). Politics, parents, and prophylaxis - Mandating HPV vaccination in the United States. *New England Journal of Medicine*. https://doi.org/10.1056/NEJMp078054

Chigwedere, P., & Essex, M. (2010). AIDS Denialism and Public Health Practice. *AIDS and Behavior*, *14*(2), 237–247. https://doi.org/10.1007/s10461-009-9654-7

Chigwedere, P., Seage, G. R., Gruskin, S., Lee, T.-H., & Essex, M. (2008). Estimating the Lost Benefits of Antiretroviral Drug Use in South Africa. *JAIDS Journal of Acquired Immune Deficiency Syndromes*, *49*(4), 410–415. https://doi.org/10.1097/QAI.0b013e31818a6cd5

Clayton, S., Manning, C. M., Krygsman, K., & Speiser, M. (2017). *Mental Health and Our Changing Climate: Impacts, Implications, and Guidance.* Washington D.C.

Collomb, J.-D. (2014). The Ideology of Climate Change Denial in the United States. *European Journal of American Studies*, *9*(1). https://doi.org/10.4000/ejas.10305

Compton, J. (2013). Inoculation theory. In *The Sage handbook of persuasion: Developments in theory and practice* (pp. 220–237).

Compton, J., & Ivanov, B. (2012). Untangling threat during inoculation-conferred resistance to influence.

Communication Reports, *25*(1), 1–13. https://doi.org/10.1080/08934215.2012.661018

Compton, J., Jackson, B., & Dimmock, J. A. (2016). Persuading others to avoid persuasion: Inoculation theory and resistant health attitudes. *Frontiers in Psychology*, *7*. Retrieved from http://search.ebscohost.com/login.aspx?direct=true&db=psyh&AN=2016-19527-001&lang=de&site=ehost-live

Cook, J. (2019). Understanding and Countering Misinformation About Climate Change. In *Handbook of Research on Deception, Fake News, and Misinformation Online* (pp. 281–306). https://doi.org/10.4018/978-1-5225-8535-0.ch016

Cook, J., Ellerton, P., & Kinkead, D. (2018). Deconstructing climate misinformation to identify reasoning errors. *Environmental Research Letters*, *13*(2). https://doi.org/10.1088/1748-9326/aaa49f

Cook, J., & Lewandowsky, S. (2011). The debunking handbook. *Scientist*, 9.

Cook, J., Lewandowsky, S., & Ecker, U. K. H. (2017). Neutralizing misinformation through inoculation: Exposing misleading argumentation techniques reduces their influence. *PLoS ONE*, *12*(5), e0175799. https://doi.org/10.1371/journal.pone.0175799

Corbett, J. B., & Durfee, J. L. (2004). Testing public (Un)certainty of science: Media representations of global warming. *Science Communication*, *26*(2), 129–151. https://doi.org/10.1177/1075547004270234

Cortland, C. I., Shapiro, J. R., Guzman, I. Y., & Ray, L. A. (2019). The ironic effects of stigmatizing smoking: combining stereotype threat theory with behavioral pharmacology. *Addiction*. https://doi.org/10.1111/add.14696

Cummings, K. M., & Proctor, R. N. (2014, January). The changing public image of smoking in the United States: 1964-2014. *Cancer Epidemiology Biomarkers and Prevention*. NIH Public Access. https://doi.org/10.1158/1055-9965.EPI-13-0798

Darwin Correspondence Project. (2006). Letter no. 2109. Retrieved December 19, 2019, from https://www.darwinproject.ac.uk/letter/DCP-LETT-2109.xml

Darwin Correspondence Project. (2016). Six things Darwin never said – and one he did | Darwin Correspondence Project. Retrieved December 19, 2019, from https://www.darwinproject.ac.uk/people/about-darwin/six-things-darwin-never-said

Davies, P., Chapman, S., & Leask, J. (2002). Antivaccination activists on the world wide web. *Archives of Disease in Childhood*. https://doi.org/10.1136/adc.87.1.22

Del Vicario, M., Vivaldo, G., Bessi, A., Zollo, F., Scala, A., Caldarelli, G., & Quattrociocchi, W. (2016). Echo Chambers: Emotional Contagion and Group Polarization on Facebook. *Scientific Reports*, *6*. https://doi.org/10.1038/srep37825

Dentith, M. R. X. (2014). Evidence and Conspiracy Theories. In M. R. X. Dentith (Ed.), *The Philosophy of Conspiracy Theories* (pp. 124–143). London: Palgrave Macmillan UK. https://doi.org/10.1057/9781137363169_9

Diethelm, P., & McKee, M. (2009). Denialism: What is it and how should scientists respond? *European Journal of Public Health*. Oxford University Press. https://doi.org/10.1093/eurpub/ckn139

Dixon, G. N., & Clarke, C. E. (2013). The effect of falsely balanced reporting of the autism-vaccine controversy on vaccine safety perceptions and behavioral intentions. *Health Education Research*, *28*(2), 352–359. Retrieved from https://academic.oup.com/her/article-abstract/28/2/352/595490

Douglas, K. M., Sutton, R. M., & Cichocka, A. (2017). The psychology of conspiracy theories. *Current*

Directions in Psychological Science, *26*(6), 538–542. https://doi.org/10.1177/0963721417718261

Douglas, K. M., Uscinski, J. E., Sutton, R. M., Cichocka, A., Nefes, T., Ang, C. S., & Deravi, F. (2019). Understanding Conspiracy Theories. *Political Psychology*, *40*(S1), 3–35. https://doi.org/10.1111/pops.12568

Drope, J., & Chapman, S. (2001). Tobacco industry efforts at discrediting scientific knowledge of environmental tobacco smoke: A review of internal industry documents. *Journal of Epidemiology and Community Health*, *55*(8), 588–594. https://doi.org/10.1136/jech.55.8.588

Dryzek, J. S., Norgaard, R. B., & Schlosberg, D. (2012). *The Oxford handbook of climate change and society*. *The Oxford Handbook of Climate Change and Society*. https://doi.org/10.1093/oxfordhb/9780199566600.001.0001

Dunlap, R. E. (2013). Climate Change Skepticism and Denial: An Introduction. *American Behavioral Scientist*, *57*(6), 691–698. https://doi.org/10.1177/0002764213477097

Durnová, A. (2019). Der ‚March for Science' als Schauplatz der gesellschaftspolitischen Polarisierung zwischen Elite und Volk: ein interpretativer Beitrag zur Analyse von Postfaktizität. *Zeitschrift Für Politikwissenschaft*. https://doi.org/10.1007/s41358-019-00186-3

Dyer, O. (2016, December 5). Andrew Wakefield calls Trump "on our side" over vaccines after meeting. *BMJ (Clinical Research Ed.)*. British Medical Journal Publishing Group. https://doi.org/10.1136/bmj.i6545

Eagly, A. H., & Chaiken, S. (1993). *The psychology of attitudes*. Harcourt Brace Jovanovich College Publishers.

Ecker, U. K. H., Hogan, J. L., & Lewandowsky, S. (2017). Reminders and Repetition of Misinformation: Helping or Hindering Its Retraction? *Journal of Applied Research in Memory and Cognition*, *6*(2), 185–192. https://doi.org/10.1016/j.jarmac.2017.01.014

Ecker, U. K. H., Lewandowsky, S., Jayawardana, K., & Mladenovic, A. (2019). Refutations of Equivocal Claims: No Evidence for an Ironic Effect of Counterargument Number. *Journal of Applied Research in Memory and Cognition*, *8*(1), 98–107. https://doi.org/10.1016/j.jarmac.2018.07.005

Ernster, V., & Burns, D. (1984). A rebuttal to the tobacco industry's paper, "cigarette smoke and the nonsmoker." *Journal of Public Health Policy*, *5*(3), 368–375. https://doi.org/10.2307/3342161

European Comission. (2019). Tackling online disinformation. Retrieved from https://ec.europa.eu/digital-single-market/en/tackling-online-disinformation

Fielding, K. S., Head, B. W., Laffan, W., Western, M., & Hoegh-Guldberg, O. (2012). Australian politicians' beliefs about climate change: Political partisanship and political ideology. *Environmental Politics*. https://doi.org/10.1080/09644016.2012.698887

Gallup. (2019). *Wellcome Global Monitor – First Wave Findings*.

Gifford, R. (2011). The Dragons of Inaction: Psychological Barriers That Limit Climate Change Mitigation and Adaptation. *American Psychologist*, *66*(4), 290–302. https://doi.org/10.1037/a0023566

Gilens, M., & Murakawa, N. (2002). *Elite Cues and Political Decision-Making*. *Political Decision-Making, Deliberation and Participation*.

Goldman, A. (2001). Experts: Which Ones Should You Trust? *Philosophy and Phenomenological Research*, *63*(1), 85–110. https://doi.org/10.1111/j.1933-1592.2001.tb00093.x

Gollust, S. E., Attanasio, L., Dempsey, A., Benson, A. M., & Fowler, E. F. (2013). Political and News Media Factors Shaping Public Awareness of the HPV Vaccine. *Women's Health Issues*. https://doi.org/10.1016/j.whi.2013.02.001

Gorard, S. (2002). Fostering scepticism: The importance of warranting claims. *Evaluation and Research in Education*, *16*(3), 136–149. https://doi.org/10.1080/09500790208667014

Grimes, D. R. (2016). On the viability of conspiratorial beliefs. *PLoS ONE*, *11*(1), e0147905. https://doi.org/10.1371/journal.pone.0147905

Gurajala, S., White, J. S., Hudson, B., Voter, B. R., & Matthews, J. N. (2016). Profile characteristics of fake Twitter accounts. *Big Data and Society*, *3*(2), 205395171667423. https://doi.org/10.1177/2053951716674236

Haase, N., Betsch, C., & Renkewitz, F. (2015). Source Credibility and the Biasing Effect of Narrative Information on the Perception of Vaccination Risks. *Journal of Health Communication*, *20*(8), 920–929. https://doi.org/10.1080/10810730.2015.1018605

Haglin, K. (2017). The limitations of the backfire effect. *Research and Politics*. https://doi.org/10.1177/2053168017716547

Häkkinen, K., & Akrami, N. (2014). Ideology and climate change denial. *Personality and Individual Differences*, *70*, 62–65. https://doi.org/10.1016/j.paid.2014.06.030

Hameleers, M., & van der Meer, T. G. L. A. (2019). Misinformation and Polarization in a High-Choice Media Environment: How Effective Are Political Fact-Checkers? *Communication Research*. https://doi.org/10.1177/0093650218819671

Hamilton, L. C., Hartter, J., Lemcke-Stampone, M., Moore, D. W., & Safford, T. G. (2015). Tracking Public Beliefs About Anthropogenic Climate Change. *PLOS ONE*, *10*(9), e0138208. https://doi.org/10.1371/journal.pone.0138208

Hansson, S. O. (2017). Science denial as a form of pseudoscience. *Studies in History and Philosophy of Science Part A*, *63*, 39–47. https://doi.org/10.1016/j.shpsa.2017.05.002

Hansson, S. O. (2018). Dealing with climate science denialism: experiences from confrontations with other forms of pseudoscience. *Climate Policy*, *18*(9), 1094–1102. https://doi.org/10.1080/14693062.2017.1415197

Hoffman, B. L., Felter, E. M., Chu, K. H., Shensa, A., Hermann, C., Wolynn, T., … Primack, B. A. (2019). It's not all about autism: The emerging landscape of anti-vaccination sentiment on Facebook. *Vaccine*. https://doi.org/10.1016/j.vaccine.2019.03.003

Hornsey, M. J., & Fielding, K. S. (2017). Attitude roots and jiu jitsu persuasion: Understanding and overcoming the motivated rejection of science. *American Psychologist*, *72*(5), 459–473. https://doi.org/10.1037/a0040437

Iyengar, S., & Massey, D. S. (2019). Scientific communication in a post-truth society. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(16), 7656–7661. https://doi.org/10.1073/pnas.1805868115

Kahan, D. M., Peters, E., Wittlin, M., Slovic, P., Ouellette, L. L., Braman, D., & Mandel, G. (2012). The polarizing impact of science literacy and numeracy on perceived climate change risks. *Nature Climate Change*, *2*(10), 732–735. https://doi.org/10.1038/nclimate1547

Kalichman, S. C. (2014). The psychology of AIDS denialism: Pseudoscience, conspiracy thinking, and medical mistrust. *European Psychologist*, *19*(1), 13–22. https://doi.org/10.1027/1016-9040/a000175

Kata, A. (2012). Anti-vaccine activists, Web 2.0, and the postmodern paradigm--an overview of tactics and tropes used online by the anti-vaccination movement. *Vaccine*, *30*(25), 3778–3789.

https://doi.org/10.1016/j.vaccine.2011.11.112

Kaufman, A. B., & Kaufman, J. C. (2018). *Pseudoscience: The conspiracy against science*. *Pseudoscience: The Conspiracy against Science*. Retrieved from https://scholar.google.com/scholar?hl=en&as_sdt=0%2C5&q=pseudoscience+the+conspiracy+against+science&btnG=

Keeley, B. L. (1999). Of Conspiracy Theories. *The Journal of Philosophy*, *96*(3), 109–126. https://doi.org/10.4324/9781315259574-4

Kemp, J., Milne, R., & Reay, D. S. (2010). Sceptics and deniers of climate change not to be confused. *Nature*. https://doi.org/10.1038/464673a

Kennedy, J. (2019). Populist politics and vaccine hesitancy in Western Europe: An analysis of national-level data. *European Journal of Public Health*, *29*(3), 512–516. https://doi.org/10.1093/eurpub/ckz004

Koehler, D. (2016). Can Journalistic "False Balance" Distort Public Perception of Consensus in Expert Opinion? *Journal of Experimental Psychology. Applied*, *22*(1), 24–38. Retrieved from https://psycnet.apa.org/record/2016-00600-001

Kruger, J., & Dunning, D. (1999). Unskilled and unaware of it: How difficulties in recognizing one's own incompetence lead to inflated self-assessments. *Journal of Personality and Social Psychology*, *77*(6), 1121–1134. https://doi.org/10.1037/0022-3514.77.6.1121

Landman, A., & Glantz, S. A. (2009). Tobacco industry efforts to undermine policy-relevant research. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.2007.130740

Landrum, A. R., Olshansky, A., & Richards, O. (2019). Differential susceptibility to misleading flat earth arguments on youtube. *Media Psychology*, 1–30. https://doi.org/10.1080/15213269.2019.1669461

Lanoszka, A. (2019). Disinformation in international politics. *European Journal of International Security*, *4*(2), 227–248. https://doi.org/10.1017/eis.2019.6

Larson, H. J. (2018). The biggest pandemic risk? Viral misinformation. *Nature*. https://doi.org/10.1038/d41586-018-07034-4

Lee, C. J., Sugimoto, C. R., Zhang, G., & Cronin, B. (2013). Bias in peer review. *Journal of the American Society for Information Science and Technology*. John Wiley & Sons, Ltd. https://doi.org/10.1002/asi.22784

Lehmkuhl, M., & Leidecker-Sandmann, M. (2019). „Visible scientists revisited": Zum Zusammenhang von wissenschaftlicher Reputation und der Präsenz wissenschaftlicher Experten in der Medienberichterstattung über Infektionskrankheiten"Visible scientists revisited": on the relationship between scientific . *Publizistik*, *64*(4), 479–502. https://doi.org/10.1007/s11616-019-00530-1

Leman, P. J., & Cinnirella, M. (2013). Beliefs in conspiracy theories and the need for cognitive closure. *Frontiers in Psychology*, *4*, 378. https://doi.org/10.3389/fpsyg.2013.00378

Lewandowsky, S., Ecker, U. K. H., & Cook, J. (2017). Beyond Misinformation: Understanding and Coping with the "Post-Truth" Era. *Journal of Applied Research in Memory and Cognition*, *6*(4), 353–369. https://doi.org/10.1016/j.jarmac.2017.07.008

Lewandowsky, S., Ecker, U. K. H., Seifert, C. M., Schwarz, N., & Cook, J. (2012). Misinformation and Its Correction: Continued Influence and Successful Debiasing. *Psychological Science in the Public Interest, Supplement*, *13*(3), 106–131. https://doi.org/10.1177/1529100612451018

Lewandowsky, S., Mann, M. E., Brown, N. J. L., & Friedman, H. (2016). Science and the public: Debate, denial, and skepticism. *Journal of Social and Political Psychology*, *4*(2), 537–553. https://doi.org/10.5964/jspp.v4i2.604

Lewandowsky, S., & Oberauer, K. (2016). Motivated Rejection of Science. *Current Directions in Psychological Science*, *25*(4), 217–222. https://doi.org/10.1177/0963721416654436

Lewandowsky, S., Oberauer, K., & Gignac, G. E. (2013). NASA Faked the Moon Landing—Therefore, (Climate) Science Is a Hoax. *Psychological Science*, *24*(5), 622–633. https://doi.org/10.1177/0956797612457686

Lewandowsky, S., Stritzke, W. G. K., Freund, A. M., Oberauer, K., & Krueger, J. I. (2013). Misinformation, disinformation, and violent conflict: From iraq and the "war on terror" to future threats to peace. *American Psychologist*, *68*(7), 487–501. https://doi.org/10.1037/a0034515

Liu, D. W. C. (2012). Science denial and the science classroom. *CBE Life Sciences Education*, *11*(2), 129–134. https://doi.org/10.1187/cbe.12-03-0029

Lobato, E., Mendoza, J., Sims, V., & Chin, M. (2014). Examining the Relationship Between Conspiracy Theories, Paranormal Beliefs, and Pseudoscience Acceptance Among a University Population. *Applied Cognitive Psychology*, *28*(5), 617–625. https://doi.org/10.1002/acp.3042

Lockwood, M. (2018). Right-wing populism and the climate change agenda: exploring the linkages. *Environmental Politics*. https://doi.org/10.1080/09644016.2018.1458411

MacKenzie, A., & Bhatt, I. (2018). Lies, Bullshit and Fake News: Some Epistemological Concerns. *Postdigital Science and Education*. https://doi.org/10.1007/s42438-018-0025-4

Mann, B. W. (2019). Autism Narratives in Media Coverage of the MMR Vaccine-Autism Controversy under a Crip Futurism Framework. *Health Communication*, *34*(9), 984–990. https://doi.org/10.1080/10410236.2018.1449071

Maras, M. H., & Alexandrou, A. (2019). Determining authenticity of video evidence in the age of artificial intelligence and in the wake of Deepfake videos. *International Journal of Evidence and Proof*, *23*(3), 255–262. https://doi.org/10.1177/1365712718807226

Marzouk, S., & Choi, H. (2019). *What does the next 25 years hold for global health?* London.

Mazo, J. (2013). Climate Change: Strategies of Denial. *Survival*, *55*(4), 41–49. https://doi.org/10.1080/00396338.2013.823019

McGarity, T., & Wagner, W. (2008). *Bending science: How special interests corrupt public health research*. Cambridge, Massachusetts, London: Harvard University Press. Retrieved from https://books.google.com/books?hl=en&lr=&id=Ah6-__otORAC&oi=fnd&pg=PR7&dq=Bending+Science:+How+Special+Interests+Corrupt+Public+Health+Research&ots=TpesgwX6no&sig=-UAGoRwy8TcdRsQSRUJh_ZaynQk

McGuire, W. (1964). Inducing Resistance to Persuasion. Some Contemporary Approaches. *Advances in Experimental Social Psychology*, *1*, 192–230.

McGuire, W. J. (1961a). Resistance to persuasion conferred by active and passive prior refutation of the same and alternative counterarguments. *The Journal of Abnormal and Social Psychology*, *63*(2), 326–332. https://doi.org/10.1037/h0048344

McGuire, W. J. (1961b). The Effectiveness of Supportive and Refutational Defenses in Immunizing and Restoring Beliefs Against Persuasion. *Sociometry*, *24*(2), 184. https://doi.org/10.2307/2786067

McGuire, W. J., & Papageorgis, D. (1962). Effectiveness of Forewarning in Developing Resistance to

Persuasion. *Public Opinion Quarterly*, *26*(1), 24. https://doi.org/10.1086/267068

McKee, M., & Diethelm, P. (2010). How the growth of denialism undermines public health. *BMJ*, *341*.

McLaughlin, A. C., & McGill, A. E. (2017). Explicitly Teaching Critical Thinking Skills in a History Course. *Science and Education*, *26*(1–2), 93–105. https://doi.org/10.1007/s11191-017-9878-2

Meyer-Weitz, A. (2005). Understanding fatalism in HIV/AIDS protection: The individual in dialogue with contexual factors. *African Journal of AIDS Research*, *4*(2), 75–82. https://doi.org/10.2989/16085900509490345

Muggli, M. E., Ebbert, J. O., Robertson, C., & Hurt, R. D. (2008). Waking a sleeping giant: The tobacco industry's response to the polonium-210 issue. *American Journal of Public Health*, *98*(9), 1643–1650. https://doi.org/10.2105/AJPH.2007.130963

Murphy, K. R., & Aguinis, H. (2019). HARKing: How Badly Can Cherry-Picking and Question Trolling Produce Bias in Published Results? *Journal of Business and Psychology*, *34*(1), 1–17. https://doi.org/10.1007/s10869-017-9524-7

Najera, R. F. (2019). The College of Physicians of Philadelphia - Randomized Clinical Trials for Vaccine Safety, Efficacy and Effectiveness | History of Vaccines. Retrieved December 19, 2019, from https://www.historyofvaccines.org/content/blog/vaccine-randomized-clinical-trials

National Cancer Institute. (2008). The role of the media in promoting and reducing tobacco use. *Tobacco Control Monograph No 19: The Role of the Media in Promoting and Reducing Tobacco Use*.

Nickerson, R. S. (1998). Confirmation bias: A ubiquitous phenomenon in many guises. *Review of General Psychology*, *2*(2), 175–220. https://doi.org/10.1037/1089-2680.2.2.175

Nisbet, E. C., Cooper, K. E., & Garrett, R. K. (2015). The Partisan Brain: How Dissonant Science Messages Lead Conservatives and Liberals to (Dis)Trust Science. *Annals of the American Academy of Political and Social Science*. https://doi.org/10.1177/0002716214555474

Nygren, T. (2017). Mass youth experiment about source criticism. Retrieved from https://www.uu.se/en/media/news/article/?id=8798&typ=artikel

Nyhan, B., & Reifler, J. (2010). When corrections fail: The persistence of political misperceptions. *Political Behavior*, *32*(2), 303–330. https://doi.org/10.1007/s11109-010-9112-2

Nyhan, B., & Reifler, J. (2015). Does correcting myths about the flu vaccine work? An experimental evaluation of the effects of corrective information. *Vaccine*, *33*(3), 459–464. Retrieved from http://www.embase.com/search/results?subaction=viewrecord&from=export&id=L601971812

Oliver, J. E., & Wood, T. (2014). Medical conspiracy theories and health behaviors in the United States. *JAMA Internal Medicine*. https://doi.org/10.1001/jamainternmed.2014.190

Ong, E., & Glantz, S. (2000). Tobacco Industry Effort Subverting the International Agency for Research on Cancer's Secondhand Smoke Study. *Lancet*, *355*, 1253–1259. Retrieved from https://www.sciencedirect.com/science/article/pii/S0140673600020985

Ong, E., & Glantz, S. (2001). Constructing "sound science" and "good epidemiology": Tobacco, lawyers, and public relations firms. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.91.11.1749

Oreskes, N., & Conway, E. (2011). Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming.

Oxford University Press. (2019a). Misinformation | Meaning of Misinformation. Retrieved December 15, 2019, from https://www.lexico.com/definition/misinformation

Oxford University Press. (2019b). Disinformation | Meaning of Disinformation. Retrieved December 15, 2019, from https://www.lexico.com/definition/disinformation

Oxford University Press. (2019c). Misrepresentation | Meaning of Misrepresentation. Retrieved December 18, 2019, from https://www.lexico.com/definition/misrepresentation

Peter, C., & Koch, T. (2016). When Debunking Scientific Myths Fails (and When It Does Not). *Science Communication*. https://doi.org/10.1177/1075547015613523

Petersen, A. M., Vincent, E. M., & Westerling, A. L. (2019). Discrepancy in scientific authority and media visibility of climate change scientists and contrarians. *Nature Communications*, *10*(1), 3502. https://doi.org/10.1038/s41467-019-09959-4

Petrilli, C. M., Saint, S., Jennings, J. J., Caruso, A., Kuhn, L., Snyder, A., & Chopra, V. (2018). Understanding patient preference for physician attire: A cross-sectional observational study of 10 academic medical centres in the USA. *BMJ Open*, *8*(5). https://doi.org/10.1136/bmjopen-2017-021239

Pew Research Center. (2015). *Global Concern about Climate Change, Broad Support for Limiting Emissions*.

Pfau, M., Tusing, J., Koerner, A. F., Lee, W., Godbold, L. C., Penaloza, L. J., … Hong, Y. Y.-H. (1997). Enriching the Inoculation Construct The Role of Critical Components in the Process of Resistance. *Human Communication Research*, *24*(2), 187–215. https://doi.org/10.1111/j.1468-2958.1997.tb00413.x

Pfau, M., Semmler, S. M., Deatrick, L., Mason, A., Nisbett, G., Lane, L., … Banas, J. (2009). Nuances about the role and impact of affect in inoculation. *Communication Monographs*, *76*(1), 73–98. https://doi.org/10.1080/03637750802378807

Poland, G. A., & Jacobson, R. M. (2011). The age-old struggle against the antivaccinationists. *The New England Journal of Medicine*, *364*(2), 97–99. https://doi.org/10.1056/NEJMp1010594

Proctor, R. N. (2012a). *Golden holocaust: Origins of the cigarette catastrophe and the case for abolition*. *Golden Holocaust: Origins of the Cigarette Catastrophe and the Case for Abolition*. University of California Press. https://doi.org/10.1136/medhum-2012-010202

Proctor, R. N. (2012b). The history of the discovery of the cigaretteelung cancer link: Evidentiary traditions, corporate denial, global toll. *Tobacco Control*, *21*(2), 87–91. https://doi.org/10.1136/tobaccocontrol-2011-050338

Quattrociocchi, W., Scala, A., & Sunstein, C. R. (2018). Echo Chambers on Facebook. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2795110

Rakow, T., Heard, C. L., & Newell, B. R. (2015). Meeting Three Challenges in Risk Communication: Phenomena, Numbers, and Emotions. *Policy Insights from the Behavioral and Brain Sciences*, *2*(1), 147–156. https://doi.org/10.1177/2372732215601442

Reay, D. S. (2010). Lessons from climategate. *Nature*, *467*(7312), 157. https://doi.org/10.1038/467157a

Ricciardi, A., & Ryan, R. (2018). Invasive species denialism revisited: response to Sagoff. *Biological Invasions*, *20*(10), 2731–2738. https://doi.org/10.1007/s10530-018-1753-9

Rid, A., Saxena, A., Baqui, A. H., Bhan, A., Bines, J., Bouesseau, M. C., … Smith, P. G. (2014). Placebo use in vaccine trials: Recommendations of a WHO expert panel. *Vaccine*, *32*(37), 4708–4712. https://doi.org/10.1016/j.vaccine.2014.04.022

Roozenbeek, J., & van der Linden, S. (2019). Fake news game confers psychological resistance against online misinformation. *Palgrave Communications*, *5(1)*(12). Retrieved from https://www.nature.com/articles/s41599-019-0279-9

Royal College of Physicians. (1962). *Smoking and Health*. London.

Saad, L. (1998). A half-century of polling on tobacco: most don't like smoking but tolerate it. *Public Perspective*, *9*(5), 1–4.

Schäfer, M. (2011). Science journalism and fact checking. *Journal of Science Communication*. https://doi.org/10.22323/2.10040302

Schmid, P., & Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nature Human Behaviour*. https://doi.org/10.17605/OSF.IO/XX2KT

Schmidt, A. L., Zollo, F., Scala, A., Betsch, C., & Quattrociocchi, W. (2018). Polarization of the vaccination debate on Facebook. *Vaccine*. https://doi.org/10.1016/j.vaccine.2018.05.040

Schudson, M. (2001). The objectivity norm in American journalism. *Journalism*, *2*(2), 149–170. https://doi.org/10.1177/146488490100200201

Schwarz, N., Sanna, L. J., Skurnik, I., & Yoon, C. (2007). Metacognitive Experiences and the Intricacies of Setting People Straight: Implications for Debiasing and Public Information Campaigns. *Advances in Experimental Social Psychology*. https://doi.org/10.1016/S0065-2601(06)39003-X

Scullard, P., Peacock, C., & Davies, P. (2010). Googling children's health: Reliability of medical advice on the internet. *Archives of Disease in Childhood*. https://doi.org/10.1136/adc.2009.168856

Skeptical Science. (2019). Arguments from Global Warming Skeptics and what the science really says. Retrieved December 16, 2019, from https://skepticalscience.com/argument.php

Skurnik, I., Yoon, C., Park, D. C., & Schwarz, N. (2005). How Warnings about False Claims Become Recommendations. *Journal of Consumer Research*, *31*(4), 713–724. https://doi.org/10.1086/426605

Sobo, E. J. (2015). Social Cultivation of Vaccine Refusal and Delay among Waldorf (Steiner) School Parents. *Medical Anthropology Quarterly*, *29*(3), 381–399. https://doi.org/10.1111/maq.12214

Southwell, B., Thorson, E., & Sheble, L. (2018). *Misinformation and mass audiences*. (B. Southwell, E. Thorson, & L. Sheble, Eds.) (1st ed.). Texas: University of Texas Press. Retrieved from https://books.google.com/books?hl=en&lr=&id=jUw7DwAAQBAJ&oi=fnd&pg=PR9&dq=Southwell,+Thorson+and+Sheble+misinformation+and+mass+audiences&ots=Cu6VojC9G5&sig=jFFu9EKWNCySTjqsyhDh_36LV2M

Stirling, A. (2011). Intolerance: retain healthy scepticism. *Nature*, *471*(7338), 305–305. https://doi.org/10.1038/471305a

Stuart, J. C. (1672). King James his counterblast to tobacco : to which is added a learned discourse proving that tobacco is a procuring cause of the scurvy. (J. Hancock, Ed.). London: Printed for John Hancock.

Swami, V., Voracek, M., Stieger, S., Tran, U. S., & Furnham, A. (2014). Analytic thinking reduces belief in conspiracy theories. *Cognition*, *133*(3), 572–585. https://doi.org/10.1016/j.cognition.2014.08.006

Swire, B., Ecker, U. K. H., & Lewandowsky, S. (2017). The role of familiarity in correcting inaccurate information. *Journal of Experimental Psychology: Learning Memory and Cognition*, *43*(12), 1948–1961. https://doi.org/10.1037/xlm0000422

The Washington Post. (2019). Tracking all of President Trump's false or misleading claims - Washington Post. Retrieved December 20, 2019, from https://www.washingtonpost.com/graphics/politics/trump-claims-database/

Tollefson, J. (2016). Trump vs Clinton: Worlds apart on science. *Nature*. https://doi.org/10.1038/535473a

Tvinnereim, E., & Ivarsflaten, E. (2016). Fossil fuels, employment, and support for climate policies. *Energy*

Policy, *96*, 364–371. https://doi.org/10.1016/j.enpol.2016.05.052

U.S. Department of Health and Human Services. (2014). *Fifty Years of Change 1964 – 2014. The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General.* Centers for Disease Control and Prevention (US). Retrieved from https://www.ncbi.nlm.nih.gov/books/NBK294310/

U.S. Public Health Service. (1964). *Smoking and Health: Report of the Advisory Committee to the Surgeon General of the Public Health Service.* Washington (DC).

van der Linden, S. (2015). The conspiracy-effect: Exposure to conspiracy theories (about global warming) decreases pro-social behavior and science acceptance. *Personality and Individual Differences*, *87*, 171–173. https://doi.org/10.1016/j.paid.2015.07.045

van der Linden, S., Leiserowitz, A., Rosenthal, S., & Maibach, E. (2017). Inoculating the Public against Misinformation about Climate Change. *Global Challenges*, *1*(2), 1600008. https://doi.org/10.1002/gch2.201600008

van der Linden, S., Maibach, E., Cook, J., Leiserowitz, A., & Lewandowsky, S. (2017). Inoculating against misinformation. *Science*, *358*(6367), 1141.2-1142. https://doi.org/10.1126/science.aar4533

Vicario, M. Del, Bessi, A., Zollo, F., Petroni, F., Scala, A., Caldarelli, G., … Quattrociocchi, W. (2016). The spreading of misinformation online. *Proceedings of the National Academy of Sciences of the United States of America*. https://doi.org/10.1073/pnas.1517441113

Vosoughi, S., Roy, D., & Aral, S. (2018). The spread of true and false news online. *Science*, *359*(6380), 1146–1151. https://doi.org/10.1126/science.aap9559

Wagner-Egger, P., Bronner, G., Delouvée, S., Dieguez, S., & Gauvrit, N. (2019). Why “Healthy Conspiracy Theories” Are (Oxy) morons. *Social Epistemology Review & Reply Collective*, *8*(3), 50–67. Retrieved from https://socialepistemologydotcom.files.wordpress.com/2019/03/2019-03-14-pascal-wagner-on-conspiracy.pdf

Waisbord, S. (2018). Truth is What Happens to News: On journalism, fake news, and post-truth. *Journalism Studies*, *19*(13), 1866–1878. https://doi.org/10.1080/1461670X.2018.1492881

Ward, J. K., Peretti-Watel, P., Bocquier, A., Seror, V., & Verger, P. (2019). Vaccine hesitancy and coercion: all eyes on France. *Nature Immunology*. https://doi.org/10.1038/s41590-019-0488-9

Weart, S. (2011). Global warming: How skepticism became denial. *Bulletin of the Atomic Scientists*, *67*(1), 41–50. https://doi.org/10.1177/0096340210392966

Whitson, J. A., & Galinsky, A. D. (2008). Lacking control increases illusory pattern perception. *Science*, *322*(5898), 115–117. https://doi.org/10.1126/science.1159845

Wilson, J. A. (2018). Reducing Pseudoscientific and Paranormal Beliefs in University Students Through a Course in Science and Critical Thinking. *Science and Education*, *27*(1–2), 183–210. https://doi.org/10.1007/s11191-018-9956-0

Winterbottom, A., Bekker, H. L., Conner, M., & Mooney, A. (2008). Does narrative information bias individual’s decision making? A systematic review. *Social Science and Medicine*, *67*(12), 2079–2088. https://doi.org/10.1016/j.socscimed.2008.09.037

Wolburg, J. M. (2006). College students’ responses to antismoking messages: Denial, defiance, and other boomerang effects. *Journal of Consumer Affairs*. https://doi.org/10.1111/j.1745-6606.2006.00059.x

Wong, N. C. H. (2016). “Vaccinations are Safe and Effective”: Inoculating Positive HPV Vaccine Attitudes Against Antivaccination Attack Messages. *Communication Reports*.

https://doi.org/10.1080/08934215.2015.1083599

Wood, T., & Porter, E. (2019). The Elusive Backfire Effect: Mass Attitudes' Steadfast Factual Adherence. *Political Behavior*. https://doi.org/10.1007/s11109-018-9443-y

World Health Organization. (2005). *WHO Framework Convention on Tobacco Control*. Geneva.

World Health Organization. (2019a). Fact-sheet Tobacco. Retrieved December 9, 2019, from https://www.who.int/news-room/fact-sheets/detail/tobacco

World Health Organization. (2019b). Ten threats to global health in 2019. Retrieved December 19, 2019, from https://www.who.int/emergencies/ten-threats-to-global-health-in-2019

Zollo, F., Bessi, A., Del Vicario, M., Scala, A., Caldarelli, G., Shekhtman, L., … Quattrociocchi, W. (2017). Debunking in a world of tribes. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0181821

Article 1

Commentary to: How to Respond to Vocal Vaccine Deniers in Public

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Commentary to: How to Respond to Vocal Vaccine Deniers in Public

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In spite of the huge positive impact of immunization on fighting infectious diseases and improving health outcomes, acceptance of vaccines cannot be taken for granted. Sadly, vaccine refusal and denial persists. Denying the necessity and safety of recommended vaccines presents a major threat to a healthy society as it subverts community protection against vaccine-preventable diseases (WHO, 2014). This commentary introduces the new evidence-informed guidance document of the World Health Organization on how to respond to vaccine refusal and denial in public (available online, see link below).

The spreading of vaccine misinformation by vocal vaccine deniers contributes to vaccine hesitancy (Dubé et al., 2013). Vocal vaccine deniers are at the extreme end of the subgroup of vaccine refusers (MacDonald et al., 2015) and actively advocate against vaccination, using *s*cience denialism techniques to justify their beliefs i.e. "*the employment of rhetorical arguments to give the appearance of legitimate debate where there is none*" (Hoofnagle & Hoofnagle, 2007) "*an approach that has the ultimate goal of rejecting a proposition on which a scientific consensus exists*" (Diethelm & McKee, 2009, p. 2). They reject any pro-vaccine argument and, on principle, do not accept recommended vaccines.

The potential damage a vocal vaccine denier can cause through mass media as an amplifier of myths and misinformation is significant. Furthermore, unprepared or rash responses to vocal vaccine deniers in public fora may undermine the pro-vaccine stance of the audience and shift their beliefs (Gesser-Edelsburg, Walter, Shir-Raz, & Green, 2015). When engaging in a public discussion with a vocal vaccine denier it is not only necessary to provide scientific evidence, but also to mitigate his or her negative influence on the public audience by responding in a way that appeals to and is understood by the public. This poses a challenge when vocal vaccine deniers refer to alleged or quasi-scientific evidence (Kata, 2012) and play on emotions that appeal to and raise concerns in the audience (Kata, 2010).

While general skills on engaging in a public debate or interview are helpful, they do not provide a strategy for how to address the specific issues and rhetoric techniques used by the vocal vaccine deniers. Given the potential impact of vocal vaccine deniers, the lack of readily available advice in this area and the frequent requests for support from WHO Member States, a best practice evidence-informed guidance document has been developed by the WHO Regional Office for Europe. The document introduces an algorithm to develop responses to anti-vaccination rhetoric and guides health authority spokespersons in assessing whether to engage in the specific public discussion with the vaccine denier or not. The document is based on public health data, literature reviews in the areas of public health, psychology, communication and vaccinology as well as expert opinion. The document was reviewed and discussed by the members of the *European Technical Advisory Group of Experts on Immunization* (ETAGE) at their annual meeting (2015; Copenhagen, Denmark) and by participants of the *WHO European Regional Meeting of National Immunization Programme Managers* (2015; Antwerp, Belgium), which included the immunization programme managers of the 53 Member States of the WHO European Region, and it was tested and evaluated by national immunization managers of Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Montenegro, Serbia and the former Yugoslav Republic of Macedonia during the *Technical consultation on addressing vaccination opposition* (2016; Belgrade, Serbia).

The guiding principles of the algorithm are: 1) the general public is the target audience, not the vocal vaccine denier and 2) the aim is to correct the misinformation content and to unmask the techniques used by the vocal vaccine denier.

In a public discussion vocal vaccine deniers are not likely to be convinced by any quantity of evidence; on the contrary they are likely to question the science of immunization as a whole. But even if evidence will not change the mind of the vocal vaccine denier, it may still appeal to the general public. By following the first guiding principle the spokesperson should see it as his or her role to inform undecided individuals, equip vaccine advocates with evidence-based arguments and even convince sceptics and not be distracted by any ambition to convince the vaccine denier.

Knowing the common science denialism techniques (Diethelm & McKee, 2009) and the topics most often raised by vocal vaccine deniers, the health authority spokesperson can prepare responses which aim to correct misinformation as well as to unmask the techniques used. The algorithm (see Figure) illustrates this process. Building on the literature reviewed, the core topics of vocal vaccine deniers have been reduced to five: *threat of disease*, *alternatives to vaccines*, *effectiveness of vaccines*, *trust in health authorities* and *safety of vaccines*. The common techniques of vocal vaccine deniers have been identified as: *conspiracies*, *fake experts*, *selectivity*, *impossible expectations* and *misrepresentation/false logic (Diethelm & McKee, 2009)*. For example, by saying "I am not against vaccination, but I will not recommend it to anyone until it is 100% safe." the vocal vaccine denier is addressing the topic of safety and using the technique *impossible expectations*. By saying "There are a variety of alternatives to vaccines, which are natural and therefore healthy for a natural organism like the human being. We need to focus on these approaches instead of chemical and artificial solutions like vaccines." the denier is addressing the topic of alternatives and using the technique of *false logic.*

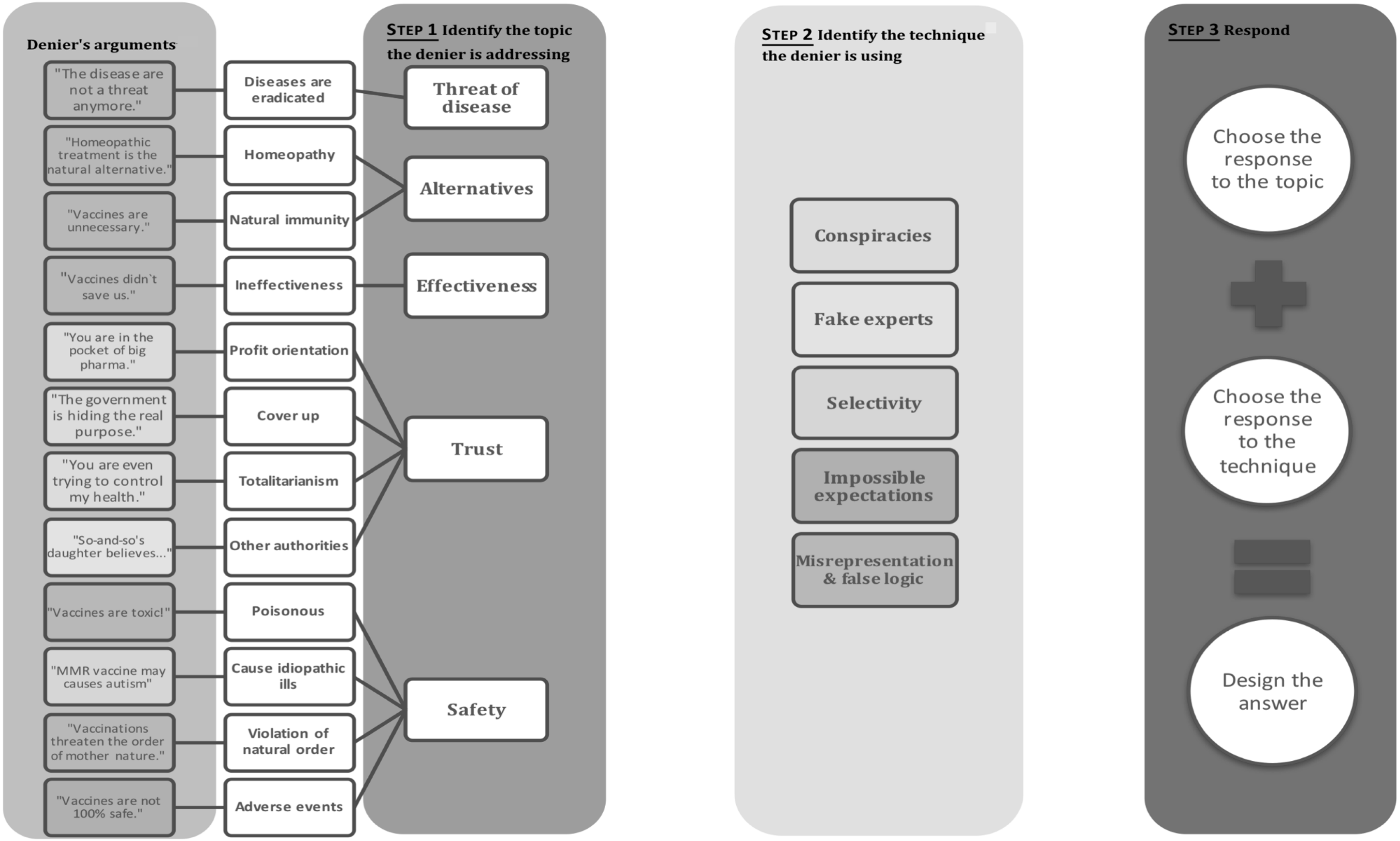

Figure: The algorithm of how to respond to vocal vaccine deniers. The denier's arguments are based on previous work by Kata (2012). The techniques that the denier is using are based on previous work by Diethelm & McKee (2009).

Once the spokesperson has identified the topic and the technique, a context-specific and culturally appropriate response can be prepared *to* correct misinformation and unmask the technique. The document provides key messages for every topic and technique to serve as inspiration. Depending on the culture and context, the response to the example of impossible expectation above may be “Expecting 100% safety is impossible*; no* medical product or intervention, from aspirin to heart surgery, can ever be guaranteed 100% safe. What we do know for sure is that the risks of these vaccine-preventable diseases far outweigh those of vaccines. In the worst of cases, these diseases kill.” The response to the false logic example may be “Mr X is using false logic when he is claiming that something is good because it is a natural product. Sometimes natural things are good – for example the immune system– sometimes they are bad – for example vaccine-preventable diseases. Whether a medical product is natural or not is irrelevant for the evaluation of its effectiveness and safety. I will repeat what is supported by an overwhelming body of scientific evidence: There are no alternatives that are as safe and effective as vaccines in preventing these diseases.”

The document also provides basic evidence-informed verbal and non-verbal do’s and don’ts on how to behave in a public discussion or interview with a vocal vaccine denier.

The theoretical value of this best practice guidance document will be limited without practical training opportunities. Therefore, the WHO Regional Office for Europe is currently developing workshops that will equip participants with the theoretical “know why” and the practical “know how”. We encourage spokespersons of any health authority and scientists alike to read the document and offer further comments and suggestions (available online at http://www.euro.who.int/en/health-topics/disease-prevention/vaccines-and-immunization/publications/2016/best-practice-guidance-how-to-respond-to-vocal-vaccine-deniers-in-public-2016). Designing responses to arguments of vocal vaccine deniers is an evolutionary process and a continuous challenge that needs context-specific tailored approaches and feedback on their effectiveness. The scientific community needs to discuss and refine approaches like those outlined in the document in order to clarify and strengthen the local evidence-based voice for vaccination. As the new algorithm is based on theoretical work about science denialism (Diethelm & McKee, 2009; McKee & Diethelm, 2010) and expert opinions further research needs to validate the usage of the proposed topics and techniques of vocal vaccine deniers.

Lastly, the proposed rules and algorithm process and techniques are also likely applicable and adaptable to other public arenas where scientific denialism is central such as anti-fluoride in water campaigners, straight from the cow unpasteurized milk zealots and extollers of natural remedies to cure cancer. In each of these three instances and many similar areas, as with vocal vaccine deniers, the target audience is the general public, the aim is to correct misinformation, support the public in being resilient to the vocal scientific deniers' claims and encourage acceptance of evidence-based preventive and/or therapeutic public health or medical interventions by the public. There is still much to be learned on how to best address vocal vaccine deniers in public, but this best practice guidance document provides a beginning for health authority spokespersons facing such stressful situations.

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References

Diethelm, P., & McKee, M. (2009, October 16). Denialism: What is it and how should scientists respond? *European Journal of Public Health*. Oxford University Press. https://doi.org/10.1093/eurpub/ckn139

Dubé, E., Laberge, C., Guay, M., Bramadat, P., Roy, R., & Bettinger, J. (2013). Vaccine hesitancy: An overview. *Human Vaccines and Immunotherapeutics*. https://doi.org/10.4161/hv.24657

Gesser-Edelsburg, A., Walter, N., Shir-Raz, Y., & Green, M. S. (2015). Voluntary or Mandatory? the Valence Framing Effect of Attitudes Regarding HPV Vaccination. *Journal of Health Communication*. https://doi.org/10.1080/10810730.2015.1018642

Hoofnagle, M., & Hoofnagle, C. (2007). What is denialism. Retrieved December 22, 2015, from http://scienceblogs.com/denialism/about/

Kata, A. (2010). A postmodern Pandora's box: Anti-vaccination misinformation on the Internet. *Vaccine*. https://doi.org/10.1016/j.vaccine.2009.12.022

Kata, A. (2012). Anti-vaccine activists, Web 2.0, and the postmodern paradigm - An overview of tactics and tropes used online by the anti-vaccination movement. *Vaccine*, *30*(25), 3778–3789. https://doi.org/10.1016/j.vaccine.2011.11.112

MacDonald, N. E., Eskola, J., Liang, X., Chaudhuri, M., Dube, E., Gellin, B., … Schuster, M. (2015). Vaccine hesitancy: Definition, scope and determinants. *Vaccine*, *33*(34), 4161–4164. https://doi.org/10.1016/j.vaccine.2015.04.036

McKee, M., & Diethelm, P. (2010). How the growth of denialism undermines public health. *BMJ*, *341*.

World Health Organization. (2014). *Global immunization data*. Retrieved from http://www.who.int/immunization/monitoring_surveillance/global_immunization_data.pdf?ua=1

Article 2

Effective Strategies for Rebutting Science Denialism in Public Discussions

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Effective Strategies for Rebutting Science Denialism in Public Discussions

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Abstract

Science deniers question scientific milestones and spread misinformation, contradicting decades of scientific endeavour. Advocates for science need effective rebuttal strategies and are concerned about backfire effects in public debates. Six experiments assess how to mitigate a denier's influence on the audience. An internal meta-analysis across all experiments reveals that not responding to science deniers has a negative effect on attitudes towards behaviours favoured by science (e.g. vaccination) and intentions to perform these behaviours. Providing the facts regarding the topic or uncovering the rhetorical techniques typical for denialism had positive effects. We find no evidence that complex combinations of topic and technique rebuttal are more effective than single strategies, nor that rebutting science denialism in public discussions backfires, not even in vulnerable groups (e.g. U.S. conservatives). As science deniers use the same rhetoric across domains, uncovering their rhetorical techniques is an effective and economic extension of the advocates' toolbox.

Vaccines are safe and effective (WHO, 2009). *Humans cause global warming* (EC, 2014). *Evolution theory explains the diversity and change of life* (ACS, 2017). While a majority takes these robust results of scientific inquiry for granted, science deniers publicly oppose these results and spread misinformation, which evidently biases the public's opinion (Carmichael, Brulle, & Huxster, 2017; Mildenberger & Leiserowitz, 2017) and blurs significant decisions (Lewandowsky, Ecker, & Cook, 2017). Historically, science denialism has persuaded people to turn down life-saving HIV/AIDS treatments (Chigwedere, Seage, Gruskin, Lee, & Essex, 2008) or preventive measures such as vaccinations (Flaherty, 2011), leading to distorted attitudes and years of severe illness and death.

Science denialism must not be confused with scepticism (Björnberg, Karlsson, Gilek, & Hansson, 2018; Lewandowsky, Ballard, Oberauer, & Benestad, 2016; Odenbaugh, 2017). Scepticism towards scientific propositions is a crucial element of science itself. In fact, it functions as a driving force of scientific debates and increases the quality of new propositions via mechanisms such as peer review and the replication of experimental research (Ziman, 1996). The common ground of this *functional scepticism* is the scientific ethos that scientists use data to update their prior beliefs regardless of the outcome. However, in contrast to functional scepticism, science deniers accept evidence only if it confirms their prior beliefs - that usually contradict the scientific consensus (Diethelm & McKee, 2009). This *dysfunctional scepticism* is driven by how the denier would like things to be rather than what he has evidence for, making science denialism a motivated rejection of science (Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016).

The scientific community has ignored the question of how to counter arguments of science denialism effectively for too long (Betsch, 2017; Oreskes & Conway, 2010), now recognizing the urgent need for advocates for science to publicly engage in debunking misinformation (Williamson, 2016). Advocates for science are spokespersons that follow scientific consensus and argue for the evidence-based position (Cockrell, Dubickas, Hepner, Ilich, & McCarthy, 2018), for example in the media. Researchers have now indeed increased efforts to focus on how advocates for science can inoculate individuals against misinformation before they encounter it (Cook, Lewandowsky, & Ecker, 2017; van der Linden, Leiserowitz, Rosenthal, & Maibach, 2017) and how misinformation can be corrected once individuals believe in it (Ecker, Hogan, & Lewandowsky, 2017; Lewandowsky, Ecker, Seifert, Schwarz, & Cook, 2012). A third option is to counter arguments of denial in the very moment that they reach an audience, that is, rebutting deniers in public discussions (Schmid, MacDonald, Habersaat, & Butler, 2018). In the remainder we will focus on this third option.

Public discussions, for example in social media or as televised debates, are popular and persuasive (Benoit, Hansen, & Verser, 2003). Moreover, they allow scientists to leave their ivory tower and contribute to opinion making. This seems increasingly important in an era where false news stories about science spread faster than true ones (Vosoughi, Roy, & Aral, 2018). However, public discussions also entail risks for the discussants. Bad performance can, in the worst case, serve the opponent's cause (Seiter, Weger, Jensen, & Kinzer, 2010). Moreover, backfire effects in attempts to debunk misconceptions (Ecker et al., 2017; Nyhan & Reifler, 2010, 2015) may further question whether publicly rebutting misinformation is useful and successful. These backfire effects are most likely to be found among audiences whose prior beliefs or political ideologies are threatened by the advocate (Cook & Lewandowsky, 2016; Nyhan & Reifler, 2015). For example, attempts to correct misconceptions about vaccination in an audience with low confidence in the safety of vaccination (Nyhan & Reifler, 2015) can ironically reinforce the misconception. The same effect occurred among United States (U.S.) conservatives who strongly object to governmental regulation when there were attempts to debunk misinformation about climate change (Cook & Lewandowsky, 2016), that is, when they received information that eventually might lead to regulation. This fear of governmental regulation has also been discussed as a cause of distrust in scientists regarding vaccination among U.S. conservatives (Lewandowsky & Oberauer, 2016). Facing these risks creates difficulty for science advocates in deciding whether they should participate in a public discussion at all (Cockrell et al., 2018), potentially leading to the absence of advocates for science from a discussion (henceforth referred to as *advocate absent*).

Beyond the question of whether to attend the discussion at all, advocates for science around the globe lack empirical advice on how to respond in a public discussion to a science denier (Betsch, 2017; WHO, 2016). Persuasion psychology highlights three components that can determine whether persuasive attempts will be successful: characteristics of the receiver (e.g. need for cognition: Cacioppo, Petty, & Morris, 1983; persuasion knowledge: Friestad & Wright, 1994), characteristics of the sender (e.g. credibility: Pornpitakpan, 2004; likeability: Chaiken, 1980) and message content and structure (e.g. type of evidence: Hronikx, 2005; message sidedness: Allen, 1991). This study assesses which message content is effective for advocates when responding to science deniers in public discussions. Rebuttal messages can have two different goals. An advocate can aim to overwhelm the opposing position by providing only support for her own view or can aim to refute the opposing position by attacking its plausibility and explaining why it is wrong (Allen, 1991; O'Keefe, 1999). As there is theoretical support for both goals of rebuttal messages, it will now be necessary to introduce practical strategies on how to achieve overwhelming and refuting in public debates about science (WHO, 2016).

Advocates for science can respond to misinformation by supporting the scientific standpoint with scientific facts, that is, *topic rebuttal* (Fig. 1). For example, when a denier argues that vaccines should be 100% safe, the advocate can provide evidence of the excellent safety record. Thus, *topic rebuttal* provides guidance on how to overwhelm the deniers' opposition. Such a mere provision of facts has been criticized as insufficient to reduce the influence of misinformation because, inter alia, it lacks the important explanation of why the misinformation is wrong (Lewandowsky et al., 2012).

There is advice put forward by the World Health Organization's Regional Office for Europe (WHO/Euro) regarding how to handle science deniers in public anti-vaccination debates (Schmid et al., 2018; WHO, 2016), which introduces a second strategy: *technique rebuttal,* that is, uncovering the techniques of science denial. Previous research has identified major techniques of science denialism (overview in Fig. 1) that are widely used across several domains of science denialism to make the appearance of a strong argument where there is none (Cook et al., 2017; Diethelm & McKee, 2009). Unmasking these techniques will educate the audience about why arguments of denial are appealing but incorrect (Cook & Lewandowsky, 2011; Diethelm & McKee, 2009; Schmid et al., 2018). For example, when a denier argues that vaccines should be 100% safe, the advocate can uncover the technique of impossible expectations – because no medical product can ever guarantee 100% safety. The assumptions about the benefits of *technique rebuttal* are also in line with findings from research about resistance to persuasion showing that individuals can better cope with persuasive attempts when they are aware of the techniques used on them (Friestad & Wright, 1994). Thus, *technique rebuttal* provides a strategy on how to refute a denier's position in public discussions about science. Fig. 1. provides an example of topics and techniques frequently used in the area of vaccination; Supplementary Figure 1 adapts the example to climate change.

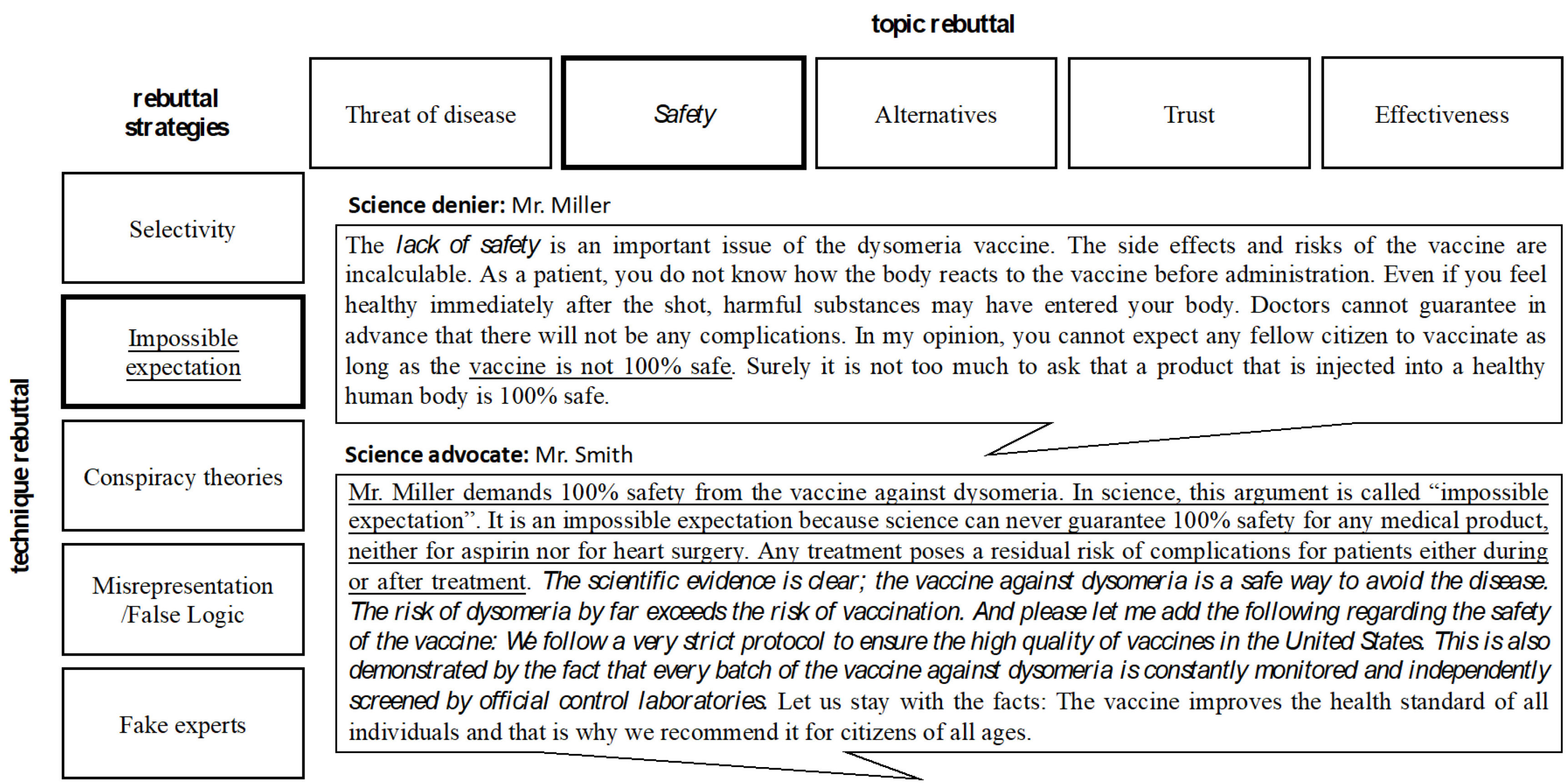

Fig. 1. 5 × 5 matrix of rebutting science denialism in public discussions about vaccination. The abundance of arguments against vaccination is reduced to five recurring core topics (columns 'topical rebuttal') and five typical strategies of science denialism (rows 'technique rebuttal'). The dialogue represents an example of the bold categories from the materials used in Experiment 4 (combination of technique and topic rebuttal). Italics indicate the *topic,* and underlined text indicates the <u>technique</u> of science denialism. Contents are adapted to climate change in Experiment 5 and displayed in the Supplement (Supplementary Figure 1).

Moreover, technique and topic rebuttal are not mutually exclusive, that is, combining arguments yields a third possibility to respond to science deniers. In fact, the WHO/Euro approach (Schmid et al., 2018; WHO, 2016) claims that combining topic plus technique rebuttal will make advocates for science most effective in mitigating the influence of a denier. Established dual-process theories of persuasion (elaboration likelihood model: Petty & Cacioppo, 1986; heuristic-systematic model: Chaiken, 1980) suggests two potential reasons, why combining several arguments should be superior in limiting the denier's influence on the audience. According to these models, persuasion is more likely when high quality messages are provided – given the receiver has high motivation to process the information. Given only limited motivation or ability, peripheral cues will guide persuasion, referring to cues that point to the validity of arguments such as the mere length of the argument. Thus, a combination of several arguments might be more effective than single strategies because either the combination increases the quality of the argument (central route) and/or merely because it contains more arguments and is longer (peripheral route; Eisend, 2007). Despite the theoretical benefits of the combination, the WHO/Euro guidance document also acknowledges the practical complexity of delivering a rebuttal message that covers both dimensions in a public debate (Schmid et al., 2018; WHO, 2016). Hence, it is important for advocates to know whether training in and use of the most complex strategy is justified by evidence or whether the less complex single strategies are sufficient to strengthen the evidence-based voice for science.

To provide empirical tests of the strategies' single and combined effectiveness in the specific context of public discussions about science denialism, we 1) examined whether a science denier influences the audience differently when followed by an advocate for science who uses either *topic* or *technique rebuttal*; 2) assessed whether the combination of the rebuttal strategies is more effective than the single strategies and 3) analysed the potential damage when the *advocate is absent,* and there is no reaction to the denial at all. Finally, we explored potential damage and backfire effects as a function of prior beliefs and political ideology.

In six online experiments (N = 1,773) we collected data on the attitude towards a behaviour favoured by science (Experiments 1–4 & 6: vaccination; Experiment 5: taking action against climate change) and the intention to perform this behaviour before and after participants listened to or read a debate with a science denier. The selection of primary outcomes was based on previous research showing that the attitude towards a behaviour and the intention to perform the behaviour are major predictors of actual behaviour (Sheeran et al., 2016). Additionally, attitude change and resistance to change is the primary focus of research on persuasion (O'Keefe, 2002), which delivers the theoretical underpinnings of this work (Friestad & Wright, 1994). In Experiments 2–6 we explored potential moderators regarding the effectiveness of denialism and rebuttal strategies (Experiments 2–4 & 6: individuals' general confidence in the safety and effectiveness of vaccination; Experiments 4 & 6: U.S. residents' political ideology on a conservatism–liberalism spectrum). This allows exploring whether rebuttals that threaten an audience's prior beliefs about a scientific measure or threaten an audience's political ideology are more likely to backfire.

In all the experiments, participants first received an interview with a science denier. Participants were then randomly assigned to the following design, determining the rebuttal condition: 2 (topic rebuttal versus no topic rebuttal; between subjects) × 2 (technique rebuttal versus no technique rebuttal; between subjects) × 2 (time of measurement: before versus after the debate; within subjects) mixed design. Depending on condition, a science advocate was thus either absent from the debate, responded to the denier by using topic rebuttal or technique rebuttal or responded with a combination of both strategies (Fig.1 provides an example of the materials used in Experiments 1–4 & 6). The first experiment was conducted among German university students. The experiment addressed vaccination, and the debate was presented auditorily as a radio show. Following best practices in research (O'Keefe, 2015) we replicated the results of the first experiment in more heterogeneous samples (Experiments 2 & 3), in a different language and political landscape (U.S.: Experiments 4 & 6), in a different domain (climate change: Experiment 5) and in a different presentation format (written: Experiments 2–6). We preregistered Experiments 2 through 6 (see Methods section). First, we analysed whether the denier influences the attitude towards and intention to perform the respective behaviour. Second, we analysed whether technique or topic rebuttal are effective strategies to reduce the denier's influence and whether the combined strategy is more effective than the single strategies. Finally, we explored whether the influence of denialism and the effectiveness of rebuttal strategies are functions of the audiences' prior beliefs or political ideologies.

In the Results section we report an internal random effects meta-analysis including all six experiments (Goh, Hall, & Rosenthal, 2016; O'Keefe, 2015). Effects in confirmatory analyses are presented as Hedges' adjusted *g,* that is, standardized mean differences, because the scales measuring attitude and intention differ depending on the domain (vaccination vs. climate change). In exploratory subgroup analyses the scales are identical between studies. Therefore, we report these results as absolute mean differences (Baguley, 2009). Attitudes and intentions from the single experiments are reported using the percentage of maximum possible scores of the original scales (POMP: Cohen, Cohen, Aiken, & West, 1999), with higher values indicating a more positive attitude and higher intentions. Subgroup analyses on prior beliefs and political ideology are based on median splits for confidence in vaccination and conservatism. The Supplement contains detailed results for each experiment.

Results

The results show that public discussions with a science denier have a damaging effect on the audience, revealed by negative changes from the pre- to post-measures of attitudes (Supplementary Figure 2) and intentions (Fig. 2): the attitude towards a behaviour favoured by science and the intention to perform this behaviour were reduced by reading or listening to a discussion with a science denier (attitude: effect size Hedges' $g = -0.32$, 95% confidence interval [-0.46, -0.17]; intention: $g = -0.21$, [-0.35, -0.08]). When no advocate for science was present, the denier had the strongest effects compared with conditions where an advocate was present (attitude: $g = 0.49$, [0.37, 0.60]; intention: $g = 0.57$, [0.46, 0.68]). The climate change experiment replicated the pattern of results of all prior experiments regarding attitude change (see Supplementary Figure 2), that is, the denier decreased the attitude towards acting against climate change. However, there was no evidence of a damaging effect of the denier on the intention to act against climate change (see Fig. 2).

Uncovering the techniques of science denial had a mitigating effect on the influence of the denier (Fig. 3), that is, the influence of the denier was decreased by technique rebuttal (attitude: $g = 0.31$, [0.22, 0.41]; intention: $g = 0.31$, [0.20, 0.42]). In line with previous findings (Cook et al., 2017), these results empirically support the assumption that uncovering techniques of denial can decrease their influence (Cook & Lewandowsky, 2011; Diethelm & McKee, 2009; P. Schmid et al., 2018). The same pattern was obtained for presenting the facts in the discussion (Fig. 3): There was no evidence that topic rebuttal led to a backfire effect but indeed topic rebuttal reduced the denier's influence on individuals' intention ($g = 0.33$, [0.24, 0.43]) and attitude (attitude: $g = 0.21$, [0.04, 0.38]).

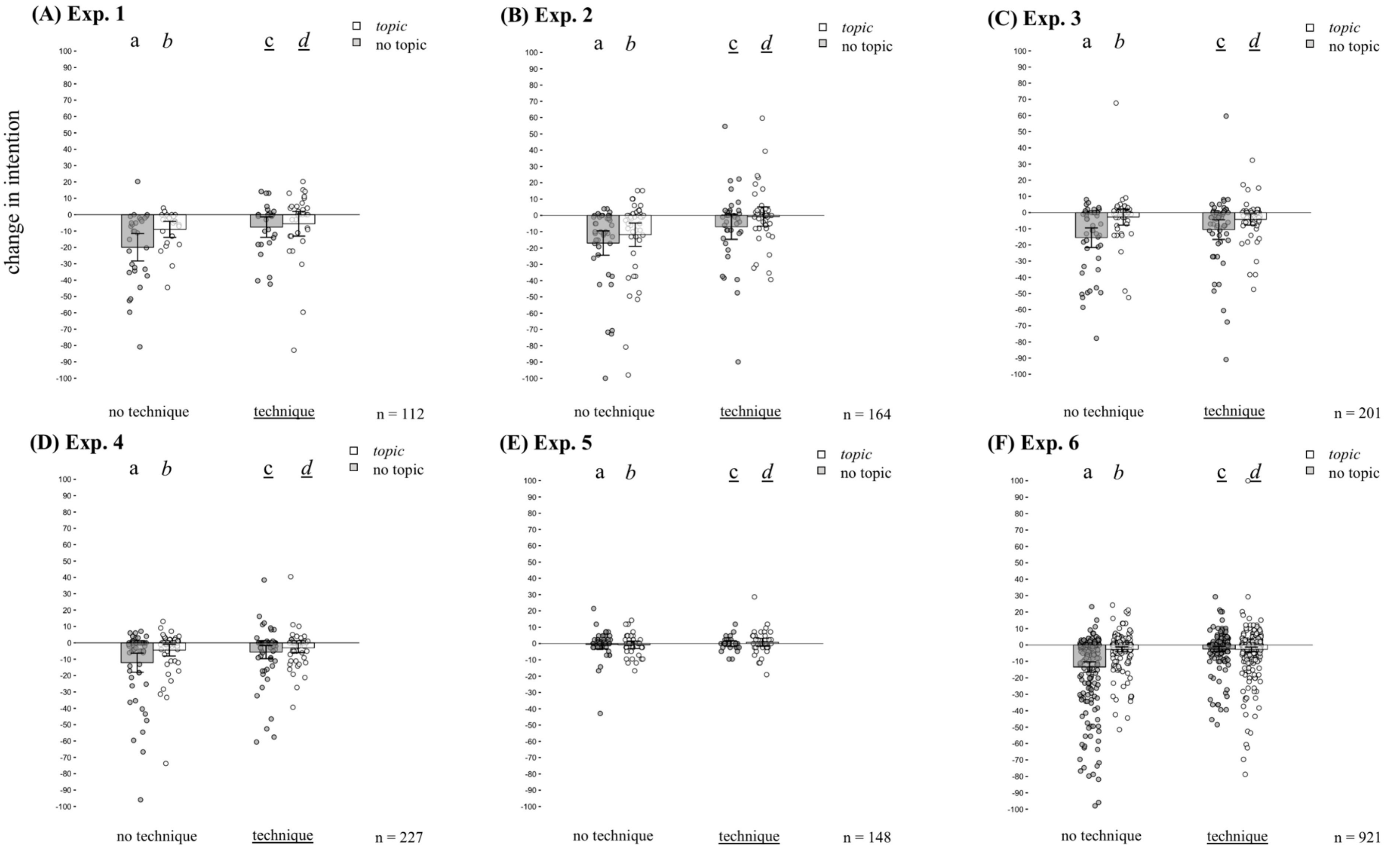

Fig. 2. Effects of denial and rebuttals on intention to perform a behaviour favoured by science (Exp. 1–4 & 6: vaccination; Exp. 5: taking action against climate change). The y axes represent mean changes in intention to perform the behaviour (POMP values, percent of maximum possible score). The x axes represent experimental conditions. The negative influence of the denier on the intention to perform the behaviour was weaker when rebuttal was used (except Exp. 5). Applying topic or technique rebuttal or a combination thereof can decrease the influence of science denialism. Error bars are 95% confidence intervals. Dots indicate individual changes in the intention of individual participants. Colours and groupings of bars indicate the conditions of the experiments, resulting in the four tested conditions: a) advocate absent b) topic rebuttal, c) technique rebuttal, d) combination.

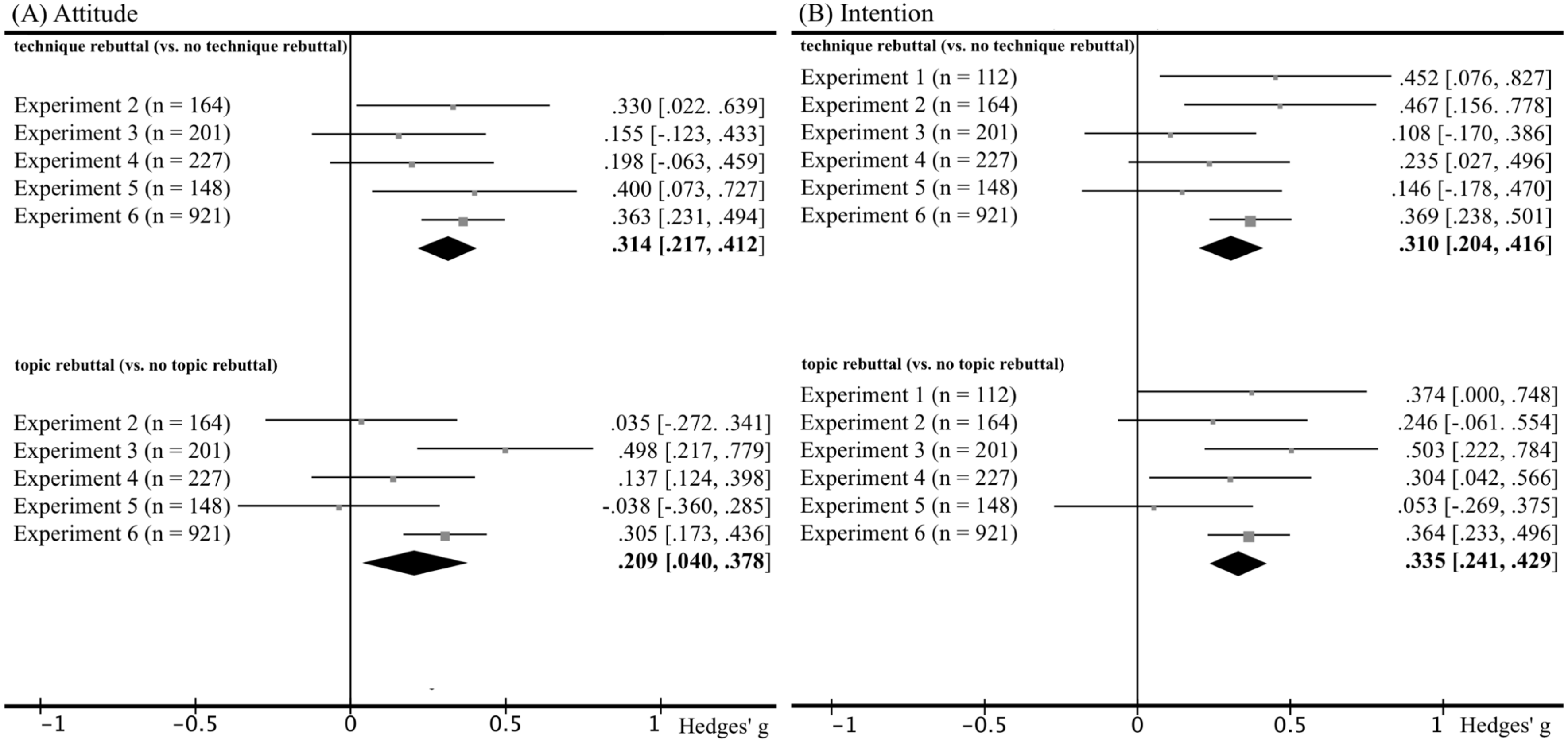

Fig. 3. Technique rebuttal and topic rebuttal mitigate the influence of the science denier. Internal meta-analyses of **(A)** changes in attitude (Exp. 2–6; N = 1,661) and **(B)** changes in intention (Exp. 1–6; N = 1,773) using random effects models. The y axes represent experiments. The x axes represent Hedges' adjusted *g*s. Hedges' adjusted *g*s are derived from comparisons of means of changes in attitude and intention from topic rebuttal vs. no topic rebuttal (main effect of topic rebuttal) and technique rebuttal vs. no technique rebuttal (main effect of technique rebuttal). Sizes of squares are proportional to the precision of the estimate. Diamonds show summary effects. Centre lines of diamonds show weighted means of the effect sizes. Error bars and width of diamonds show 95% confidence intervals. Numbers in brackets show values of confidence intervals. Heterogeneity of presented results: (technique rebuttal: **(A)** $I^2 = 0\%$ ($Tau^2 = 0$), **(B)** $I^2 = 11\%$ ($Tau^2 = 0$); topic rebuttal: **(A)** $I^2 = 57\%$ ($Tau^2 = 0.02$), **(B)** $I^2 = 0\%$ ($Tau^2 = 0$)).

Contrary to the assumptions of the dual process models of persuasion (Chaiken, 1980; Petty & Cacioppo, 1986), the direct comparison of the single strategies and the combined strategy reveals no evidence of an additive benefit of the combination. Attitudes and intentions were similarly affected as in the technique or topic rebuttal conditions (attitude: $g = 0.14$, [-0.04, 0.32]; intention: $g = 0.09$, [-0.02, 0.20]; Fig. 4). Evidence of a benefit of the combination is also absent when analysing interaction effects (see Supplementary Table 1 for meta-analyses of the respective simple main effects). Thus, using either one of the less complex single rebuttal strategies is sufficient to decrease the science denier's influence.

Exploratory subgroup analyses support the notion of motivated rejection of science among certain audiences (Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016) as a priori beliefs and political ideology moderated the effect of the science denier. The influence of the denier on individuals' attitude was higher among individuals with low a priori confidence in vaccination compared to individuals with high confidence (Fig. 5D); the same effect occurred for intention (Fig. 5A). Likewise, the influence of the denier on individuals' attitude (Fig. 6D) and intentions (Fig. 6A) was stronger for conservatives than for liberals.

However, there is also evidence that technique rebuttal and topic rebuttal are especially valuable to mitigate the denier's influence in these vulnerable subgroups. The moderator analyses presented in Fig. 6 reveal that technique rebuttal reduces the influence of the denier for liberal and conservative participants, but the effect was especially strong for conservative participants (Fig. 6B, E; attitude as a function of political ideology: chi-square (degrees of freedom = 1) = 7.11, $p = .008$, $I^2 = 85.9\%$; intention: $\chi^2(1) = 5.36$, $p = .020$, $I^2 = 81.4\%$). The same effect occurs partially for prior beliefs (Fig. 5). The effect of technique rebuttal on the intention to get vaccinated was stronger for participants with low confidence in vaccines than for participants with high confidence (Fig. 5B; $\chi^2(1) = 4.98$, $p = .030$, $I^2 = 79.9\%$). Evidence of this effect, however, was absent for individuals' attitude towards vaccination. (Fig. 5E; $\chi^2(1) = 2.90$, $p = .090$, $I^2 = 65.6\%$).

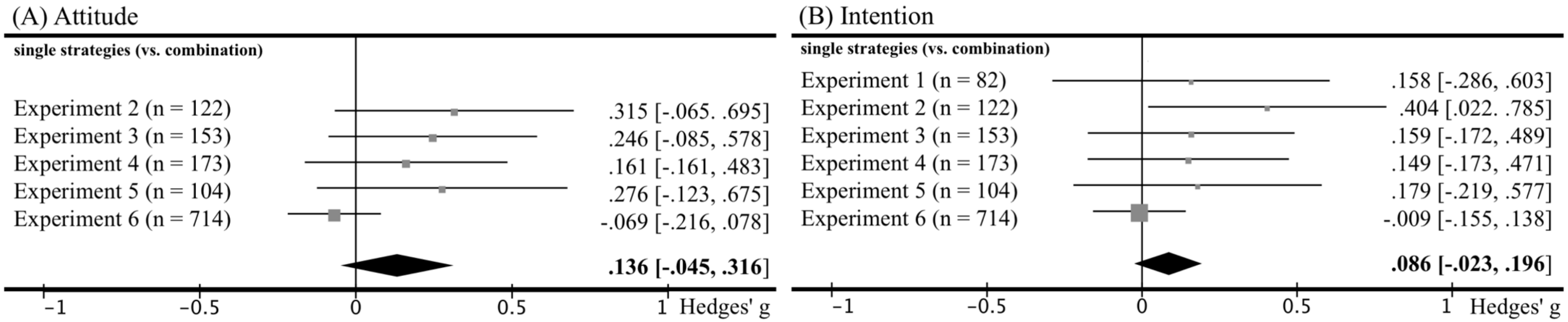

Fig. 4. No evidence that the combination of topic and technique rebuttal is more effective than the single strategies. Internal meta-analyses of **(A)** changes in attitude (Exp. 2–6; N = 1,266) and **(B)** changes in intention (Exp. 1–6; N = 1,348) using random effects models. The y axes represent experiments. The x axes represent Hedges' adjusted *g*s. Hedges' adjusted *g*s are derived from comparisons of means of changes in attitude and intention from single strategies vs. combination of strategies. Sizes of squares are proportional to the precision of the estimate. Diamonds show summary effects. Centre lines of diamonds show weighted means of the effect sizes. Error bars and width of diamonds show 95% confidence intervals. Numbers in brackets show values of confidence intervals. Heterogeneity of presented results: **(A)** $I^2 = 46\%$ ($Tau^2 = 0.02$), **(B)** $I^2 = 0\%$ ($Tau^2 = 0$).

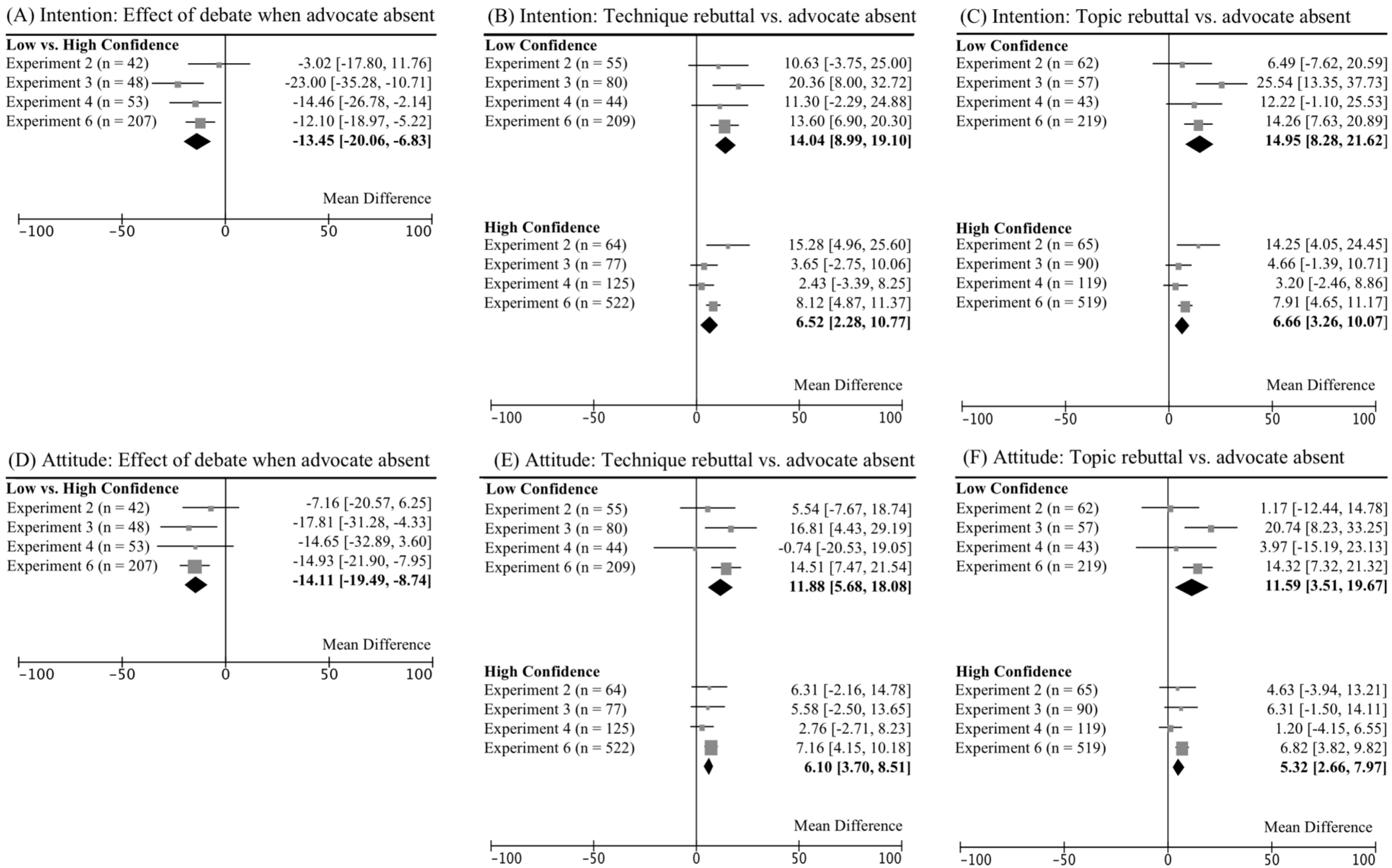

Fig. 5. The influence of the debate is stronger on audiences with low (vs. high) confidence when the advocate is absent (changes in intention: A; changes in attitude: D). The y axes represent experiments. The x axes represent absolute mean differences. Rebuttal strategies are more beneficial for participants with low confidence than with high confidence (changes in intention: B,C; changes in attitude: E,F). Sizes of squares are proportional to the precision of the estimate. Diamonds show summary effects. Centre lines of diamonds show weighted means of the effect sizes. Error bars and width of diamonds show 95% confidence intervals. Numbers in brackets show values of confidence intervals.

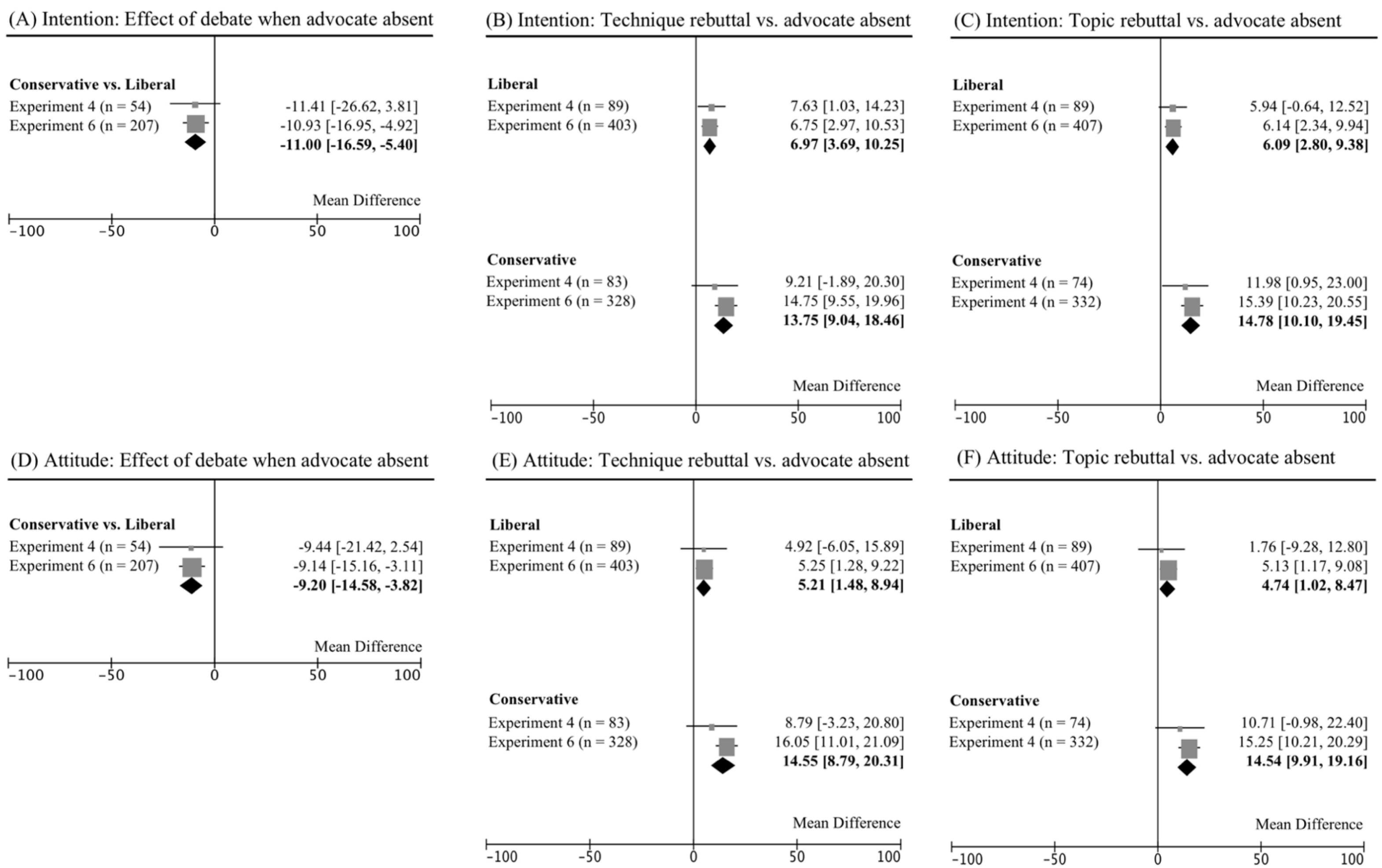

Fig. 6. The influence of the debate is stronger on U.S. conservative (vs. liberal) audiences when the advocate is absent (changes in intention: A; changes in attitude: D). The y axes represent experiments. The x axes represent absolute mean differences. In the U.S. samples, rebuttal strategies were more beneficial for conservative participants than for liberal participants (changes in intention: B,C; changes in attitude: E,F). Sizes of squares are proportional to the precision of the estimate. Diamonds show summary effects. Centre lines of diamonds show weighted means of the effect sizes. Error bars and width of diamonds show 95% confidence intervals. Numbers in brackets show values of confidence intervals.

For topic rebuttal the same pattern occurred. Topic rebuttal reduced the impact of the denier on liberal and conservative participants' attitudes and intentions, yet the effect was stronger for conservative participants (Fig. 6C, F; attitude as a function of being liberal vs. conservative: $\chi^2(1) = 10.45$, $p = .001$, $I^2 = 90.4\%$; intention: $\chi^2(1) = 8.88$, $p = .003$, $I^2 = 88.7\%$). Again, for prior beliefs we found such a moderating effect only for the intention to vaccinate (Fig. 5C; $\chi^2(1) = 4.70$, $p = .030$, $I^2 = 78.7\%$); the attitude of participants with high or low confidence was equally affected by topic rebuttal (Fig. 5F; $\chi^2(1) = 2.09$, $p = .150$, $I^2 = 52.1\%$). It is important to note that the moderating effects of conservatism are limited to U.S. conservatism and evidence of moderating effects is absent in the German samples of Experiments 3 and 5 (see Supplementary Table 2 and Supplementary Table 3 for meta-data including German samples).

In sum, the results do not support the backfire hypothesis in attempts to rebut science denial in public discussions. Instead, the results suggest that both topic and technique rebuttal as single or as a combined strategy can reduce the impact of a science denier. Moreover, it is especially beneficial to use rebuttal strategies among audiences whose prior beliefs or ideology render them particularly vulnerable to science deniers.

To explore potential psychological processes that explain the effectiveness of the rebuttal strategies in the single studies, we measured the perceived persuasiveness of the denier and advocate (Experiment 1), the perceived argument strength of the denier and advocate (Experiments 2 & 5) and participants' persuasion knowledge (Experiment 3). However, none of the mediation analyses revealed evidence of indirect effects of rebuttal on participants' changes in intention and attitude via any of these mediators (see Supplement for results of single studies).

Sensitivity analyses were conducted for all confirmatory analyses. Controlling analyses for individual knowledge about the behaviours; relevance of radio and Internet as information sources and sociodemographic data (see Supplementary Figure 3 and Supplementary Figure 4); changing models from random models to fixed models; changing outcome from standardized mean differences to mean differences; dropping Experiment 5, which differed from all others with respect to domain (climate change); including all participants instead of excluding some according to the pre-specified criteria; using estimated means of attitude and intention at T2 controlled for values at T1 rather than difference scores; and excluding statistical outliers from pre- and post-values based on median absolute deviation (MAD: Leys, Ley, Klein, Bernard, & Licata, 2013) − did not change the obtained meta-analytic patterns (see Supplementary Table 4 and Supplementary Table 5 for data of all adjusted meta-analyses).

Discussion

In the light of the findings we recommend advocates for science to train in topic and technique rebuttal. Both strategies were equally effective in mitigating the influence of science deniers in public debates. Advocates can choose, depending on levels of expertise and confidence, which strategy they prefer. For example, a researcher in vaccinology might feel more confident to rebut misinformation with facts about the safety and effectiveness of vaccines while a communication expert might choose to uncover the rhetorical technique used by the science denier. Thus, advocates for science do not need to pre-manufacture and practice the combination of both strategies as there was no additional benefit from combining topic and technique rebuttal.

Still, being in a public debate with a science denier requires diligent preparation. It may seem like an endless universe of potential misinformation that is difficult to anticipate. However, analyses revealed that most topic arguments fall into five core categories and that deniers use the same five techniques to make those arguments appealing (Fig. 1; Schmid et al., 2018). Hence, if one implements only one strategy (topic or technique rebuttal), advocates need to prepare only five key messages that address the core topics or techniques. It is important to note that we did not test all possible topics and techniques and that the effectiveness of the strategies may vary with specific topics and techniques. Nevertheless, training in technique rebuttal seems especially valuable as the techniques are the same across a broad range of scientific domains (Diethelm & McKee, 2009; Schmid et al., 2018) – while the topics vary across domains (see Fig. 1 and Supplementary Figure 1). Therefore, technique rebuttal is the more universal strategy in the fight against misinformation. Applying only one of the strategies may seem less complex; however, doing so successfully during an ongoing discussion will still require sufficient training. Recognizing this fact, the World Health Organization already conducts training workshops to support advocates for vaccination in the European region (Tatum, 2017). Adapting such trainings to other regions and scientific domains should be considered.

The data presented here have a second important implication. Advocates for science do not need a well-disposed audience to effectively mitigate the influence of science denialism in the public. Research shows mixed evidence regarding the question of whether presenting the facts is ineffective or might even backfire in audiences whose prior beliefs or political ideology are threatened by the correction (Cook & Lewandowsky, 2016; Nyhan & Reifler, 2015; Van Der Linden, Leiserowitz, & Maibach, 2018; van der Linden et al., 2017). We find no evidence of backfire effects when using conventional ways of topic rebuttal (presenting the facts) in the present experiments. Moreover, there was no evidence that the effectiveness of this strategy was reduced by political ideology (Experiments 4 & 6) or prior beliefs (Experiments 2–4 & 6). In fact, audiences that were most vulnerable to messages of denial (individuals with low vaccine confidence and U.S. conservatives) benefitted the most from topic and technique rebuttal. Thus, an advocate for science does not need to back off from audiences that are assumed to be difficult to convince. Still, being present and rebutting science denial makes a positive difference.

The advocate being absent from the debate, however, can have negative effects on important determinants of behaviour (attitude, intention; Sheeran et al., 2016), as shown in the present experiments. We acknowledge that in some situations context factors may still force the advocate to avoid participation (e.g. the format of the discussion is not serious or personal safety is at risk (WHO, 2016)). However, with regard to the effectiveness of messages in conventional contexts, not turning up at the discussion at all seems to result in the worst effect. There might be one exception to this: if the advocate's refusal to take part in a debate about scientific facts leads to its cancellation, this outcome should be preferred (Cook et al., 2017; Cook, Maibach, van der Linden, & Lewandowsky, 2018) to avoid a negative impact on the audience. Also, as can be seen in five out of the six present experiments (Fig. 2), the debate usually had an overall negative impact on attitudes and intentions even though an advocate for science is present.

In relation to this, a third general take-home message is that advocates who take part in debates should not expect too much of their efforts. Therefore, facing deniers in public debates can only be one building block in the concerted effort to fight misinformation. Other recent approaches try to fight misinformation by pre-emptively providing laypeople the ability to identify false information themselves (Cook et al., 2017; Nsangi et al., 2017; van der Linden et al., 2017). For example, in a study conducted with Ugandan primary school children, researchers educated 10- to 12-years-olds to separate misconceptions about health treatments from facts (Nsangi et al., 2017). Such educative approaches are in line with psychological research that attempts to inoculate individuals against misinformation (Cook et al., 2017; van der Linden et al., 2017). The idea of inoculation is to make individuals aware of arguments of denial *before* the actual information is obtained and to provide them with the ability to come up with counter-arguments. An inoculated audience might be less susceptible to deniers' arguments and the effects shown in the present experiments may be weaker in such an audience.

The presented studies have some limitations. In all experiments we collected data on individuals' intention to perform a behaviour rather than the actual behaviour. Research about the intention–behaviour gap (Sheeran, 2002) highlights that a behavioural intention does not necessarily translate into actual behaviour. Several practical or environmental barriers can hinder vaccination and actions against climate change despite individuals' high intentions to perform these behaviours. Moreover, we do not know whether the attitudes and behavioural intentions expressed in the experiments remain stable after a longer period of time. The presented meta-analyses report the short-term effectiveness of rebuttal, that is, immediately after the public discussion. Therefore, we cannot estimate the effectiveness of the discussed strategies over time or after repeated exposure to science denial. Longitudinal studies should address this question.

All experiments were conducted online. This media channel represents a natural habitat of misinformation and public debate. However, it may also lead to an underestimation of effects compared to laboratory experiments because participants are more easily distracted from instructions and stimulus materials. Following the Elaboration Likelihood Model (Petty & Cacioppo, 1986), distractions impair the ability to process strong arguments. Distracted individuals could be persuaded by peripheral cues rather than the content of the argument. We therefore included two attention checks (Berinsky, Margolis, & Sances, 2014) in Experiment 4 to assess whether participants were able to process the varying contents of the arguments presented in that experiment (see Supplementary Information for explanation). Encouragingly, 94% of the participants passed both checks and we therefore assume a highly attentive sample. Generally speaking, it cannot be expected that the entire audience of a public discussion is equally motivated or capable of processing strong arguments. It therefore remains an important question as to whether peripheral cues (e.g., celebrity status of the science advocate) could facilitate the rebuttal strategies by drawing the attention of an unmotivated or distracted audience to the content of arguments.

All moderator analyses were explorative rather than confirmatory. Furthermore, a priori statistical power analyses were based on the size of expected main effects rather than interaction effects of moderation. Therefore, the results of subgroup analyses should be treated as suggestive only.

The spread of misinformation in the public has become one of the major challenges of the scientific community. The public speaks about a post-truth era (Lewandowsky et al., 2017) and even the U.S. Environmental Protection Agency (EPA) has been feared to adopt techniques of science denialism (Oreskes, 2018). Despite these alarming developments, researchers have proven to be capable of detecting patterns of science denialism in history (Oreskes & Conway, 2010), the underlying motivations of the rejection of science (Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016) and the spread of the deniers' false claims in media channels (Vosoughi et al., 2018). This has led researchers to better understand and respond by inoculating the public against misinformation (Cook et al., 2017; van der Linden et al., 2017) and debunk misconceptions (Lewandowsky et al., 2012). With the introduction of the rebuttal strategies the present study adds another tool for effectively mitigating the influence of denial.

Methods

All experiments conform to the ethical principles for psychological research provided by the German Research Foundation. The research was exempt from the requirement of ethical approval by the institutional review board of the University of Erfurt as it is negligible risk research and it involves only non-identifiable data about human beings. Participants gave their informed consent and could quit the experiments at any time. All participants received a debriefing after the experiment and the possibility to contact researchers for further information.

In sum $N = 2{,}202$ finalized the experiments and $n = 1{,}773$ (Experiment 1 $n = 112$, Experiment 2 $n = 164$, Experiment 3 $n = 201$, Experiment 4 $n = 227$, Experiment 5 $n = 148$ and Experiment 6 $n = 921$) were found eligible for further analyses (see exclusion criteria below). No statistical methods were used to pre-determine the sample size of Experiment 1. The samples sizes of Experiment 2 through 5 were pre-determined using a power-analyses to provide at least .80 power to detect a medium effect of $f = .25$ in an ANOVA with four groups. As a result of the meta-analyses of Experiment 1 through 5 we adjusted our assumption for the effect sizes of the final Experiment 6. Thus, the sample size of Experiment 6 was pre-determined using a power-analyses to provide at least .80 power to detect a small effect of $f = .10$ for all confirmatory analyses. Deviations from the preregistered sample sizes are due to the fact that: more (Experiment 2, Experiment 5, Experiment 6) or less individuals

(Experiment 4) than expected met the preregistered exclusion criteria or the recruiting agency invited more individuals than planned (Experiment 3). For demographics of the samples see specific Method sections of single experiments in the Supplementary Information. All preregistration protocols are available at aspredicted.org (Experiment 2: https://aspredicted.org/3hv7m.pdf; Experiment 3: https://aspredicted.org/ve6hv.pdf; Experiment 4: https://aspredicted.org/bf9qe.pdf; Experiment 5: https://aspredicted.org/ce2am.pdf and Experiment 6: https://aspredicted.org/ij55n.pdf).

Participants under the age of 18 were screened out at the beginning of all experiments. The following exclusion criteria were preregistered for Experiments 2–6: Participants were excluded when they did not finish the experiment, when the duration of participation exceeded 30 minutes or fell below five minutes (Experiment 5: three minutes) and when participants failed to answer a simple attention check. All exclusion criteria were applied to increase quality of responses in online experiments. The attention check for all experiments was a single choice question about the content of the discussion that they had read or heard depending on the experiment (see Supplementary Table 6 for wording). The attention check was not preregistered in Experiment 5 by mistake. We still applied this exclusion criterion to align the quality of results with those of the previous four experiments. We also applied these exclusion criteria to Experiment 1. Thus, we excluded the following numbers of participants from further analyses: $n = 13$ for Experiment 1, $n = 42$ for Experiment 2, $n = 60$ for Experiment 3, $n = 29$ for Experiment 4, $n = 69$ for Experiment 5 and $n = 216$ for Experiment 6. A sensitivity analysis tested the robustness of the results maintaining all participants in the analyses.

All experiments were conducted online using an Enterprise Feedback Suite (EFS) survey by Questback. Participants received an invitation via different recruiting systems and received compensation that varied depending on the experiment (see specific Method sections of single experiments in the Supplement). All experiments used a similar procedure. First, participants were randomly assigned to one of the four rebuttal conditions (advocate absent, topic only, technique only, combination of topic and technique). All participants were asked to read or listen to two vignettes from an audiotaped or written radio discussion. The subsequent vignettes presented a radio discussion with a science denier who argued against a behaviour favoured by science (vaccination: Experiments 1–4 & 6; taking action against climate change: Experiment 5). The two vignettes presented two different arguments of the denier. In all experiments in the domain of vaccination the denier used the topic and technique combination of safety and impossible expectation in the first vignette (see Fig. 1 for the specific argument) and the combination of trust and conspiracy in the second vignette (see https://osf.io/xx2kt/ for all stimuli). In Experiment 5 (climate change) the denier used the combination of consequence and selectivity (see Supplementary Figure 1 for the specific argument) in the first vignette, and consequence and fake expert in the second vignette (https://osf.io/xx2kt/). Depending on condition, the science advocate was either absent from the debate (no topic and no technique rebuttal condition) or present at the discussion (remaining three conditions). Conditions including a science advocate differed regarding the rebuttal of the denier. The advocate either corrected the facts about the topic, uncovered the technique of the denier or used a combination of both (see Fig. 1 and Supplementary Figure 1 for examples and https://osf.io/xx2kt/ for all stimuli). Prior to the discussion, all participants indicated their attitude towards the evidence-based behaviour under discussion and their intention to perform that behaviour (see Supplementary Table 6 for scales, reliability scores and references of all items). Participants indicated their attitude and intention a second time after they read or listened to the discussion. In addition, we collected U.S. residents' political ideology (Experiments 4 & 6) and general confidence in vaccination (Experiments 2–4 & 6). Changes in the intentions and attitudes for single experiments (post/pre) are reported in Fig. 2 using the percentage of maximum possible scores (POMP: Cohen et al., 1999) of the original scale, with higher values indicating a higher intention and a more positive attitude. Using POMP values allows for an easy interpretation of model parameters as each variable in the models ranges from 0–100 after the POMP transformation (changes in intention and attitude can be positive or negative, leading to a range of -100–100 after the POMP transformation). An increase of one unit on a POMP scale can be translated into an increase of 1% of the maximum possible score of the original scale. For example, a decrease in the attitude towards vaccination by 20 units (%) of the POMP scale would translate into a decrease of one point (20%) of the original five-point scale. Within forest plots values of political ideology and confidence are reported as low and high (based on median splits) to report rebuttal strategies as a function of these moderating variables. Median values for both moderators were identical in both studies (confidence: Median = 75 [low < 75; high ≥ 75]; U.S. conservatism: Median = 37.5 [liberal ≤ 37.5; conservative > 37.5]). Contrary to the preregistered protocol of Experiment 6 we used the median rather than pre-determined categories to define subgroups for explorative analyses. The pre-determined categories resulted in highly unbalanced group sizes. The median was used to reduce this bias. Descriptive data of moderator variables and dependent variables are provided in the Supplement. In addition to these moderator variables and dependent measures, in some experiments we collected data on potential mediator variables, control variables (knowledge, source relevance, gender, age, education) and additional variables for explorative reasons. Supplementary Table 6 presents the full list of assessed variables.

In all experiments we used repeated measurements ANOVAs to analyse the influence of the denier and the effectiveness of topic rebuttal and technique rebuttal to mitigate the influence. In Experiment 2,3 and 5 ANOVAs on difference scores rather than repeated measures ANOVAs were preregistered. Both approaches lead to identical results. However, we chose to report the repeated measures ANOVAs preregistered in Experiment 4 and 6 for all experiments because it reveals the influence of the denier on individuals' attitudes and intentions and the effectiveness of the rebuttal approaches in a single test. To compare the effectiveness of any kind of rebuttal we used a planned contrast to compare the three rebuttal conditions with the advocate absent condition (advocate absent vs. any kind of rebuttal: -3 1 1 1). A second planned contrast assessed the effectiveness of the combination of topic and technique rebuttal compared to the single strategies (single strategies vs. combined strategy: 0 -1 -1 2). The contrast analyses were not specified in the preregistration protocols of Experiments 2 and 3. All ANOVA results of single experiments are reported in the Supplementary Information.

As recommended (Goh et al., 2016; O'Keefe, 2015), we report and derive our conclusions using an internal random effects meta-analysis including all six experiments in the main manuscript. Effects in confirmatory analyses are presented as Hedges' adjusted *g*, that is, standardized mean differences, because the scales measuring attitude and intention differ between studies. In explorative subgroup analyses the scales to measure attitude and intention are identical between studies. In these analyses we report the results in absolute mean differences (Baguley, 2009). Meta-analyses of interaction effects of subgroups by experimental conditions (moderator analyses) are based on Cochran's Q test and Higgin's I^2 threshold of 50% (Sedgwick, 2013). Calculations of statistical power of confirmatory meta-analyses are reported in the Supplement. Participants of all experiments were blinded to group allocation. Owing to the automatic randomization mechanism, the investigators were blind to the group allocation process. The analyses were not performed blind to the conditions of the experiments.

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Authors' contributions. Both authors substantially contributed to this article. P.S. and C.B. developed and designed the study, conducted the analyses and wrote the paper and Supplementary Information. P.S. visualized and curated the data. C.B. secured the funding.

Data Accessibility Statement. The data supporting the findings of this study are available from the Open Science Framework with the identifier doi: https://doi.org/10.17605/OSF.IO/XX2KT (Schmid & Betsch, 2019).

Code Accessibility Statement. The syntax used to analyse the datasets in this study are available from the Open Science Framework with the identifier doi: https://doi.org/10.17605/OSF.IO/XX2KT (Schmid & Betsch, 2019).

Conflict of interest statement. The authors declare no competing interests.

References

Allen, M. (1991). Meta-analysis comparing the persuasiveness of one-sided and two-sided messages. *Western Journal of Speech Communication*, *55*(4), 390–404. https://doi.org/10.1080/10570319109374395

American Chemical Society. (2017). Teaching of Evolution: Fact and Theory. Retrieved November 14, 2018, from https://www.acs.org/content/acs/en/policy/publicpolicies/education/evolution.html

Baguley, T. (2009). Standardized or simple effect size: What should be reported? *British Journal of Psychology*, *100*(3), 603–617. https://doi.org/10.1348/000712608X377117

Benoit, W. L., Hansen, G. J., & Verser, R. M. (2003). A Meta-analysis of the Effects of Viewing U.S. Presidential Debates. *Communication Monographs*, *70*(4), 335–350. https://doi.org/10.1080/0363775032000179133

Berinsky, A. J., Margolis, M. F., & Sances, M. W. (2014). Separating the shirkers from the workers? Making sure respondents pay attention on self-administered surveys. *American Journal of Political Science*, *58*(3), 739–753. https://doi.org/10.1111/ajps.12081

Betsch, C. (2017, June 27). Advocating for vaccination in a climate of science denial. *Nature Microbiology*. https://doi.org/10.1038/nmicrobiol.2017.106

Björnberg, K. E., Karlsson, M., Gilek, M., & Hansson, S. O. (2018, November 20). Climate and environmental science denial: A review of the scientific literature published in 1990–2015. *Journal of Cleaner Production*. Elsevier. https://doi.org/10.1016/j.jclepro.2017.08.066

Cacioppo, J. T., Petty, R. E., & Morris, K. J. (1983). Effects of need for cognition on message evaluation, recall, and persuasion. *Journal of Personality and Social Psychology*, *45*(4), 805–818. https://doi.org/10.1037/0022-3514.45.4.805

Carmichael, J. T., Brulle, R. J., & Huxster, J. K. (2017). The great divide: understanding the role of media and other drivers of the partisan divide in public concern over climate change in the USA, 2001–2014. *Climatic Change*, *141*(4), 599–612. https://doi.org/10.1007/s10584-017-1908-1

Chaiken, S. (1980). Heuristic versus systematic information processing and the use of source versus message cues in persuasion. *Journal of Personality and Social Psychology*, *39*(5), 752–766. https://doi.org/10.1037/0022-3514.39.5.752

Chigwedere, P., Seage, G. R., Gruskin, S., Lee, T.-H., & Essex, M. (2008). Estimating the Lost Benefits of Antiretroviral Drug Use in South Africa. *JAIDS Journal of Acquired Immune Deficiency Syndromes*, *49*(4), 410–415. https://doi.org/10.1097/QAI.0b013e31818a6cd5

Cockrell, M., Dubickas, K., Hepner, M., Ilich, A., & McCarthy, M. (2018). Embracing Advocacy in Science. *Fisheries*, *43*(4), 179–182. https://doi.org/10.1002/fsh.10055

Cohen, P., Cohen, J., Aiken, L. S., & West, S. G. (1999). The problem of units and the circumstance for POMP. *Multivariate Behavioral Research*, *34*(3), 315–346. https://doi.org/10.1207/S15327906MBR3403_2

Cook, J., & Lewandowsky, S. (2011). *The debunking handbook*. https://doi.org/10.1017/CBO9781107415324.004

Cook, J., & Lewandowsky, S. (2016). Rational Irrationality: Modeling Climate Change Belief Polarization Using Bayesian Networks. *Topics in Cognitive Science*, *8*(1), 160–179. https://doi.org/10.1111/TOPS.12186

Cook, J., Lewandowsky, S., & Ecker, U. K. H. (2017). Neutralizing misinformation through inoculation:

Exposing misleading argumentation techniques reduces their influence. *PLoS ONE*, *12*(5), e0175799. https://doi.org/10.1371/journal.pone.0175799

Cook, J., Maibach, E., van der Linden, S., & Lewandowsky, S. (2018). *The Consensus Handbook climate change is important*. https://doi.org/10.1016/j.vacuum.2008.03.035

Diethelm, P., & McKee, M. (2009, October 16). Denialism: What is it and how should scientists respond? *European Journal of Public Health*. Oxford University Press. https://doi.org/10.1093/eurpub/ckn139

Ecker, U. K. H., Hogan, J. L., & Lewandowsky, S. (2017). Reminders and Repetition of Misinformation: Helping or Hindering Its Retraction? *Journal of Applied Research in Memory and Cognition*, *6*(2), 185–192. https://doi.org/10.1016/j.jarmac.2017.01.014

Eisend, M. (2007). Understanding two-sided persuasion: An empirical assessment of theoretical approaches. *Psychology and Marketing*, *24*(7), 615–640. https://doi.org/10.1002/mar.20176

European Comission. (2014). Causes of climate change | Climate Action. Retrieved May 13, 2019, from https://ec.europa.eu/clima/change/causes_en

Flaherty, D. K. (2011). The vaccine-autism connection: A public health crisis caused by unethical medical practices and fraudulent science. *Annals of Pharmacotherapy*, *45*(10), 1302–1304. https://doi.org/10.1345/aph.1Q318

Friestad, M., & Wright, P. (1994). The Persuasion Knowledge Model: How People Cope with Persuasion Attempts. *Journal of Consumer Research*, *21*(1), 1. https://doi.org/10.1086/209380

Goh, J. X., Hall, J. A., & Rosenthal, R. (2016). Mini Meta-Analysis of Your Own Studies: Some Arguments on Why and a Primer on How. *Social and Personality Psychology Compass*, *10*(10), 535–549. https://doi.org/10.1111/spc3.12267

Hornsey, M. J., & Fielding, K. S. (2017). Attitude roots and jiu jitsu persuasion: Understanding and overcoming the motivated rejection of science. *American Psychologist*, *72*(5), 459–473. https://doi.org/10.1037/a0040437

Hronikx, J. (2005). A review of experimental research on the relative persuasiveness of anecdotal, statistical, causal, and expert evidence. *Studies in Communication Sciences*, *5*(1), 205–216. Retrieved from http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.725.6516&rep=rep1&type=pdf

Lewandowsky, S., Ballard, T., Oberauer, K., & Benestad, R. (2016). A blind expert test of contrarian claims about climate data. *Global Environmental Change*, *39*, 91–97. https://doi.org/10.1016/j.gloenvcha.2016.04.013

Lewandowsky, S., Ecker, U. K. H., & Cook, J. (2017). Beyond Misinformation: Understanding and Coping with the "Post-Truth" Era. *Journal of Applied Research in Memory and Cognition*, *6*(4), 353–369. https://doi.org/10.1016/j.jarmac.2017.07.008

Lewandowsky, S., Ecker, U. K. H., Seifert, C. M., Schwarz, N., & Cook, J. (2012). Misinformation and Its Correction: Continued Influence and Successful Debiasing. *Psychological Science in the Public Interest, Supplement*, *13*(3), 106–131. https://doi.org/10.1177/1529100612451018

Lewandowsky, S., & Oberauer, K. (2016). Motivated Rejection of Science. *Current Directions in Psychological Science*, *25*(4), 217–222. https://doi.org/10.1177/0963721416654436

Leys, C., Ley, C., Klein, O., Bernard, P., & Licata, L. (2013). Detecting outliers : Do not use standard deviation around the mean , use absolute deviation around the median. *Journal of Experimental Social Psychology*, *49*(4), 764–766. https://doi.org/10.1016/j.jesp.2013.03.013

Mildenberger, M., & Leiserowitz, A. (2017). Public opinion on climate change: Is there an economy–environment tradeoff? *Environmental Politics*, *26*(5), 801–824. https://doi.org/10.1080/09644016.2017.1322275

Nsangi, A., Semakula, D., Oxman, A. D., Austvoll-Dahlgren, A., Oxman, M., Rosenbaum, S., … Sewankambo, N. K. (2017). Effects of the Informed Health Choices primary school intervention on the ability of children in Uganda to assess the reliability of claims about treatment effects: a cluster-randomised controlled trial. *The Lancet*, *390*(10092), 374–388. https://doi.org/10.1016/S0140-6736(17)31226-6

Nyhan, B., & Reifler, J. (2010). When corrections fail: The persistence of political misperceptions. *Political Behavior*, *32*(2), 303–330. https://doi.org/10.1007/s11109-010-9112-2

Nyhan, B., & Reifler, J. (2015). Does correcting myths about the flu vaccine work? An experimental evaluation of the effects of corrective information. *Vaccine*, *33*(3), 459–464. https://doi.org/10.1016/j.vaccine.2014.11.017

O'Keefe, D. J. (2002). *Persuasion: Theory and Research* (2nd ed.). SAGE. https://doi.org/psycinfo/1990-97697-000

O'Keefe, D. J. (1999). How to Handle Opposing Arguments in Persuasive Messages: A Meta-Analytic Review of the Effects of One-Sided and Two-Sided Messages. *Annals of the International Communication Association*, *22*(1), 209–249. https://doi.org/10.1080/23808985.1999.11678963

O'Keefe, D. J. (2015). Message Generalizations That Support Evidence-Based Persuasive Message Design: Specifying the Evidentiary Requirements. *Health Communication*, *30*(2), 106–113. https://doi.org/10.1080/10410236.2014.974123

Odenbaugh, J. (2017). On the Contrary: How to Think About Climate Skepticism *. *Routledge Companion to Environmental Ethics*, (Benjamin Hale and Andrew Light, eds.Routledge Press). Retrieved from http://www.academia.edu/download/37954133/On_the_Contrary.pdf

Oreskes, N. (2018). Beware: Transparency rule is a Trojan Horse. *Nature*, *557*(7706), 469. https://doi.org/10.1038/d41586-018-05207-9

Oreskes, N., & Conway, E. M. (2010). Defeating the merchants of doubt. *Nature*. https://doi.org/10.1038/465686a

Petty, R. E., & Cacioppo, J. T. (1986). The Elaboration Likelihood Model of Persuasion. *Advances in Experimental Social Psychology*. https://doi.org/10.1016/S0065-2601(08)60214-2

Pornpitakpan, C. (2004). The Persuasiveness of Source Credibility: A Critical Review of Five Decades' Evidence. *Journal of Applied Social Psychology*, *34*(2), 243–281. https://doi.org/10.1111/j.1559-1816.2004.tb02547.x

Schmid, P., MacDonald, N. E., Habersaat, K., & Butler, R. (2018). Commentary to: How to respond to vocal vaccine deniers in public. *Vaccine*, *36*(2). https://doi.org/10.1016/j.vaccine.2016.09.065

Schmid, P., & Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. https://doi.org/10.1038/s41562-019-0632-4

Sedgwick, P. (2013). Meta-analyses heterogeneity and subgroup analysis _ The BMJ. *British Medical Journal*, *346*(f4040). Retrieved from https://www.bmj.com/content/346/bmj.f4040.full

Seiter, J., Weger, H., Jensen, A., & Kinzer, H. (2010). The role of background behavior in televised debates:

Does displaying nonverbal agreement and/or disagreement benefit either debater? *Journal of Social Psychology*, *150*(3), 278–300. https://doi.org/10.1080/00224540903510811

Sheeran, P. (2002). Intention — Behavior Relations : A Conceptual and Empirical Review. *European Review of Social Psychology*, *12*(1), 1–36. https://doi.org/10.1080/14792772143000003

Sheeran, P., Maki, A., Montanaro, E., Avishai-Yitshak, A., Bryan, A., Klein, W. M. P., … Rothman, A. J. (2016). The impact of changing attitudes, norms, and self-efficacy on health-related intentions and behavior: A meta-analysis. *Health Psychology*, *35*(11), 1178–1188. https://doi.org/10.1037/hea0000387

Tatum, A. (2017). Communicating science-based messages on vaccines. *World Health Organization. Bulletin of the World Health Organization*, *95*(10), 670–671. https://doi.org/http://dx.doi.org/10.2471/BLT.17.021017

van der Linden, S., Leiserowitz, A., & Maibach, E. (2018). Scientific agreement can neutralize politicization of facts. *Nature Human Behaviour*. https://doi.org/10.1038/s41562-017-0259-2

van der Linden, S., Leiserowitz, A., Rosenthal, S., & Maibach, E. (2017). Inoculating the Public against Misinformation about Climate Change. *Global Challenges*, *1*(2), 1600008. https://doi.org/10.1002/gch2.201600008

Vosoughi, S., Roy, D., & Aral, S. (2018). The spread of true and false news online. *Science*, *359*(6380), 1146–1151. https://doi.org/10.1126/science.aap9559

Williamson, P. (2016). Take the time and effort to correct misinformation. *Nature*, *540*(7632), 171–171. https://doi.org/10.1038/540171a

World Health Organization. (2009). Vaccines and immunization. Retrieved June 10, 2019, from http://www.euro.who.int/en/health-topics/disease-prevention/vaccines-and-immunization/vaccines-and-immunization

World Health Organization. (2016). *Best practice guidance: How to respond to vocal vaccine deniers in public*. Copenhagen: World Health Organization,. Retrieved from http://www.euro.who.int/de/health-topics/disease-prevention/vaccines-and-immunization/publications/2016/best-practice-guidance-how-to-respond-to-vocal-vaccine-deniers-in-public-2016

Ziman, J. (1996). Is Science Losing its Objectivity? *Nature*, *382*, 751–754. Retrieved from http://www.uio.no/studier/emner/matnat/ifi/MNSES9100/v13/pensumliste/introduction/Ziman Nature.pdf

Supplementary Information

Article 2

Effective strategies for rebutting science denialism in public discussions

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Supplementary Methods

In the following we will report the general methods and materials of the six single experiments. For data analysis of single studies, we used IBM SPSS 23. For analysis of meta results and forest plots we used Review Manager 5.3 from the Cochrane Collaboration (Cochrane Collaboration, 2014). In addition, we used Meta Essentials (Suurmond, van Rhee, & Hak, 2017) to calculate meta effect-sizes of repeated measures. In all experiments we used a repeated measurements ANOVA to analyse the influence of the denier and the effectiveness of topic rebuttal and technique rebuttal to mitigate the influence. To compare the effectiveness of any kind of rebuttal we used a planned contrast to compare the three rebuttal conditions with the advocate absent condition (advocate absent vs. any kind of rebuttal): -3 1 1 1). A second planned contrast assessed the effectiveness of the combination of topic and technique rebuttal compared to the single strategies (single strategies vs. combined strategy): 0 -1 -1 2). ANCOVAs included preregistered control variables to test for the robustness of the effects (Supplementary Tables 7–9). The control variables were not preregistered for Experiment 5 by mistake; however, we applied these control variables to all datasets. The analyses of potential mediators and moderators of the effectiveness of the rebuttal strategies in single studies (see specific Methods of single experiments below) were analysed using the PROCESS macro for SPSS (Hayes, 2013). The significances or p-values for hypothesis tests in all models are two-sided. Data distributions were assumed to be normal and variances were assumed to be homogeneous but this was not formally tested (see Figure 2 for data distributions). All reported error bars are 95% confidence intervals except for partial eta-squared. 90% confidence intervals are reported for partial eta-squared due to the characteristics of the F-distribution (Lakens, 2013).

Experiment 1

Participants of Experiment 1 were students of the University of Erfurt and received the invitation to participate via a mailing list. For compensation, participants entered a lottery and had the chance of winning one of two €10 vouchers for a café on campus. Experiment 1 was not preregistered. We aligned analysis and exclusion criteria with preregistration forms of Experiment 2, 3, 4 and 6. Participants of Experiment 1 received the materials of the discussion in audio format. Due to the presentation format we excluded the relevance of the internet as a control variable in the ANCOVA (see Supplementary Tables 7–9) because the scenario included radio as a source of information only. In this experiment we measured the perceived persuasiveness(Cacioppo, Petty, & Morris, 1983) of the denier and advocate as potential mediators of the effectiveness of the rebuttal strategies. The full list of items, scales, sources and reliability scores for this experiment are also available in Supplementary Table 6.

Experiment 2

Participants of Experiment 2 received the invitation to participate via the recruiting agency Norstat from which they received compensation (bonus points to exchange into money). The recruiting agency used stratified sampling to recruit a more heterogenous sample compared to Experiment 1. The sample of Experiment 2 was representative for the general German population with regard to age, gender and education (Quotas: 23.5% low education; 51.41% middle education; 25.06% high education; 48.55% males; 18.07% males aged 18 – 29; 15.2% males aged 30 – 39; 21.36% males aged 40 – 49; 17.25% males aged 50– 59; 28.13 males with age > 59; 16.67% females aged 18 – 29; 13.95% females aged 30 – 39; 19.38% females aged 40 – 49; 16.28% females aged 50– 59; 33.72 females with age > 59). The quotas are representative for the German population. Sampling took place until the quotas were reached. Experiment 2 was preregistered via aspredicted.org (see https://aspredicted.org/3hv7m.pdf). Participants of Experiment 2 received the same materials as in Experiment 1, however this time in written format (the materials are available at https://osf.io/xx2kt/). In this experiment we measured the perceived argument strength (Zhao, Strasser, Cappella, Lerman, & Fishbein, 2011) of the denier and advocate as potential mediators of the effectiveness of the rebuttal strategies. In addition we measured general confidence in vaccination (Betsch et al., 2018) as a potential moderator of the effectiveness of messages of science denial and the effectiveness of rebuttal strategies (see main text for the rationale). The full list of items, scales, sources and reliability scores for this experiment are also available in Supplementary Table 6.

Experiment 3

Participants of Experiment 3 received the invitation to participate via the recruiting agency Norstat from which they received compensation (bonus points to exchange into money). Again, the recruiting agency used stratified sampling to recruit a more heterogenous sample compared to Experiment 1. The sample of Experiment 3 was representative for the general German population with regard to age, gender and education (see Experiment 2 for quotas). This study explored the influence of the denier and the effectiveness of rebuttal with increasing time between encoding and measurement. Therefore, participants additionally indicated their intention and attitude one week after the first measure. Experiment 3 was preregistered via aspredicted.org (see https://aspredicted.org/ve6hv.pdf). Participants of Experiment 3 received the same discussion materials as in Experiment 2. A minor change was conducted regarding the penultimate sentence of the science advocate in the technique rebuttal only condition. It read: "What we are absolutely certain about is that the risk of the disease by far outweighs the risk of the disease." This sentence could additionally provide a topic rebuttal rather than only concluding a technique rebuttal. To avoid potential overlap of topic rebuttal and technique rebuttal, we changed this sentence to "Therefore, the claims of *[name of science denier]* are not tenable."

In this experiment we measured individuals' persuasion knowledge (Tutaj & van Reijmersdal, 2012) as a potential mediator of the effectiveness of the rebuttal strategies. In addition we measured general confidence in vaccination (Betsch et al., 2018) and conservatism as potential moderators of the effectiveness of messages of science denial and the effectiveness of rebuttal strategies (see main text for the rationale). The full list of items, scales, sources and reliability scores for this experiment are also available in Supplementary Table 6.

Experiment 4

Participants of Experiment 4 received the invitation to participate via Amazon Mechanical Turk. The invitation was restricted to US residents to recruit a sample from a different country with a different language compared to the previous experiments. Participants received the fixed amount of $2 for participation. Participants of Experiment 4 received the same materials as in Experiments 1-3. The materials were translated into English. Compared to previous experiments, the last sentence of the science advocate in the technique only condition was changed slightly. The technique only condition failed to reach the same effectiveness in Experiment 3 compared to the previous experiments. The change of the last sentence in Experiment 3 ("Therefore, the claims of *[name of science denier]* are not tenable."; Method section of Experiment 3) might have been perceived as too devaluing compared to the previous ones. In fact, participants of the technique only condition in Experiment 3 rated the character of the advocate as more negative compared to the other rebuttal conditions, ($F(2, 150) = 5.32$, $p = .006$, $\eta^2_p = .066$, [.012, .131]). We therefore aligned the final sentence in all rebuttal conditions using the following wording: "The vaccine improves the health standard for all individuals and that is why we recommend it."

This direct recommendation is neither specific for topic rebuttal nor technique rebuttal. Experiment 4 was preregistered via aspredicted.org (see https://aspredicted.org/bf9qe.pdf).

Following our preregistration form we included two screener questions in Experiment 4 to stratify results by attention of participants (see Supplementary Table 6). This has been recommended for online experiments (Berinsky, Margolis, & Sances, 2014). As data revealed that 94% of participants passed both screener questions we thus chose not to report stratified results. Attention measured via screener questions was no preregistered exclusion criteria. Therefore, all following analyses are based on the full sample. In this Experiment we measured general confidence in vaccination (Betsch et al., 2018) and conservatism as potential moderators of the effectiveness of messages of science denial and the effectiveness of rebuttal strategies (see main text for the rationale). The full list of items, scales, sources and reliability scores for this experiment are also available in Supplementary Table 6.

Experiment 5

Participants of Experiment 5 received the invitation to participate via a mailing list and advertisement on social media. For compensation, participants entered a lottery and had the chance of winning one of three €15 vouchers for an online store. Participants of Experiment 5 received materials adapted to the context of climate change (available at https://osf.io/xx2kt/; Supplementary Figure 1 provides one example). Experiment 5 was preregistered via aspredicted.org (see https://aspredicted.org/ce2am.pdf).The dependent variables in this experiment were the attitude towards actions against climate change adapted from Askelson et al. (2010) and the intention to take action against climate change with 7 specific behaviours adapted from Montada et al. (2014). In addition, we gave participants the opportunity to donate their prize of €15 to an environmental organization (e.g., World Wide Fund for Nature, WWF) instead of receiving a voucher. This option was given before and after the debate. Differences in changes in the decision to donate between groups were analysed using Generalized Estimating Equations (GEE). Results of the GEE model are discussed below. In this experiment we measured the perceived argument strength(Zhao et al., 2011) of the denier and advocate as a potential mediator of the effectiveness of the rebuttal strategies. In addition, we measured conservatism as a potential moderator of the effectiveness of messages of science denial and the effectiveness of rebuttal strategies (see main text for the rationale). The full list of items, scales, sources and reliability scores for this experiment are also available in Supplementary Table 6.

Experiment 6

Participants of Experiment 6 received the invitation to participate via Amazon Mechanical Turk. The invitation was restricted to U.S. residents. Participants received the fixed amount of $1.5 for participation. Experiment 6 was preregistered via aspredicted.org (see https://aspredicted.org/ij55n.pdf). Participants of Experiment 6 received the same materials and the same screener questions as in Experiment 4. As data revealed that 94% of participants passed both screener questions, we thus chose not to report stratified results. Attention measured via screener questions was no preregistered exclusion criteria. Therefore, all following analyses are based on the full sample. In this experiment we measured general confidence in vaccination (Betsch et al., 2018) and conservatism as potential moderators of the effectiveness of messages of science denial and the effectiveness of rebuttal strategies (see main text for the rationale). The full list of items, scales, sources and reliability scores for this experiment are also available in Supplementary Table 6.

Supplementary Results

In the following we will report the results of the six single experiments.

Experiment 1

N = 202 participants clicked on the link, 168 proceeded after the introduction page and 125 finished the experiment. The exclusion of 13 participants due to the specified criteria (see Methods section in the main text) resulted in a sample size of n = 112 for all following analyses (age: $M_{age} = 22.81$, $SD_{age} = 4.10$; gender: 84% female; education: 99% reported a university entrance diploma or a higher education). Participants of Experiment 1 indicated a high willingness to get vaccinated ($M_{prior\_intention} = 76.68$, $SD_{prior\_intention} = 21.77$) prior to the stimulus material. On average they reached 57.14% ($SD_{knowledge} = 27.82$) of the maximum possible knowledge score. Participants reported a low relevance of radio as an information source about vaccination ($M_{relevance\_radio} = 10.34$, $SD_{relevance\_radio} = 9.42$). There was no evidence of differences between conditions in intention to get vaccinated (ANOVA, $F(3, 108) = 1.29$, $p = .281$, effect size $\eta^2_p = .035$, 90% confidence interval [.000, .085]), knowledge about vaccination ($F(3, 108) = 1.00$, $p = .396$, $\eta^2_p = .027$, [.000, .071]) and relevance of radio ($F(3, 108) = 0.55$, $p = .649$, $\eta^2_p = .015$, [.000, .046]).

Influence of the Denier and Effectiveness of Rebuttal. The cell sizes, means, and standard deviations of changes in intention and attitude for all conditions of all experiments are reported in Supplementary Table 10 and Supplementary Table 11. Across all conditions the discussion with the science denier significantly decreased individuals' intention to get vaccinated (repeated-measurement ANOVA, $F(1, 108) = 35.45$, $p < .001$, $\eta^2_p = .247$, [.136, .351]). Planned contrast analysis reveals that the science denier had a stronger effect when the advocate was absent compared to conditions where the advocate was present ($F(1, 108) = 9.89$, $p = .002$, $\eta^2_p = .084$, [.019, .174]).

The influence of the science denier decreased when the advocate used technique rebuttal compared to no technique rebuttal ($F(1, 108) = 4.93$, $p = .028$, $\eta^2_p = .044$, [.002, .120]). The effect of topic rebuttal in decreasing the influence of the denier compared to no topic rebuttal was marginally significant ($F(1, 108) = 3.34$, $p = .070$, $\eta^2_p = .030$, [.000, .099]). There was no evidence of an interaction effect of topic and technique rebuttal on changes of individuals' intention to get vaccinated ($F(1, 108) = 1.57$, $p = .213$, $\eta^2_p = .014$, [.000, .071]).

Planned contrast analysis revealed no evidence of a benefit of the combination compared to the single strategies in mitigating the influence of the denier ($F(1, 108) = 0.42$, $p = .519$, $\eta^2_p = .004$, [.000, .045]).

Repetition of all ANOVAs with control variables revealed the same pattern of results (see Supplementary Table 7–9 for ANCOVA results).

Indirect Effects of Rebuttal – Mediation Analysis. In the following analysis we explore whether the significant effect of technique rebuttal (vs. no technique rebuttal) on mitigating the influence of the denier on individuals' attitude and intention could be explained via a decreased perceived persuasiveness of the denier and/or an increased perceived persuasiveness of the advocate (see Supplementary Table 6 for items). The perceived persuasiveness of the denier (Model 1) and the perceived persuasiveness of the advocate (Model 2) are analysed as mediators in separate models due to different sample sizes of the models (values of the perceived persuasiveness of the advocate are missing in the advocate absent condition).

The mediation models revealed that increased perceived persuasiveness of the denier decreases the intention to get vaccinated (Model 1: $B = -0.51$, 95% confidence interval [-0.63, -0.39], $p < .001$) and that an increased perceived persuasiveness of the advocate mitigates the decrease (Model 2: $B = 0.47$, [0.27, 0.68], $p < .001$). However, the analyses showed no evidence of an effect of technique rebuttal on the perceived persuasiveness of the denier or advocate (Model 1: $B = -4.52$, [-13.19, 4.16], $p = .304$; Model 2: $B = -2.41$, [-10.38, 5.57], $p = .550$). Bootstrap estimation approaches with 1,000 samples revealed no evidence of indirect effects of technique rebuttal on changes in intention via perceived persuasiveness of the denier (Model 1: B = 2.30, [-1.45, 7.07]) or advocate (Model 2: B = -1.14, [-4.91, 2.01]). Repetition of all mediation models with control variables (see Method section) revealed a similar pattern of results (see Supplementary Table 12). Hence, there was no evidence that technique rebuttal mitigated the influence of the denier via a decreased perceived persuasiveness of the denier or an increased perceived persuasiveness of the advocate.

Experiment 2

N = 260 participants clicked on the link, 238 proceeded after the introduction page and 206 finished the experiment. The exclusion of 42 participants due to the exclusion criteria (see Methods section in the main text) results in a sample size of n = 164 for all following analyses (age: M_{age} = 49.58, $SD_{age =}$ 14.70; gender: 54% female; education: 40% reported a university entrance diploma or a higher education). Participants of Experiment 2 were moderately confident in vaccination in general ($M_{confidence}$ = 59.60, $SD_{confidence}$ = 26.76). They indicated a moderately positive attitude towards vaccination against dysomeria ($M_{prior\_attitude}$ = 70.33, $SD_{prior\_attitude}$ = 23.43) and a moderate willingness to get vaccinated ($M_{prior\_intention}$ = 68.71, $SD_{prior\_intention}$ = 27.97) prior to the stimulus material. On average they reached 54.27% ($M_{knowledge}$ = 54.27, $SD_{knowledge}$ = 29.42) of the possible maximum knowledge score. Participants reported a low relevance of radio ($M_{relevance\_radio}$ = 12.64, $SD_{relevance\_radio}$ = 12.67) and a low relevance of the internet ($M_{relevance\_internet}$ = 16.80, $SD_{relevance\_internet}$ = 14.84) as an information source about vaccination. There was no evidence of significant differences between conditions in prior attitude towards vaccination (F(3, 160) = 0.16, p = .926, η^2_p = .003, [.000, .006]), prior intention to get vaccinated (F(3, 160) = 0.70, p = .551, η^2_p = .013, [.000, .038]), relevance of radio (F(3, 155) = 0.77, p = .512 η^2_p = .015, [.000, .042]), relevance of the internet (F(3, 159) = 0.39, p = .758, η^2_p = .007, [.000, .024]) and knowledge about vaccination (F(3, 160) = 2.37, p = .073, η^2_p = .043, [.000, .090]).

Influence of the Denier and Effectiveness of Rebuttal. The discussion with the science denier significantly decreased individuals' positive attitude towards vaccination, repeated-measurement ANOVA (F(1, 160) = 36.15, p < .001, η^2_p = .184, [.101, .270]. This was also observed for the intention to get vaccinated (F(1, 160) = 26.77, p < .001, η^2_p = .143, [.069, .226]). Planned contrast reveals that the science denier had a stronger effect on individuals' intention when the advocate was absent compared to conditions where the advocate was present ($F(1, 160) = 6.72$, $p = .010$, $\eta^2_p = .040$, [.005, .100]). There was no evidence of this effect for attitude ($F(1, 160) = 0.87$, $p = .351$, $\eta^2_p = .005$, [.000, .039]).

In line with Experiment 1, the influence of the science denier decreased when the advocate used technique rebuttal compared to no technique rebuttal, (attitude: $F(1, 160) = 4.34$, $p = .039$, $\eta^2_p = .026$, [.001, .079]; intention: $F(1, 160) = 8.95$, $p = .003$, $\eta^2_p = .053$, [.011, .118]). Evidence for this mitigating effect when using topic rebuttal was absent (attitude: $F(1, 160) = 0.07$, $p = .791$, $\eta^2_p < .001$, [.000, .018]; intention: $F(1, 160) = 2.62$, $p = .108$, $\eta^2_p = .016$, [.000, .062]). There was also no evidence of an interaction effect of topic and technique rebuttal on changes of individuals' intention to get vaccinated ($F(1, 160) = 0.27$, $p = .870$, $\eta^2_p < .001$, [.000, .027]) or changes of attitude towards vaccination ($F(1, 160) = 0.56$, $p = .457$, $\eta^2_p = .003$, [.000, .034]).

Planned contrast analysis revealed a significant benefit of the combination compared to the single strategies for mitigating the influence of the denier on the audience's intention ($F(1, 160) = 4.00$, $p = .047$, $\eta^2_p = .024$, [.000, .076]), but there was no evidence of a benefit for mitigating the influence on the audience's attitude ($F(1, 160) = 2.42$, $p = .122$, $\eta^2_p = .015$, [.000, .060]).

Repetition of all ANOVAs with control variables revealed a similar pattern of results (see Supplementary Tables 7–9 for ANCOVA results). However, two relevant changes occurred. After controlling for the covariates, the mitigating effect of technique rebuttal on the audience's attitude was only marginally significant and there was no evidence of a benefit of the combination compared to the single strategies on the audience's intention.

Indirect Effects of Rebuttal – Mediation Analysis. In the following analysis we explore whether the significant effect of technique rebuttal (vs. no technique rebuttal) on mitigating the influence of the denier could be explained via decreased perceived argument strength of the denier and/or increased perceived argument strength of the advocate (see Supplementary Table 6 for items). The perceived argument strength of the denier (Model 1 outcome: change in attitude; Model 2 outcome: change in intention) and the perceived argument strength of the advocate (Model 3 outcome: change in attitude; Model 4 outcome: change in intention) are analysed as mediators in separate models due to different sample sizes of the models (perceived argument strength of the advocate are lacking in the advocate absent condition).

The mediation models revealed that increased perceived argument strength of the denier decreases the positive attitude towards vaccination (Model 1: $B = -0.45$, [-0.60, -0.29], $p < .001$) and decreases the intention to get vaccinated (Model 2: $B = -0.61$, [-0.77, -0.45], p

< .001). Furthermore, an increased perceived argument strength of the advocate mitigates the decrease of attitude (Model 3: *B* = 0.45, [0.25, 0.64], p < .001) and intention (Model 4: *B* = 0.51, [0.31, 0.71], *p* < .001). However, the analyses showed no evidence of an effect of technique rebuttal on the perceived argument strength of the denier (Model 1 and Model 2: *B* = -1.44, [-7.37, 4.48], *p* = .631) or advocate (Model 3 and Model 4: *B* = 2.51, [-4.16, 9.19], *p* = .458). Bootstrap estimation approaches with 1,000 samples revealed no evidence for indirect effects of technique rebuttal on attitude (Model 1: *B* = 0.64, [-1.54, 3.68]; Model 3: *B* = 1.12, [-1.59, 5.30]) or intention (Model 2: *B* = 0.88, [-2.34, 5.48]; Model 4: *B* = -1.29, [-2.00, 5.68]) via perceived argument strength of the denier or advocate. Repetition of all mediation models with control variables (see Method section) revealed a similar pattern of results (see Supplementary Table 13). Hence, there was no evidence that technique rebuttal mitigated the influence of the denier via a decreased perceived argument strength of the denier or an increased perceived argument strength of the advocate.

Experiment 3

N = 383 clicked on the link, 333 proceeded after the introduction page and 261 finished the experiment. The exclusion of 60 participants due to the exclusion criteria (see main text Methods section) results in a sample size of n = 201 for all following analyses (age: M_{age} = 50.90, SD_{age} = 15.90; gender: 55% female; education: 42% reported a university entrance diploma or a higher education). Participants of Experiment 3 were rather liberal ($M_{conservatism}$ = 44.92, $SD_{conservatism}$ = 20.60) and moderately confident in vaccination in general ($M_{confidence}$ = 63.31, $SD_{confidence}$ = 27.73). They indicated a moderately positive attitude towards vaccination against dysomeria ($M_{prior\_attitude}$ = 74.71, $SD_{prior\_attitude}$ = 22.52) and a moderate willingness to get vaccinated ($M_{prior\_intention}$ = 71.23, $SD_{prior\_intention}$ = 26.85) prior to the stimulus material. On average they reached 57.6% ($M_{knowledge}$ = 57.60, $SD_{knowledge}$ = 28.57) of the maximum possible knowledge score. Participants reported a low relevance of radio ($M_{relevance\_radio}$ = 15.67, $SD_{relevance\_radio}$ = 16.03) and a low relevance of the internet ($M_{relevance\_internet}$ = 17.85, $SD_{relevance\_internet}$ = 15.11) as an information source about vaccination. There was no evidence of differences between conditions in prior attitude towards vaccination ($F(3, 197) = 0.74$, $p = .531$, $\eta^2_p = .011$, [.000, .033]), prior intention to get vaccinated ($F(3, 197) = 0.87$, $p = .456$, $\eta^2_p = .013$, [.000, .037]), relevance of radio ($F(3, 194) = 0.82$, $p = .483$, $\eta^2_p = .013$, [.000, .036]), relevance of the internet ($F(3, 197) = 1.34$, $p = .263$, $\eta^2_p = .020$, [.000, .050]) and knowledge about vaccination ($F(3, 197) = 1.20$, $p = .312$, $\eta^2_p = .018$, [.000, .046]).

Influence of the Denier and Effectiveness of Rebuttal. In line with Experiment 2, the discussion with the science denier significantly decreased individuals' attitude towards vaccination ($F(1, 197) = 87.40$, $p < .001$, $\eta^2_p = .307$, [.221, .385]) and individuals' intention to get vaccinated ($F(1, 197) = 39.88$, $p < .001$, $\eta^2_p = .168$, [.095, .245]). Planned contrast analysis reveals that the denier had a stronger effect when the science advocate was absent compared to conditions where the advocate was present (attitude: $F(1, 197) = 9.66$, $p = .002$, $\eta^2_p = .047$, [.010, .103]; intention: $F(1, 197) = 10.01$, $p = .002$, $\eta^2_p = .048$, [.011, .105]).

Contrary to Experiment 1 and 2, there was no evidence that the influence of the science denier decreased when the advocate used technique rebuttal compared to no technique rebuttal, (attitude: $F(1, 197) = 1.05$, $p = .308$, $\eta^2_p = .005$, [.000, .035]; intention: $F(1, 197) = 0.45$, $p = .503$, $\eta^2_p = .002$, [.000, .026]). However, results revealed a significant effect of topic rebuttal in decreasing the influence of the denier compared to no topic rebuttal (attitude: $F(1, 197) = 12.78$, $p < .001$, $\eta^2_p = .061$, [.018, .121]; intention: $F(1, 197) = 13.34$, $p < .001$, $\eta^2_p = .063$, [.019, .125]). There was no evidence of an interaction effect of topic and technique rebuttal on changes of individuals' intention to get vaccinated ($F(1, 197) = 1.57$, $p = .222$, $\eta^2_p = .008$, [.000, .041]) or on changes of attitude towards vaccination ($F(1, 197) = 0.73$, $p = .394$, $\eta^2_p = .004$, [.000, .030]).

Planned contrast analysis revealed no evidence of a benefit of the combination compared to the single strategies for mitigating the influence on attitude and intention (attitude: $F(1, 197) = 1.47$, $p = .227$, $\eta^2_p = .007$, [.000, .039]; intention: $F(1, 197) = 0.62$, $p = .433$, $\eta^2_p = .003$, [.000, .029]).

Repetition of all ANOVAs with control variables revealed the same pattern of results (see Supplementary Tables 7–9 for ANCOVA results).

Indirect Effects of Rebuttal – Mediation Analysis. Based on the preregistration we tested whether technique rebuttal (vs. no technique rebuttal) indirectly mitigated the influence of the denier on individuals' changes in attitude (Model 1) and change in intention (Model 2) via an increase in individuals' persuasion knowledge (see Supplementary Table 6 for items).

Contrary to our hypothesis, analyses revealed that technique rebuttal decreased individuals' persuasion knowledge (Model 1 and Model 2: $B = -6.85$, [-13.69, -0.00], $p = .050$). Moreover, there was no evidence that persuasion knowledge influenced individuals' change in attitude (Model 1: $B = 0.04$, [-0.06, 0.14], $p = .437$) or intention (Model 2: $B = 0.11$, [-0.00, 0.214], $p = .053$). Bootstrap estimation approaches with 1,000 samples revealed no evidence of an indirect effect of technique rebuttal on attitude (Model 1: $B = -0.28$, [-1.64, 0.34]) via persuasion knowledge. However, the analysis revealed a significant indirect effect on intention (Model 1: B = -0.73, [-2.46, -0.02]), which, however, contradicts the expected positive effect. Repetition of all mediation models with control variables (see Method section) revealed some relevant changes of results (see Supplementary Table 14). After controlling for the effects of the covariates, evidence of any effects was absent. To conclude, there was no evidence that technique rebuttal mitigated the influence of the denier via an increase in individuals' persuasion knowledge.

Analysis of attitudes and intention after one week. In this experiment we also collected data on individuals' attitude and intention one week after the initial experiment. All 270 participants who completed T1 received an invitation to participate at T2, 234 clicked on the link, 230 proceeded after the introduction page and 215 finished the experiment at T2. The exclusion of 63 participants due to the specified criteria (see Method section) results in a sample size of n = 152 at T2. We first analysed whether mortality from T1 to T2 (n = 49) varies systematically. We analysed whether there were systematic differences in the participants who participated vs. who did not participate in T2. Indeed, individuals in the combined condition who did not participate again at T2 were less influenced by the denier at T1 ($M_{change\_intention}$ = -0.89, SD = 12.04) than the participants that participated at T2 ($M_{change\_intention}$ = -5.69, SD = 13.12). This pattern was reversed for the advocate absent condition (not participating at T2: $M_{change\_intention}$ = -25.34, SD = 25.80; participating at T2: $M_{change\_intention}$ = -12.23, SD = 18.24) leading to a significant interaction of these two conditions and drop out, $F(1, 99) = 5.84$, $p = .017$, $\eta^2_p = .056$, [.005, .142]. Thus, individuals who were effectively protected from the influence of the denier by the combination of topic and technique rebuttal at T1 dropped out while individuals who were strongly influenced by the denier in the advocate absent condition participated at T2. Due to this confound, we refrained from further analysing the data. For transparency the data is fully accessible via https://osf.io/xx2kt/.

Experiment 4

N = 345 clicked on the link, 276 proceeded after the introduction page and 256 finished the experiment. The exclusion of 29 participants due to the exclusion criteria (see Method section) results in a sample size of n = 227 for all following analyses (age: M_{age} = 39.43, SD_{age} = 12.02; gender: 47% female; education: 74% reported an associate's degree or a higher education). Participants of Experiment 4 were rather liberal ($M_{conservatism}$ = 41.30,

$SD_{conservatism}$ = 28.10) and highly confident in vaccination in general ($M_{confidence}$ = 71.65, $SD_{confidence}$ = 30.59). They indicated a high positive attitude towards vaccination against dysomeria ($M_{prior\_attitude}$ = 86.60, $SD_{prior\_attitude}$ = 20.16) and a high willingness to get vaccinated ($M_{prior\_intention}$ = 79.75, $SD_{prior\_intention}$ = 27.36) prior to the stimulus material. On average they reached 67.89% ($M_{knowledge}$ = 67.89, $SD_{knowledge}$ = 31.36) of the maximum possible knowledge score. Participants reported a low relevance of radio ($M_{relevance\_radio}$ = 15.92, $SD_{relevance\_radio}$ = 17.48) and a low relevance of the internet ($M_{relevance\_internet}$ = 30.39, $SD_{relevance\_internet}$ = 18.16) as information sources about vaccination. There was no evidence of differences between conditions in prior attitude towards vaccination ($F(3, 223) = 0.44$, $p = .724$, $\eta^2_p = .006$, [.000, .019]), prior intention to get vaccinated ($F(3, 223) = 0.56$, $p = .641$, $\eta^2_p = .008$, [.000, .026]), relevance of radio ($F(3, 223) = 1.47$, $p = .224$, $\eta^2_p = .019$, [.000, .048]) and knowledge about vaccination ($F(3, 223) = 0.91$, $p = .439$, $\eta^2_p = .012$, [.000, .034]). However, relevance of the internet as an information source differed between conditions ($F(3, 223) = 3.62$, $p = .014$, $\eta^2_p = .047$, [.005, .089]).

Influence of the Denier and Effectiveness of Rebuttal. Again, the discussion with the science denier significantly decreased individuals' attitude towards vaccination ($F(1, 223) = 41.91$, $p < .001$, $\eta^2_p = .158$, [.091, .230]) and individuals' intention to get vaccinated ($F(1, 223) = 35.62$, $p < .001$, $\eta^2_p = .138$, [.074, .207]). Planned contrast analysis reveals that the denier had a stronger effect on individuals' intention when the science advocate was absent compared to conditions where the advocate was present ($F(1, 223) = 9.76$, $p = .002$, $\eta^2_p = .042$, [.009, .092]). This effect was only marginally significant for attitude ($F(1, 223) = 2.86$, $p = .092$, $\eta^2_p = .013$, [.000, .047]).

There was no evidence that the influence of the denier on the audience's attitude was mitigated by topic rebuttal or by technique rebuttal (topic rebuttal: $F(1, 223) = 1.25$, $p = .264$, $\eta^2_p = .006$, [.000, .033]; technique rebuttal: $F(1, 197) = 2.35$, $p = .127$, $\eta^2_p = .010$, [.000, .043]). The influence of the science denier on the audience's intention decreased when the advocate used topic rebuttal compared to no topic rebuttal, ($F(1, 223) = 5.94$, $p = .016$, $\eta^2_p = .026$, [.003, .069]). The effect of technique rebuttal in decreasing the influence of the denier on the audience's intention compared to no technique rebuttal was marginally significant ($F(1, 223) = 3.45$, $p = .064$, $\eta^2_p = .015$, [.000, .052]). There was no evidence of an interaction effect of topic and technique rebuttal on changes of individuals' intention to get vaccinated ($F(1, 223) = 1.43$, $p = .233$, $\eta^2_p = .006$, [.000, .035]) or on changes of attitude towards vaccination ($F(1, 223) = 0.11$, $p = .746$, $\eta^2_p < .001$, [.000, .015]).

Planned contrast analysis revealed no evidence of a benefit of the combination compared to the single strategies (attitude: $F(1, 223) = 0.66$, $p = .418$, $\eta^2_p = .003$, [.000, .026]; intention: $F(1, 223) = 0.59$, $p = .442$, $\eta^2_p = .003$, [.000, .025]).

Repetition of all ANOVAs with control variables revealed the same pattern of results (see Supplementary Table 7–9 for ANCOVA results).

Experiment 5

N = 1,149 clicked on the link, 339 proceeded after the introduction page and 217 finished the experiment. The exclusion of 69 participants due to the exclusion criteria (see Methods section in main article) results in a sample size of n = 148 for all following analyses (age: $M_{age} = 29.14$, $SD_{age} = 12.08$; gender: 62% female; education: 87% reported a university entrance diploma or a higher education). Participants of Experiment 5 were rather liberal ($M_{conservatism} = 37.84$, $SD_{conservatism} = 20.69$), indicated a high positive attitude towards actions against climate change ($M_{prior\_attitude} = 92.17$, $SD_{prior\_attitude} = 16.39$) and a high intention to act against climate change ($M_{prior\_intention} = 58.16$, $SD_{prior\_intention} = 14.50$) prior to the stimulus material. On average they reached 47.01% ($M_{knowledge} = 47.01$, $SD_{knowledge} = 20.36$) of the maximum possible knowledge score. Participants reported a low relevance of radio ($M_{relevance\_radio} = 30.39$, $SD_{relevance\_radio} = 19.57$) and a low relevance of the internet ($M_{relevance\_internet} = 41.43$, $SD_{relevance\_internet} = 18.03$) as an information source about climate change. There was no evidence of differences between conditions in prior attitude towards taking action ($F(3, 144) = 2.07$, $p = .107$, $\eta^2_p = .041$, [.000, .090]), relevance of radio ($F(3, 144) = 0.85$, $p = .467$, $\eta^2_p = .017$, [.000, .026]), relevance of the internet ($F(3, 144) = 2.50$, $p = .062$, $\eta^2_p = .050$, [.000, .102]) and knowledge about climate change ($F(3, 144) = 0.36$, $p = .783$, $\eta^2_p = .007$, [.000, .024]). However, the a priori intention to act against climate change happened to be different between conditions ($F(3, 144) = 3.88$, $p = .011$, $\eta^2_p = .075$, [.010, .137]). Therefore, as part of a sensitivity analysis (see results of main article), we will complement the analyses on changes in intention and attitude with analyses that assess changes in the a posteriori intention and attitude, controlled for a priori values.

Influence of the Denier and Effectiveness of Rebuttal. In contrast to the discussion about vaccination, there was no evidence that the climate denier decreased the audience's willingness to act against climate change (intention: $F(1, 144) = 0.03$, $p = .854$, $\eta^2_p < .001$, [.000, .009]). There was also no evidence of a difference between topic rebuttal vs. no topic rebuttal; the same was true for technique rebuttal vs. no technique rebuttal (topic rebuttal:

$F(1, 144) = 0.06$, $p = .800$, $\eta^2_p < .001$, [.000, .017]; technique rebuttal: $F(1, 144) = 0.68$, $p < .410$, $\eta^2_p = .005$, [.000, .040]). The same absence of evidence regarding the influence of the denier and the effect of rebuttal was observed for the willingness to donate (see Supplementary Table 15). However, participants were not completely unaffected by the discussion. The attitude towards climate change initiatives decreased significantly due to the denier ($F(1, 144) = 7.39$, $p = .007$, $\eta^2_p = .049$, [.007, .116]). The influence of the science denier decreased when the advocate used technique rebuttal compared to no technique rebuttal ($F(1, 144) = 5.95$, $p = .016$, $\eta^2_p = .040$, [.004, .103]). There was no evidence of an effect of topic rebuttal ($F(1, 144) = 0.23$, $p = .631$, $\eta^2_p = .002$, [.000, .029]). In addition, there was no evidence of an interaction effect of topic and technique rebuttal on changes of individuals' willingness to act ($F(1, 144) = 0.15$, $p = .698$, $\eta^2_p = .001$, [.000, .025]) or on changes of attitude towards actions against climate change ($F(1, 144) = 0.28$, $p = .599$, $\eta^2_p = .002$, [.000, .030]).

Planned contrast analysis revealed no evidence of a benefit of the combination compared to the single strategies (attitude: $F(1, 144) = 1.53$, $p = .219$, $\eta^2_p = .010$, [.000, .054]; intention: $F(1, 144) = 0.58$, $p = .447$, $\eta^2_p = .004$, [.000, .038]).

Repetition of all ANOVAs with control variables revealed the same pattern of results (see Supplementary Tables 7–9 for ANCOVA results).

Indirect Effects of Rebuttal – Mediation Analysis. In the following analyses we explore whether the significant effect of technique rebuttal (vs. no technique rebuttal) on mitigating the influence of the denier on individuals' attitude towards initiatives against climate change could be explained via a decreased perceived argument strength of the denier and/or an increased perceived argument strength of the advocate (see Supplementary Table 6 for items). The perceived argument strength of the denier (Model 1) and the perceived argument strength of the advocate (Model 2) were analysed as mediators in separate models due to different sample sizes of the models (perceived argument strength of the advocate is lacking in the advocate absent condition).

The mediation models revealed no evidence of an influence of the perceived argument strength of the denier (Model 1: $B = -0.10$, [-0.21, 0.01], $p = .063$) or advocate (Model 2: $B = 0.10$, [-0.30, 0.22], $p = .133$) on individuals' changes in attitude towards initiatives against climate change. Furthermore, the analyses showed no evidence of an effect of technique rebuttal on the perceived argument strength of the denier (Model 1: $B = -3.80$, [-9.10, 1.49], $p = .158$) but evidence of an effect of technique rebuttal on the perceived argument strength of the advocate (Model 2: B = 8.29, [1.40, 15.18], $p = .019$). Bootstrap estimation approaches with 1,000 samples revealed no evidence of indirect effects of technique rebuttal on attitude via perceived argument strength of the denier (Model 1: B = 0.39, [-0.05, 1.65]) or advocate (Model 2: B = 0.80, [-0.23, 3.08]). Repetition of all mediation models with control variables (see Method section) revealed similar pattern of results (see Supplementary Table 16). However, one relevant change occurred. After controlling for the effects of the covariates, Model 1 revealed that increased perceived argument strength of the denier decreases the positive attitude towards initiatives against climate change (Model 1: B = -0.11, [-0.23, -0.00], p = .048). Evidence of the indirect effect of Model 1, however, was absent. Hence, there was no evidence that technique rebuttal mitigated the influence of the denier via decreased perceived argument strength of the denier or increased perceived argument strength of the advocate.

Experiment 6

N = 2,105 clicked on the link, 1,416 proceeded after the introduction page and 1,137 finished the experiment. The exclusion of 216 participants due to the exclusion criteria (see main text Methods section) results in a sample size of n = 921 for all following analyses (age: M_{age} = 36.81, SD_{age} = 10.92; gender: 46% female; education: 71% reported an associate's degree or a higher education). Participants of Experiment 6 were rather liberal ($M_{conservatism}$ = 39.22, $SD_{conservatism}$ = 28.40) and highly confident in vaccination in general ($M_{confidence}$ = 71.69, $SD_{confidence}$ = 30.97). They indicated a high positive attitude towards the vaccination against dysomeria ($M_{prior\_attitude}$ = 85.56, $SD_{prior\_attitude}$ = 20.97) and a high willingness to get vaccinated ($M_{prior\_intention}$ = 81.91, $SD_{prior\_intention}$ = 26.87) prior to the stimulus material. On average they reached 66.34% ($M_{knowledge}$ = 66.34, $SD_{knowledge}$ = 32.46) of the maximum possible knowledge score. Participants reported a low relevance of radio ($M_{relevance\_radio}$ = 16.30, $SD_{relevance\_radio}$ = 19.38) and a low relevance of the internet ($M_{relevance\_internet}$ = 33.16, $SD_{relevance\_internet}$ = 20.36) as an information source about vaccination. There was no evidence of differences between conditions in prior attitude towards vaccination (F(3, 917) = 1.62, p = .184, η^2_p = .005, [.000, .013]), relevance of radio (F(3, 917) = 0.55, p = .646, η^2_p = .002, [.000, .006]) and relevance of the internet as an information source (F(3, 917) = 0.15, p = .931, η^2_p < .000, [.000, .001]). However, prior intention to get vaccinated (F(3, 917) = 2.62, p = .500, η^2_p = .009, [.000, .018]) and knowledge about vaccination (F(3, 917) = 4.113, p = .007, η^2_p = .013, [.002, .026]) were lower in the advocate absent condition. Therefore, as part of a sensitivity analysis (see results of main article), we will complement the analyses on changes in intention and attitude with analyses that assess changes in the a posteriori intention and attitude, controlled for a priori values. We also repeat analyses controlling for knowledge about vaccination (see Method section for preregistered control variables).

Influence of the Denier and Effectiveness of Rebuttal. The discussion with the science denier significantly decreased individuals' attitude towards vaccination ($F(1, 917) = 172.03$, $p < .001$, $\eta^2_p = .158$, [.124, .193]) and individuals' intention to get vaccinated ($F(1, 917) = 107.55$, $p < .001$, $\eta^2_p = .105$, [.076, .137]). Planned contrast analysis reveals that the denier had a stronger effect on individuals' intention when the science advocate was absent compared to conditions where the advocate was present ($F(1, 917) = 82.26$, $p < .001$, $\eta^2_p = .082$, [.056, .112]). This effect was also significant for attitude ($F(1, 917) = 77.66$, $p < .001$, $\eta^2_p = .078$, [.052, .107]).

The influence of the denier on the audience's attitude was significantly mitigated by topic rebuttal and also by technique rebuttal (topic rebuttal: $F(1, 917) = 18.57$, $p < .001$, $\eta^2_p = .020$, [.008, .037]; technique rebuttal: $F(1, 917) = 29.86$, $p < .001$, $\eta^2_p = .032$, [.016, .052]). The same pattern was observed for mitigating the influence of the denier on the audience's intention (topic rebuttal: $F(1, 917) = 26.78$, $p < .001$, $\eta^2_p = .028$, [.013, .048]; technique rebuttal: $F(1, 917) = 29.00$, $p < .001$, $\eta^2_p = .031$, [.015, .051]). There was a significant interaction effect of topic and technique rebuttal on changes of individuals' intention to get vaccinated ($F(1, 917) = 28.97$, $p < .001$, $\eta^2_p = .031$, [.015, .051]) and on changes of attitude towards vaccination ($F(1, 917) = 32.69$, $p < .001$, $\eta^2_p = .034$, [.018, .056]). Simple main effects analyses showed that topic rebuttal significantly mitigated the influence of the denier when technique rebuttal was absent (intention: $p < .001$; attitude: $p < .001$), but there was no evidence of a difference between topic rebuttal and no topic rebuttal when technique rebuttal was present (intention: $p = .853$; attitude: $p = .212$).

Planned contrast analysis revealed no evidence of a benefit of the combination compared to the single strategies for mitigating the influence on attitude and intention (attitude: $F(1,917) = 0.66$, $p = .418$, $\eta^2_p = .003$, [.000, .007]; intention: $F(1, 917) = 0.57$, $p = .451$, [.000, .006]). Moreover, and contrary to the preregistered hypotheses we find no evidence that the effectiveness of the combination of strategies (vs. single strategies) is a function of individuals' confidence or calculation values (see Supplementary Table 17).

Repetition of all ANOVAs with control variables revealed the same pattern of results (see Supplementary Table S7–S9 for ANCOVA results).

Statistical power for meta-analytic results

Statistical power for meta-analyses were calculated using the R-Script by Tiebel(Tiebel, 2018) which is based on the formulas of Valentine, Pigott & Rothstein(Valentine, Pigott, & Rothstein, 2010) for random effects meta-analyses when alpha .05 (two-tailed; syntax: https://osf.io/xx2kt/). Expected effect sizes for power calculation of the final meta-analyses are based on averaged effect sizes of the first 5 experiments. For the non-significant difference between topic and no-topic rebuttal on attitude we defined $g = 0.20$ as the smallest effect size of interest. Sample size of Experiment 6 was calculated to reach a minimum of .8 statistical power for the individual study results and the overall meta-analytic tests.

Final statistical power of tests based on the expected effect sizes and the actual number of participants (after using preregistered exclusion criteria) are as follows: Technique rebuttal vs. no technique rebuttal (intention: .997 [$g = 0.26$, $N_{\text{studies}} = 6$, $n_{\text{experimental}} = 158$, $n_{\text{control}} = 136$, heterogeneity = 0.33]; attitude: .999 [$g = 0.26$, $N = 5$, $n_e = 179$, $n_c = 153$, heterogeneity = 0]), topic rebuttal vs. no topic rebuttal (intention: .999 [$g = 0.30$, $N = 6$, $n_e = 159$, $n_c = 136$, heterogeneity = 0]; attitude: .817 [$g = 0.20$, $N = 5$, $n_e = 180$, $n_c = 152$, heterogeneity = 1]), combined strategy vs. single strategies (intention: .977 [$g = 0.22$, $N = 6$, $n_e = 93$, $n_c = 131$, heterogeneity = 0]; attitude: .970 [$g = 0.22$, $N = 5$, $n_e = 105$, $n_c = 147$, heterogeneity = 0]).

Supplementary References

Askelson, N. M., Campo, S., Lowe, J. B., Smith, S., Dennis, L. K., & Andsager, J. (2010). Using the theory of planned behavior to predict mothers' intentions to vaccinate their daughters against HPV. The Journal of School Nursing : The Official Publication of the National Association of School Nurses, 26(3), 194–202. https://doi.org/10.1177/1059840510366022

Berinsky, A. J., Margolis, M. F., & Sances, M. W. (2014). Separating the shirkers from the workers? Making sure respondents pay attention on self-administered surveys. American Journal of Political Science, 58(3), 739–753. https://doi.org/10.1111/ajps.12081

Betsch, C., Bödeker, B., Schmid, P., & Wichmann, O. (2018). How baby's first shot determines the development of maternal attitudes towards vaccination. Vaccine, 36(21). https://doi.org/10.1016/j.vaccine.2018.04.023

Betsch, C., Böhm, R., & Chapman, G. B. (2015). Using Behavioral Insights to Increase Vaccination Policy Effectiveness. Policy Insights from the Behavioral and Brain Sciences, 2(1), 61–73.

Betsch, C., Schmid, P., Heinemeier, D., Korn, L., Holtmann, C., & Böhm, R. (2018). Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. PLOS ONE, 13(12), e0208601. https://doi.org/10.1371/journal.pone.0208601

Betsch, C., Haase, N., Renkewitz, F., & Schmid, P. (2015). The narrative bias revisited: What drives the biasing influence of narrative information on risk perceptions? Judgment and Decision Making, 10(3), 241–264.

Bruder, M., Haffke, P., Neave, N., Nouripanah, N., & Imhoff, R. (2013). Measuring Individual Differences in Generic Beliefs in Conspiracy Theories Across Cultures: Conspiracy Mentality Questionnaire. Frontiers in Psychology, 4. https://doi.org/10.3389/fpsyg.2013.00225

Cacioppo, J. T., Petty, R. E., & Feng Kao, C. (1984). The Efficient Assessment of Need for Cognition. Journal of Personality Assessment, 48(3), 306–307. https://doi.org/10.1207/s15327752jpa4803_13

Cacioppo, J. T., Petty, R. E., & Morris, K. J. (1983). Effects of need for cognition on message evaluation, recall, and persuasion. Journal of Personality and Social Psychology, 45(4), 805–818. https://doi.org/10.1037/0022-3514.45.4.805

Gosling, S. D., Rentfrow, P. J., & Swann, W. B. (2003). A very brief measure of the Big-Five personality domains. Journal of Research in Personality, 37(6), 504–528. https://doi.org/10.1016/S0092-6566(03)00046-1

Hayes, A. (2013). Introduction to mediation, moderation, and conditional process analysis (1st ed.). New York: Guilford Press. https://doi.org/978-1-60918-230-4

Hurtt, R. K. (2010). Development of a scale to measure professional skepticism. Auditing, 29(1), 149–171. https://doi.org/10.2308/aud.2010.29.1.149

Lakens, D. (2013). Calculating and reporting effect sizes to facilitate cumulative science: a practical primer for t-tests and ANOVAs. Frontiers in Psychology, 4, 863. https://doi.org/10.3389/fpsyg.2013.00863

Leiserowitz, A., Smith, N. & Marlon, J. R. (2010). Americans' Knowledge of Climate Change. Yale Project on Climate Change Communication. Retrieved from http://environment.yale.edu/climate/files/ClimateChangeKnowledge2010.pdf

Lewandowsky, S., & Oberauer, K. (2016). Motivated Rejection of Science. Current Directions in Psychological Science, 25(4), 217–222. https://doi.org/10.1177/0963721416654436

Mccright, A. M., & Dunlap, R. E. (2011). The Politicization Of Climate Change And Polarization In The American Public's Views Of Global Warming, 2001-2010. Sociological Quarterly, 52(2), 155–194. https://doi.org/10.1111/j.1533-8525.2011.01198.x

McCroskey, J. C., & Jenson, T. A. (1975). Image of mass media news sources. Journal of Broadcasting, 19(2), 169–180. https://doi.org/10.1080/08838157509363777

Montada, L., Kals, E. & Becker, R. (2014). Umweltschützende Informations- und Zahlungsbereitschaften. Zusammenstellung Sozialwissenschaftlicher Items Und Ska- Len. https://doi.org/10.6102/zis67

Schmid, P., MacDonald, N. E., Habersaat, K., & Butler, R. (2018). Commentary to: How to respond to vocal vaccine deniers in public. Vaccine, 36(2). https://doi.org/10.1016/j.vaccine.2016.09.065

Suurmond, R., van Rhee, H., & Hak, T. (2017). Introduction, comparison, and validation of Meta-Essentials: A free and simple tool for meta-analysis. Research Synthesis Methods. https://doi.org/10.1002/jrsm.1260

Cochrane Collaboration. (2014). Review Manager (RevMan). Copenhagen: The Nordic Cochrane Centre, The Cochrane Collaboration. Retrieved from https://community.cochrane.org/help/tools-and-software/revman-5

Tiebel, J. (2018). Calculation of statistical power in meta-analysis. Retrieved from https://osf.io/w4xrs/

Tutaj, K., & van Reijmersdal, E. A. (2012). Effects of online advertising format and persuasion knowledge on audience reactions. Journal of Marketing Communications, 18(1), 5–18. https://doi.org/10.1080/13527266.2011.620765

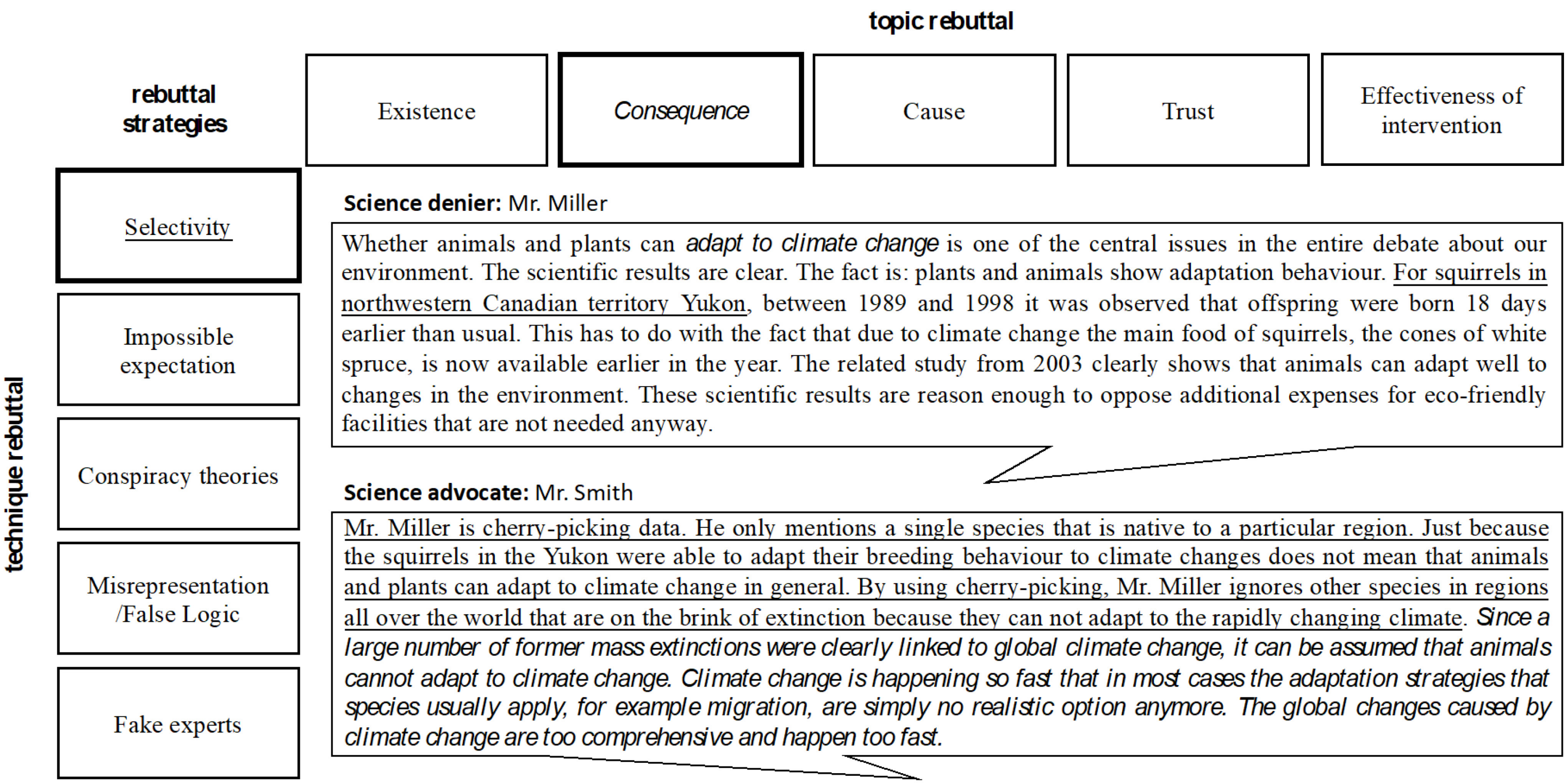
Valentine, J. C., Pigott, T. D., & Rothstein, H. R. (2010). How Many Studies Do You Need? Journal of Educational and Behavioral Statistics, 35(2), 215–247. https://doi.org/10.3102/1076998609346961

Yoo, C. Y. (2009). The effects of persuasion knowledge on click-through of search ads: Moderating role of search task and perceived fairness. Journalism and Mass Communication Quarterly, 86(2), 401–418. https://doi.org/10.1177/107769900908600209

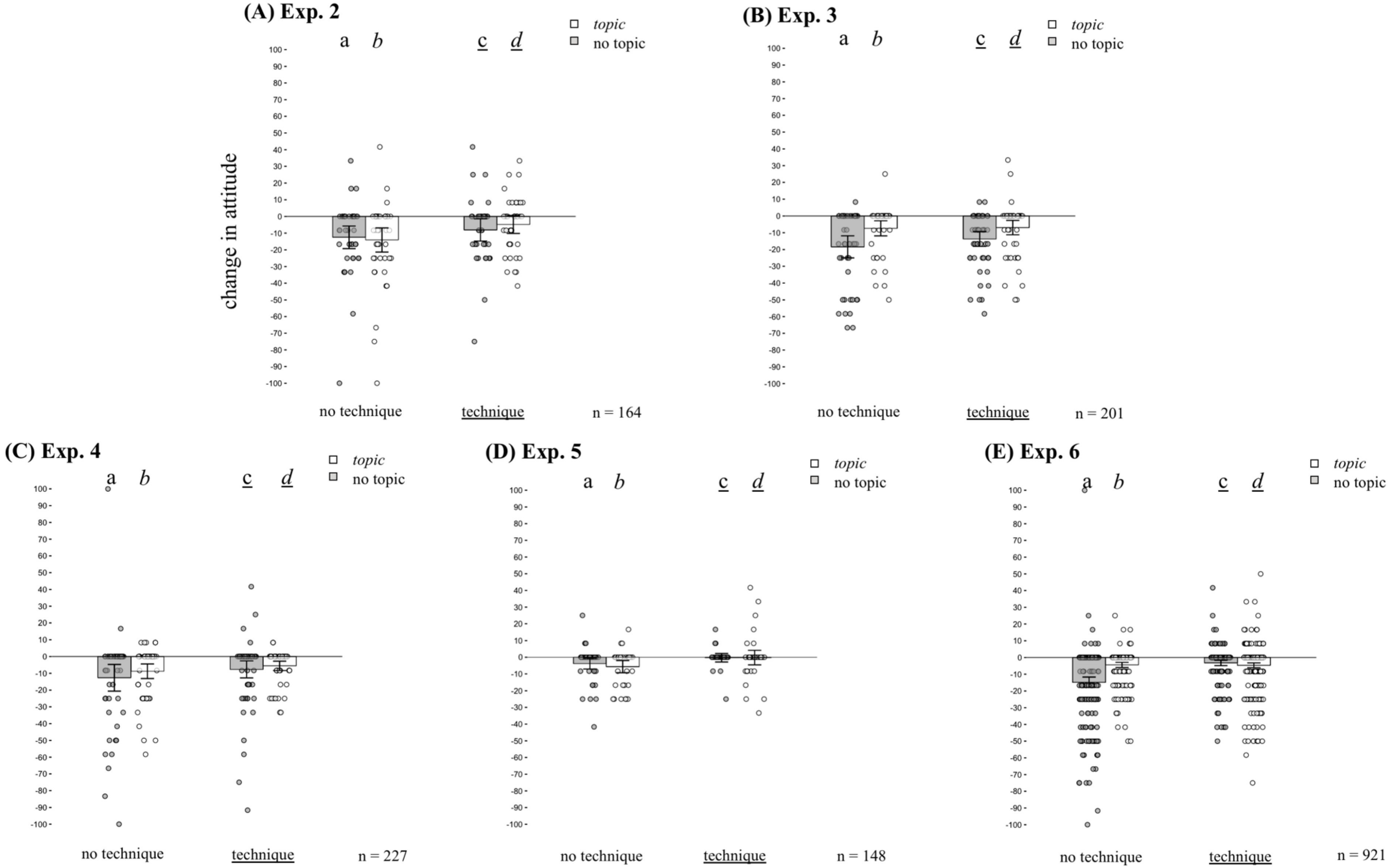
Zhao, X., Strasser, A., Cappella, J. N., Lerman, C., & Fishbein, M. (2011). A measure of perceived argument strength: Reliability and validity. Communication Methods and Measures, 5(1), 48–75. https://doi.org/10.1080/19312458.2010.547822

Zingg, A., & Siegrist, M. (2012). Measuring people's knowledge about vaccination: Developing a one-dimensional scale. Vaccine, 30(25), 3771–3777. https://doi.org/10.1016/j.vaccine.2012.03.014

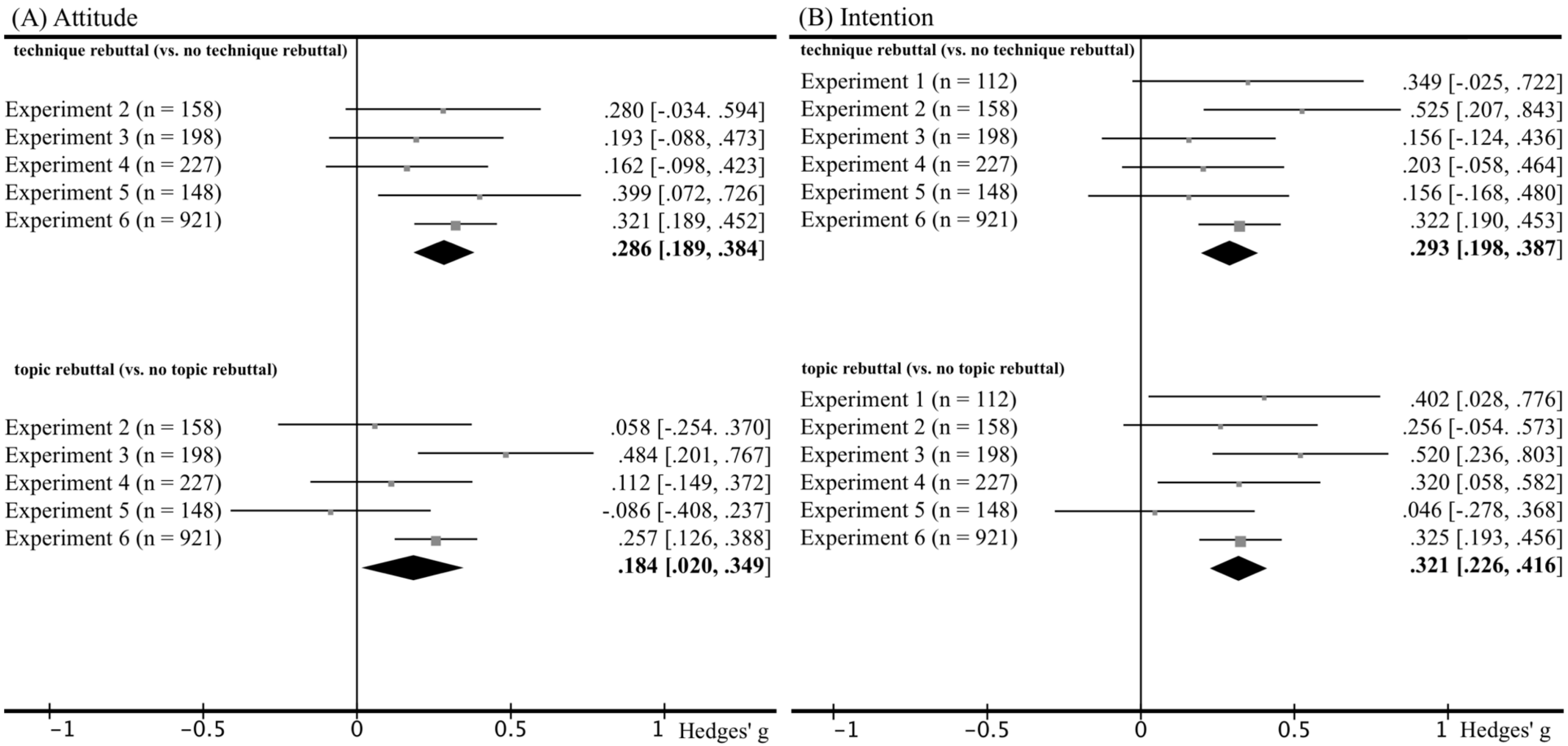
Supplementary Figures



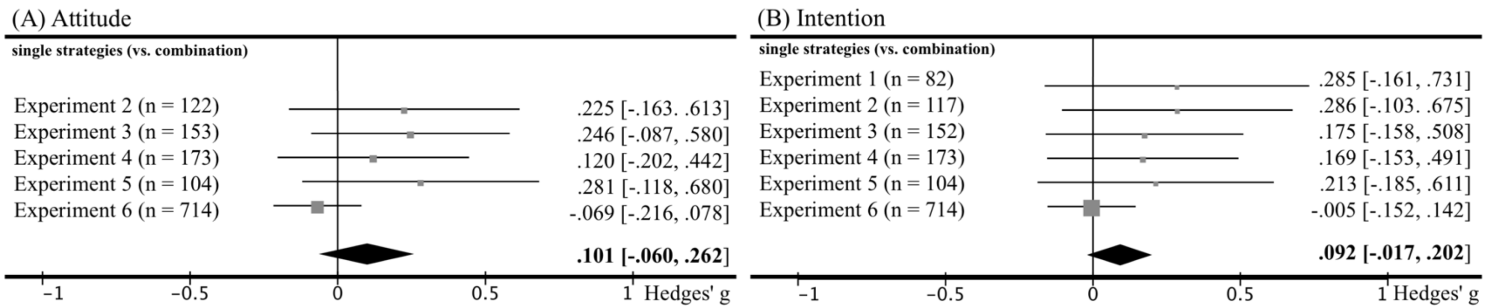
Supplementary Figure 1. 5 × 5 matrix of rebutting science denialism in public discussions about climate change. The dialogue represents an example from the materials used in Experiment 4. Italics indicate the *topic,* and underlined text indicates the technique of science denialism. The techniques are adapted from the previously published matrix in the domain of vaccination(Schmid, MacDonald, Habersaat, & Butler, 2018). The topics are the result of a review of 197 typical statements collected and debunked by the non-profit science education organization Skeptical Science. The statements are available at: https://www.skepticalscience.com/argument.php. See https://osf.io/xx2kt/ for categorizing of statements to the used topic labels.



Supplementary Figure 2. Effects of denial and rebuttals on audience attitude towards a behaviour favoured by science (Exp. 2-4 & 6: vaccination; Exp. 5: taking action against climate change). The y axes represent mean changes in attitude towards a behaviour favoured by science (POMP values, percent of maximum possible score). The x axes represent experimental conditions. The negative influence of the denier on attitude was weaker when rebuttal was used. Applying topic or technique rebuttal or a combination thereof can decrease the influence of science denialism. Bars are mean changes in attitude towards the behaviour (POMP values, percent of maximum possible score). Error bars are 95% confidence intervals. Dots indicate individual changes in the attitude of individual participants. Colours and groupings of bars indicate the conditions of the experiments, resulting in the four tested conditions: a) advocate absent, b) topic rebuttal, c) technique rebuttal, d) combined strategy.



Supplementary Figure 3. Technique rebuttal and topic rebuttal mitigate the influence of the debate with a science denier after controlling for effects of covariates. Analyses from Fig. 3 controlled for individual knowledge about the behaviours, relevance of radio and internet (Experiment 2-6) as information sources and sociodemographic data. Internal meta-analyses of **(A)** changes in attitude (Exp. 2–6; N = 1,652) and **(B)** changes in intention (Exp. 1–6; N = 1,764) using random effects models. The y axes represent experiments. The x axes represent Hedges' adjusted *g*s. Hedges' adjusted *g*s are derived from estimated means including preregistered control variables (Supplementary Table 7 and Supplementary Table 8) based on the comparisons of means of changes in attitude and intention from topic rebuttal vs. no topic rebuttal (main effect of topic rebuttal) and technique rebuttal vs. no technique rebuttal (main effect of technique rebuttal). Sizes of squares are proportional to the precision of the estimate. Error bars show 95% CIs. Diamonds show summary effects; the lateral points of which indicate 95% CIs for these estimates. Numbers in brackets show values of confidence intervals. Heterogeneity of presented results: (technique rebuttal: **(A)** $I^2 = 0\%$ ($Tau^2 = 0$), **(B)** $I^2 = 0\%$ ($Tau^2 = 0$); topic rebuttal: **(A)** $I^2 = 54\%$ ($Tau^2 = 0.02$), **(B)** $I^2 = 0\%$ ($Tau^2 = 0$)).



Supplementary Figure 4. No evidence that the combination of topic and technique rebuttal is more effective than the single strategies after controlling for effects of covariates. Analyses from Fig. 4 controlled for individual knowledge about the behaviours, relevance of radio and internet (Exp. 2–6) as information sources and sociodemographic data. Internal meta-analyses of **(A)** changes in attitude (Exp. 2–6; N = 1,266) and **(B)** changes in intention (Exp. 1–6; N = 1,342) using random effects models. The y axes represent experiments. The x axes represent Hedges' adjusted *g*s. Hedges' adjusted *g*s are derived from estimated means including preregistered control variables (Supplementary Table 9) based on the comparisons of means of changes in attitude and intention from single strategies vs. combination of strategies. Sizes of squares are proportional to the precision of the estimate. Error bars show 95% CIs. Diamonds show summary effects; the lateral points of which indicate 95% CIs for these estimates. Numbers in brackets show values of confidence intervals. Heterogeneity of presented results: **(A)** $I^2 = 34\%$ ($Tau^2 = 0.01$), **(B)** $I^2 = 0\%$ ($Tau^2 = 0$).

Supplementary Tables

Supplementary Table 1. Meta-analyses of simple main effects for the interaction effect of *technique rebuttal*topic rebuttal* on intention and attitude. Data presented are Hedges' adjusted *g*s. Summary effects are weighted means of the effect sizes. Test for subgroup differences reveal evidence for significant interaction effects of *technique rebuttal*topic rebuttal* on intention but not on attitude. Simple main effects reveal a significant benefit of using topic rebuttal (vs. no topic rebuttal) when technique rebuttal is absent for both outcomes. In addition, simple main effects reveal a significant benefit of using technique rebuttal (vs. no technique rebuttal) when topic rebuttal is absent for both outcomes. Evidence for the benefit of topic rebuttal is absent when technique rebuttal is present and vice versa. Hence, evidence of a benefit of the combination is absent when analysing interaction effects.

	Intention: Simple main effects in condition *No technique rebuttal* (random effects; Hedges' adjusted *g*s)		Intention: Simple main effects in condition *technique rebuttal* (random effects; Hedges' adjusted *g*s)		Attitude: Simple main effects in condition *No technique rebuttal* (random effects; Hedges' adjusted *g*s)		Attitude: Simple main effects in condition *Technique rebuttal* (random effects; Hedges' adjusted *g*s)	
	g [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n
Topic rebuttal (vs. no topic rebuttal)								
Experiment 1	0.58 [0.03, 1.13]	54	0.11 [-0.41, 0.62]	58	--	--	--	--
Experiment 2	0.21 [-0.21, 0.63]	87	0.30 [-0.15, 0.75]	77	-0.07 [-0.49, 0.35]	87	0.18 [-0.27, 0.63]	77
Experiment 3	0.67 [0.25, 1.09]	92	0.35 [-0.03, 0.73]	109	0.57 [0.15, 0.99]	92	0.42 [0.04, 0.80]	109
Experiment 4	0.43 [0.05, 0.81]	109	0.19 [-0.18, 0.55]	118	0.16 [-0.21, 0.54]	109	0.13 [-0.23, 0.49]	118
Experiment 5	-0.02 [-0.46, 0.42]	81	0.12 [-0.37, 0.61]	67	-0.17 [-0.61, 0.27]	81	0.01 [-0.48, 0.49]	67
Experiment 6	0.60 [0.40, 0.80]	397	-0.02 [-0.20, 0.16]	524	0.58 [0.37, 0.78]	397	-0.11 [-0.29, 0.07]	524
Summary effect	0.43 [0.23, 0.64]		0.10 [-0.03, 0.23]		0.24 [-0.08, 0.56]		0.09 [-0.12, 0.30]	
Test for subgroup differences	$\chi^2(1) = 7.30$, $p = .007$, $I^2 = 86.3\%$				$\chi^2(1) = 0.59$, $p = .440$, $I^2 = 0\%$			

	Intention: Simple main effects in condition *No topic rebuttal* (random effects; Hedges' adjusted *g*s)		Intention: Simple main effects in condition *topic rebuttal* (random effects; Hedges' adjusted gs)		Attitude: Simple main effects in condition *No topic rebuttal* (random effects; Hedges' adjusted *g*s)		Attitude: Simple main effects in condition *topic rebuttal* (random effects; Hedges' adjusted gs)	
	g [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n
Technique rebuttal (vs. no technique rebuttal)								
Experiment 1	0.38 [-0.15, 0.91]	56	0.18 [-0.35, 0.71]	56	--	--	--	--
Experiment 2	0.42 [-0.03, 0.86]	79	0.51 [0.08, 0.95]	85	0.21 [-0.24, 0.65]	79	0.44 [0.01, 0.87]	85
Experiment 3	0.23 [-0.16, 0.62]	102	-0.10 [-0.50, 0.30]	99	0.24 [-0.15, 0.63]	102	0.03 [-0.37, 0.42]	99
Experiment 4	0.34 [-0.02, 0.71]	118	0.11 [-0.26, 0.49]	109	0.20 [-0.16, 0.56]	118	0.24 [-0.14, 0.61]	109
Experiment 5	0.07 [-0.40, 0.55]	72	0.20 [-0.25, 0.65]	76	0.37 [-0.11, 0.85]	72	0.44 [-0.02, 0.89]	76
Experiment 6	0.61 [0.40, 0.81]	390	0.00 [-0.18, 0.18]	531	0.64 [0.43, 0.84]	390	-0.02 [-0.20, 0.16]	531
Summary effect	0.40 [0.23, 0.57]		0.10 [-0.06, 0.25]		0.37 [0.16, 0.59]		0.17 [-0.03, 0.37]	
Test for subgroup differences	$\chi^2(1) = 6.98$, $p = .008$, $I^2 = 85.7\%$				$\chi^2(1) = 1.83$, $p = .180$, $I^2 = 45.3\%$			

Supplementary Table 2. Exploratory subgroup analyses of differences between rebuttal and *advocate absent* conditions on changes of attitude and intention stratified by individuals' conservatism. Data presented are absolute mean differences. Summary effects are weighted means of the effect sizes. Figure 6 reveals that in the U.S. samples, rebuttal strategies were more beneficial for conservative participants than for liberal participants (Experiment 4 and Experiment 6). Evidence of these effects is absent when including German samples (Experiment 3 and Experiment 5) in the meta analyses.

	Intention: Topic rebuttal (vs. advocate absent) random effects		Intention: Technique rebuttal (vs. advocate absent) random effects		Attitude: Technique rebuttal (vs. advocate absent) random effects		Attitude: Technique rebuttal (vs. advocate absent) random effects	
	absolute mean difference [95% CI]	n	absolute mean difference [95% CI]	n	absolute mean difference [95% CI]	n	absolute mean difference [95% CI]	n
Low conservatism								
Experiment 3	11.01 [1.52, 20.50]	90	8.43 [-1.77, 18.63]	94	10.86 [0.98, 20.73]	90	9.13 [-0.90, 19.15]	94
Experiment 4	1.40 [-2.25, 5.04]	85	2.01 [-1.54, 5.55]	83	1.18 [-3.61, 5.97]	85	10.42 [1.04, 19.79]	83
Experiment 5	5.94 [-0.64, 12.52]	89	7.63 [1.03, 14.23]	89	1.76 [-9.28, 12.80]	89	4.92 [-6.05, 15.89]	89
Experiment 6	6.14 [2.34, 9.94]	406	6.75 [2.97, 10.53]	403	5.13 [1.17, 9.08]	406	5.25 [1.28, 9.22]	403
Summary effect	4.95 [1.45, 8.46]		5.24 [2.07, 8.40]		4.05 [0.72, 7.38]		6.27 [2.99, 9.54]	
High conservatism								
Experiment 3	13.89 [4.00, 23.77]	57	7.73 [-1.22, 16.67]	63	11.68 [1.03, 22.32]	57	5.93 [-4.24, 16.09]	63
Experiment 4	-1.31 [-7.38, 4.76]	35	-1.98 [-7.99, 4.03]	28	0.32 [-8.54, 9.18]	35	5.04 [-3.21, 13.30]	28
Experiment 5	11.98 [0.95, 23.00]	74	9.21 [-1.89, 20.30]	83	10.71 [-0.98, 22.40]	74	8.79 [-3.23, 20.80]	83
Experiment 6	15.39 [10.23, 20.55]	332	14.75 [9.55, 19.96]	328	15.25 [10.21, 20.29]	332	16.05 [11.01, 21.09]	328
Summary effect	9.75 [0.53, 18.96]		7.37 [-1.39, 16.12]		9.84 [2.65, 17.04]		9.81 [3.46, 16.15]	
Test for subgroup differences:	$\chi^2(1) = 0.91$, $p = .34$, $I^2 = 0\%$		$\chi^2(1) = 0.20$, $p = .65$, $I^2 = 0\%$		$\chi^2(1) = 2.05$, $p = .15$, $I^2 = 51.3\%$		$\chi^2(1) = 0.94$, $p = .33$, $I^2 = 0\%$	

Supplementary Table 3. Exploratory subgroup analyses of differences between conservative and liberal individuals on changes of attitude and intention when advocate absent. Data presented are absolute mean differences. Summary effects are weighted means of the effect sizes. Figure 6 reveals that the influence of the debate is stronger on U.S. conservative (vs. liberal) audiences when the advocate is absent (Experiment 4 and Experiment 6). Evidence of these effects is absent when including German samples (Experiment 3 and Experiment 5) in the meta analyses.

	Intention: Low conservatism (vs. high conservatism) random effects		Attitude: Low conservatism (vs. high conservatism) random effects	
	absolute mean difference [95% CI]	n	absolute mean difference [95% CI]	n
Advocate absent				
Experiment 3	0.13 [-11.82, 12.08]	44	-0.99 [-9.21, 7.23]	44
Experiment 4	1.55 [-4.64, 7.74]	48	-0.69 [-13.58, 12.20]	48
Experiment 5	-9.44 [-21.42, 2.54]	54	-11.41 [-26.62, 3.81]	54
Experiment 6	-9.14 [-15.16, -3.11]	207	-10.93 [-16.95, -4.92]	207
Summary effect	-4.12 [-10.58, 2.33]		-6.28 [-12.44, -0.13]	

Supplementary Table 4. Sensitivity analyses for all confirmatory analyses on attitude. Data presented are Hedges' adjusted *g*s (Model 6: Absolute mean differences). Summary effects are weighted means of the effect sizes. Results differ from results reported in the manuscript due to the following changes of the model: Including all participants instead of excluding some according to the pre-specified criteria (Models A); using estimated means of attitude and intention at T2 controlled for values at T1 rather than difference scores (Models B); excluding statistical outliers from pre- and post-values based on median absolute deviation (Models C); dropping Experiment 5, which differed from all others with respect to domain (climate change; Models D); changing models from random models to fixed models (Models E) and changing outcome from standardized mean differences to mean differences (Models F).

Dependent variable: Attitude	Sensitivity Models A (no exclusion criteria; random effects; Hedges' adjusted *g*s)		Sensitivity Models B (post- controlled for pre-values; random effects; Hedges' adjusted *g*s)		Sensitivity Models C (outliers excluded; random effects; Hedges' adjusted *g*s)		Sensitivity Models D (Experiment 5 excluded; random effects; Hedges' adjusted *g*s)		Sensitivity Models E (fixed effects; Hedges' adjusted *g*s)		Sensitivity Models F (random effects; absolute mean difference)	
	g [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n
Topic (vs. no topic rebuttal)												
Experiment 1	--	--	--	--	--	--	--	--	--	--	--	--
Experiment 2	0.09 [-0.18, 0.37]	206	0.04 [-0.26, 0.35]	164	0.10 [-0.21, 0.41]	160	0.09 [-0.18, 0.37]	164	0.03 [-0.27, 0.34]	164	0.74 [-5.74, 7.21]	164
Experiment 3	0.40 [0.16, 0.65]	261	0.51 [0.23, 0.79]	201	0.55 [0.26, 0.83]	198	0.40 [0.16, 0.65]	201	0.50 [0.22, 0.78]	201	8.78 [3.94, 13.61]	201
Experiment 4	0.14 [-0.10, 0.38]	267	0.16 [-0.10, 0.42]	227	0.08 [-0.29, 0.45]	115	0.14 [-0.10, 0.38]	227	0.14 [-0.12, 0.40]	227	2.77 [-2.36, 7.91]	227
Experiment 5	-0.08 [-0.34, 0.19]	217	-0.11 [-0.44, 0.21]	148	0.31 [-0.11, 0.74]	86	--		-0.04 [-0.36, 0.28]	148	-0.04 [-0.36, 0.28]	148
Experiment 6	0.27 [0.15, 0.39]	1137	0.29 [0.16, 0.42]	921	0.29 [0.14, 0.43]	770	0.27 [0.15, 0.39]	921	0.30 [0.17, 0.44]	921	4.78 [2.61, 6.96]	921
Summary effect	0.18 [0.04, 0.33]		0.20 [0.02, 0.38]		0.28 [0.13, 0.43]		0.26 [0.09, 0.42]		0.26 [0.09, 0.42]		4.68 [2.02, 7.35]	
Technique (vs. no technique rebuttal)												
Experiment 1	--	--	--	--	--	--	--	--	--	--	--	--
Experiment 2	0.24 [-0.04, 0.51]	206	0.32 [0.01, 0.63]	164	0.33 [0.02, 0.64]	160	0.24 [-0.04, 0.51]	164	0.33 [0.02, 0.64]	164	6.93 [0.61, 13.25]	164
Experiment 3	0.14 [-0.11, 0.38]	261	0.13 [-0.14, 0.41]	201	0.14 [-0.14, 0.42]	198	0.14 [-0.11, 0.38]	201	0.16 [-0.12, 0.43]	201	2.81 [-2.28, 7.90]	201
Experiment 4	0.15 [-0.09, 0.39]	267	0.21 [-0.05, 0.47]	227	0.21 [-0.16, 0.58]	115	0.15 [-0.09, 0.39]	227	0.20 [-0.06, 0.46]	227	3.99 [-1.31, 9.30]	227
Experiment 5	0.38 [0.11, 0.65]	217	0.42 [0.09, 0.75]	148	0.31 [-0.11, 0.74]	86	--		0.40 [0.07, 0.73]	148	0.40 [0.07, 0.73]	148
Experiment 6	0.28 [0.16, 0.40]	1137	0.36 [0.23, 0.50]	921	0.44 [0.30, 0.58]	770	0.28 [0.16, 0.40]	921	0.36 [0.23, 0.49]	921	5.66 [3.52, 7.80]	921
Summary effect	0.25 [0.16, 0.34]		0.31 [0.22, 0.41]		0.34 [0.22, 0.46]		0.31 [0.20, 0.41]		0.31 [0.20, 0.41]		5.23 [3.45, 7.00]	
Combination (vs.single)												
Experiment 1	--	--	--	--	--	--	--	--	--	--	--	--
Experiment 2	0.18 [-0.16, 0.53]	152	0.29 [-0.09, 0.67]	122	0.35 [-0.04, 0.73]	119	0.18 [-0.16, 0.53]	122	0.32 [-0.07, 0.70]	122	6.59 [-0.56, 13.74]	122
Experiment 3	0.27 [-0.02, 0.57]	196	0.24 [-0.09, 0.58]	153	0.28 [-0.06, 0.61]	150	0.27 [-0.02, 0.57]	153	0.25 [-0.09, 0.58]	153	3.91 [-1.32, 9.14]	153
Experiment 4	0.06 [-0.24, 0.35]	200	0.17 [-0.15, 0.49]	173	0.18 [-0.29, 0.64]	86	0.06 [-0.24, 0.35]	173	0.16 [-0.16, 0.48]	173	2.64 [-1.66, 6.93]	173
Experiment 5	0.15 [-0.17, 0.48]	161	0.30 [-0.10, 0.70]	104	0.28 [-0.25, 0.81]	59	--		0.28 [-0.12, 0.68]	104	0.28 [-0.12, 0.68]	104
Experiment 6	-0.10 [-0.23, 0.03]	891	-0.07 [-0.22, 0.08]	714	-0.03 [-0.19, 0.14]	588	-0.10 [-0.23, 0.03]	714	-0.07 [-0.22, 0.08]	714	-0.85 [-2.67, 0.97]	714
Summary effect	0.08 [-0.08, 0.23]		0.14 [-0.04, 0.32]		0.14 [-0.03, 0.32]		0.12 [-0.08, 0.32]		0.12 [-0.08, 0.32]		2.12 [-1.20, 5.43]	

Supplementary Table 5. Sensitivity analyses for all confirmatory analyses on intention. Data presented are Hedges' adjusted *g*s (Model 6: Absolute mean differences). Summary effects are weighted means of the effect sizes. Results differ from results reported in the manuscript due to the following changes of the models: Including all participants instead of excluding some according to the pre-specified criteria (Models G); using estimated means of attitude and intention at T2 controlled for values at T1 rather than difference scores (Models H); excluding statistical outliers from pre- and post-values based on median absolute deviation (Models I); dropping Experiment 5, which differed from all others with respect to domain (climate change; Models J); changing models from random models to fixed models (Models K) and changing outcome from standardized mean differences to mean differences (Models L).

Dependent variable: Attitude	Sensitivity Models G (No exclusion criteria;random effects; Hedges' adjusted *g*s)		Sensitivity Models H (post- controlled for pre-values; random effects; Hedges' adjusted *g*s)		Sensitivity Models I (Model 2 with outliers excluded; random effects; Hedges' adjusted *g*s)		Sensitivity Models J (Experiment 5 excluded; random effects; Hedges' adjusted *g*s)		Sensitivity Models K (fixed effects; Hedges' adjusted *g*s)		Sensitivity Model L (random effects; absolute mean difference)	
	g [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n	*g* [95% CI]	n
Topic (vs. no topic rebuttal)												
Experiment 1	0.40 [0.05, 0.75]	125	0.33 [-0.04, 0.71]	112	0.27 [-0.10, 0.64]	112	0.40 [0.05, 0.75]	112	0.37 [0.00, 0.75]	112	7.14 [0.12, 14.17]	112
Experiment 2	0.28 [0.00, 0.55]	206	0.23 [-0.08, 0.54]	164	0.23 [-0.08, 0.54]	164	0.28 [0.00, 0.55]	164	0.25 [-0.06, 0.55]	164	5.69 [-1.37, 12.76]	164
Experiment 3	0.46 [0.21, 0.70]	261	0.51 [0.23, 0.79]	201	0.51 [0.22, 0.79]	197	0.46 [0.21, 0.70]	201	0.50 [0.22, 0.78]	201	9.32 [4.25, 14.40]	201
Experiment 4	0.25 [0.01, 0.49]	267	0.32 [0.06, 0.58]	227	0.08 [-0.21, 0.37]	180	0.25 [0.01, 0.49]	227	0.30 [0.04, 0.57]	227	4.87 [0.78, 8.96]	227
Experiment 5	0.10 [-0.16, 0.37]	217	0.02 [-0.31, 0.34]	148	0.55 [0.13, 0.96]	105	--		0.05 [-0.27, 0.38]	148	0.39 [-1.99, 2.77]	148
Experiment 6	0.29 [0.17, 0.41]	1137	0.35 [0.22, 0.48]	921	0.46 [0.30, 0.61]	641	0.29 [0.17, 0.41]	921	0.36 [0.23, 0.50]	921	5.60 [3.46, 7.73]	921
Summary effect	0.29 [0.21, 0.38]		0.32 [0.21, 0.42]		0.36 [0.22, 0.50]		0.36 [0.26, 0.46]		0.33 [0.24, 0.43]		4.13 [2.76, 5.50]	
Technique (vs. no technique rebuttal)												
Experiment 1	0.37 [0.02, 0.73]	125	0.39 [0.02, 0.77]	112	0.43 [0.05, 0.80]	112	0.37 [0.02, 0.73]	112	0.45 [0.08, 0.83]	112	8.56 [1.58, 15.54]	112
Experiment 2	0.39 [0.11, 0.66]	206	0.44 [0.13, 0.75]	164	0.44 [0.13, 0.75]	164	0.39 [0.11, 0.66]	164	0.47 [0.16, 0.78]	164	10.58 [3.71, 17.44]	164
Experiment 3	0.15 [-0.10, 0.39]	261	0.09 [-0.18, 0.37]	201	0.10 [-0.18, 0.38]	197	0.15 [-0.10, 0.39]	201	0.11 [-0.17, 0.39]	201	2.06 [-3.25, 7.37]	201
Experiment 4	0.24 [0.00, 0.48]	267	0.25 [-0.02, 0.51]	227	0.25 [-0.05, 0.54]	180	0.24 [0.00, 0.48]	227	0.23 [-0.03, 0.50]	227	3.78 [-0.44, 8.00]	227
Experiment 5	0.20 [-0.07, 0.47]	217	0.16 [-0.17, 0.48]	148	0.63 [0.23, 1.03]	105	--		0.15 [-0.18, 0.47]	148	1.08 [-1.26, 3.41]	148
Experiment 6	0.30 [0.18, 0.42]	1137	0.36 [0.23, 0.49]	921	0.45 [0.29, 0.60]	641	0.30 [0.18, 0.42]	921	0.37 [0.24, 0.50]	921	5.67 [3.56, 7.78]	921
Summary effect	0.28 [0.19, 0.36]		0.31 [0.21, 0.40]		0.37 [0.24, 0.51]		0.33 [0.22, 0.44]		0.32 [0.22, 0.41]		3.99 [2.63, 5.35]	
Combination (vs.single)												
Experiment 1	0.09 [-0.33, 0.51]	92	0.12 [-0.32, 0.56]	82	0.05 [-0.41, 0.50]	77	0.09 [-0.33, 0.51]	82	0.16 [-0.29, 0.60]	82	2.70 [-5.50, 10.89]	82
Experiment 2	0.38 [0.03, 0.72]	152	0.38 [-0.00, 0.76]	122	0.38 [-0.00, 0.76]	122	0.38 [0.03, 0.72]	122	0.40 [0.02, 0.79]	122	8.94 [1.28, 16.59]	122
Experiment 3	0.14 [-0.15, 0.44]	196	0.17 [-0.17, 0.50]	153	0.19 [-0.15, 0.53]	149	0.14 [-0.15, 0.44]	153	0.16 [-0.17, 0.49]	153	2.84 [-2.39, 8.08]	153
Experiment 4	0.10 [-0.20, 0.39]	200	0.15 [-0.17, 0.48]	173	0.09 [-0.27, 0.45]	139	0.10 [-0.20, 0.39]	173	0.15 [-0.17, 0.47]	173	2.05 [-1.85, 5.96]	173
Experiment 5	0.21 [-0.11, 0.54]	161	0.24 [-0.16, 0.64]	104	0.39 [-0.02, 0.81]	98	--		0.18 [-0.22, 0.58]	104	0.18 [-0.22, 0.58]	104
Experiment 6	-0.05 [-0.18, 0.08]	891	-0.01 [-0.16, 0.13]	714	0.08 [-0.09, 0.26]	504	-0.05 [-0.18, 0.08]	714	-0.01 [-0.16, 0.14]	714	-0.10 [-1.87, 1.66]	714
Summary effect	0.10 [-0.04, 0.23]		0.09 [-0.02, 0.20]		0.15 [0.03, 0.28]		0.10 [-0.03, 0.24]		0.10 [-0.03, 0.24]		1.93 [-0.59, 4.46]	

Supplementary Table 6. Overview of measures used in Experiments 1–6. Reliability of multiple item scales is indicated by Cronbach's alpha; numbers behind alphas relate to the respective experiments. * indicates variables included in preregistrations for explorative purposes. Results of additional explorative analysis are not further reported. All variables are available in the datasets: https://osf.io/xx2kt/.

concept	included in:	scale type and reliability*	wording	source of adapted items
primary outcomes				
intention to get vaccinated	Experiments 1–4,6	visual analogue scale	If you had the opportunity to get vaccinated against dysomeria next week, what would you do? (1 = I will definitely not get vaccinated, 100 = I will definitely get vaccinated)	(Betsch, Haase, Renkewitz, & Schmid, 2015)
attitude towards vaccination	Experiments 2–4,6	mean score of 5-point rating scales ($\alpha2_{pre}$ = .90; $\alpha2_{post}$ = .94; $\alpha3_{pre}$ = .89; $\alpha3_{post}$ = .93; $\alpha4_{pre}$ = .92; $\alpha4_{post}$ = .94; $\alpha6_{pre}$ = .92; $\alpha6_{post}$ = .95)	Please indicate how much you agree with the following statement. 1.Vaccinating against dysomeria is necessary. 2.Vaccinating against dysomeria is a good idea. 3.Vaccinating against dysomeria is beneficial. (1 = I strongly disagree, 5 = I strongly agree)	(Askelson et al., 2010)
intention to act against climate change	Experiment 5	mean score of 6-point rating scales ($\alpha5_{pre}$ = .83; $\alpha5_{post}$ = .85)	Are you ready to learn about ways to protect the natural environment or to pay money? I am ready to 1. pay money for the installation of environmentally friendly equipment (eg installation of a temperature controller on the heating, use of solar energy, etc.). 2. spend more money on products from a specific company if they are made more environmentally friendly than comparable products. 3. read journal articles and books on ways to protect the environment. 4. actively seek newer scientific insights into the extent and potential solutions to environmental problems. 5. obtain information about environmental problems (eg pollution of air, soil, water, climatic hazards). 6. buy drinks in returnable bottles only despite the extra costs. 7. seek information from environmental authorities and other official bodies about what citizens can do to protect the environment. (1 = I strongly disagree, 6 = I strongly agree)	(Montada, Kals, & Becker, 2014)
attitude towards climate change	Experiment 5	mean score of 5-point rating scales	Please indicate how much you agree with the following statement. 1.Acting against climate change is necessary.	(Askelson et al., 2010)

Supplementary Table 6. (continued)

		($\alpha 5_{pre}$ = .89; $\alpha 5_{post}$ = .93)	2.Acting against climate change is a good idea. 3.Acting against climate change is beneficial. (1 = I strongly disagree, 5 = I strongly agree)	
control variables				
knowledge about vaccination	Experiments 1–4,6	mean score of correct/incorrect answers	Example item: Diseases like autism, multiple sclerosis, and diabetes might be triggered through vaccinations. (1 = yes, 2 = no, 3 = I do not know)	(Zingg & Siegrist, 2012)
knowledge about climate change	Experiment 5	mean score of correct/incorrect answers	Example item: The greenhouse effect refers to the protective ozone layer of the earth. (1 = yes, 2 = no, 3 = I do not know)	(Leiserowitz, Smith, & Marlon, 2010)
trust in information source	Experiments 1–6	7-point rating scales	How much do you trust the following sources of health information? example item: radio example item: internet (1 = do not trust at all, 7 = trust completely)	(Betsch, Bödeker, Schmid, & Wichmann, 2018)
frequency of using information source	Experiments 1–6	7-point rating scales	How often do you use the following sources to get health information? example item: radio example item: internet (1 = never, 7 = daily)	(Betsch et al., 2018)
relevance of information source	Experiments 1–6	product score of trust in information source and frequency of using information source		(Betsch et al., 2018)
mediator variables				
perceived persuasiveness	Experiment 1	7-point rating scale	How convincing do you judge the preceding argument to be? (1 = not convincing at all, 7 = very convincing)	(Cacioppo et al., 1983)
perceived argument strength	Experiments 2,5	mean score of a 5-point rating scale ($\alpha 2_{denier\ argument\ 1}$ = .93; $\alpha 2_{denier\ argument\ 2}$ = .94; $\alpha 2_{advocate\ argument\ 1}$ = .88; $\alpha 2_{advocate\ argument\ 2}$ = .86)	Example item: The preceding argument of *name denier/name advocate* is a convincing reason *against/for* the dysomeria vaccination. (1 = strongly disagree, 5 =strongly agree)	(Zhao et al., 2011)

Supplementary Table 6. (continued)

persuasion knowledge	Experiment 3	mean score of a 5-point rating scale ($\alpha 3_{pre}$ = .75)	Example item: The aim of *name denier* was to influence my opinion. (1 = strongly disagree, 5 =strongly agree)	(Tutaj & van Reijmersdal, 2012)
additional measures				
psychological antecedents of vaccination (incl. confidence in vaccination)*	Experiments 2–4,6	5-point rating scales	Please evaluate how much you disagree or agree with the following statements. (Confidence) I am completely confident that vaccines are safe. (Collective responsibility) When everyone is vaccinated, I don't have to get vaccinated, too. (Constrains) Everyday stress prevents me from getting vaccinated. (Complacency) Vaccination is unnecessary because vaccine-preventable diseases are not common anymore. (Calculation) When I think about getting vaccinated, I weigh benefits and risks to make the best decision possible. (1 = I strongly disagree, 5 = I strongly agree)	(Betsch, Bohm, & Chapman, 2015)
need for cognition*	Experiment 4	mean score of 5-point rating scales ($\alpha 4$ = .95)	Describe the extent to which you agree with each of the following statements. Example item: I would prefer complex to simple problems. (1 = I strongly disagree, 5 = I strongly agree)	(Cacioppo, Petty, & Feng Kao, 1984)
conservatism*	Experiments 4,6 (first item was also used in German sample of Experiments 3,5)	mean score of 5-point rating scales ($\alpha 4$ = .89; $\alpha 6$ = .87)	If you think about your own political views, where would you classify your views on this scale? (Exp 4,6: 1 = very conservative, 5 = very liberal) If you think about your own political identity, where would you classify your views on this scale? (Exp 4,6: 1 = Republican, 5 = Democrat)	(Lewandowsky & Oberauer, 2016; Mccright & Dunlap, 2011)
	Experiments 4,6	5-point rating scales	If you think about your own political identity, where would you classify your views on this scale? (Exp 4: 1 = Republican, 5 = Democrat)	
personality*	Experiment 4	mean scores of 5-point rating scales: agreeableness ($\alpha 4$ = .38);	Here are a number of personality traits that may or may not apply to you. Please evaluate the extent to which you agree or disagree with that statement. You should rate the extent to which the pair of traits applies to you, even if one characteristic applies more strongly than the other. I see myself as:	(Gosling, Rentfrow, & Swann, 2003)

Supplementary Table 6. (continued)

		extraversion (α4 = .72); conscientiousness (α4 = .47); emotional stability (α4 = .75); openness (α4 = .45)	Example item: Extraverted, enthusiastic. (1 = I strongly disagree, 5 = I strongly agree)	
conspiracy mentality*	Experiments 4,6	mean score of 5-point rating scales (α4 = .82, α6 = .86)	For each of the statements below, please indicate how likely it is in your opinion that the statement is true. Example item: Events which superficially seem to lack a connection are often the result of secret activities. (1 = certainly not, 5 = certain)	(Bruder, Haffke, Neave, Nouripanah, & Imhoff, 2013)
general attitude towards vaccination*	Experiment 2	mean score of 5-point rating scales (α2 = .93)	Please indicate how much you agree with the following statement. 1.Getting vaccinated is necessary. 2.Getting vaccinated is a good idea. 3.Getting vaccinated is beneficial. (1 = I strongly disagree, 5 = I strongly agree)	(Askelson et al., 2010)
attention	Experiments 4,6	mean score of correct/incorrect answers (α4 = .71; α6 = .47)	Example: People are very busy these days and many do not have time to follow what goes on in the government. Some do pay attention to politics but do not read questions carefully. To show that you have read this much, please ignore the question below and just press continue. That is right, just press continue and ignore the choices below.	(Berinsky et al., 2014)
scepticism*	Experiment 5	mean score of 5-point rating scales (α5 = .84)	Please indicate how much you agree with the following statement. Example: I often reject statements until I have the evidence that they are true. (1 = I strongly disagree, 5 = I strongly agree)	(Hurtt, 2010)
speaker evaluation*	Experiments 1–6	mean score of 7-point semantic differential: competence (α1denier = .88; α1advocate= .89; α2denier = .94; α2advocate= .94; α3denier = .92;	Please rate name denier/name advocate. Example item competence: 1. qualified 7. unqualified Example item character: 1. selfish 7. unselfish Example item sociability: 1. friendly 7. unfriendly	(McCroskey & Jenson, 1975)

Supplementary Table 6. (continued)

α3advocate= .91;
α4denier = .94;
α4advocate= .91;
α5denier = .90;
α5advocate= .93;
α6denier = .95;
α6advocate= .93)

character (α1denier = .64; α1advocate= .68;
α2denier = .83;
α2advocate= .87;
α3denier = .76;
α3advocate= .74;
α4denier = .86;
α4advocate= .81;
α5denier = .69;
α5advocate= .75;
α6denier = .83;
α6advocate= .86)

sociability (α1denier = .78; α1advocate= .71;
α2denier = .81;
α2advocate= .86;
α3denier = .72;
α3advocate= .81;
α4denier = .88;
α4advocate= .89;
α4denier = .61;
α4advocate= .74;
α6denier = .90;
α6advocate= .90)

Supplementary Table 6. (continued)

persuasion appropriateness*	Experiment 3	5-point rating scales	The way name denier argued against the dysomeria vaccine is appropriate.	(Yoo, 2009)
persuasion knowledge explorative*	Experiment 3	mean score of correct/incorrect answers	Which technique has name denier used in his argument? (1 = conspiracy theory, 2 = fake expert, 3 = misrepresentation, 4 = subjective probability, 5 = I do not know)	n.a.
content filter	Experiments 1–6	single item selection	For Exp. 1–4 and 6: What was the radio interview about? About the vaccination against dysomeria; About the vaccination against verococci; About the vaccination record of Steve Miller; About the effectiveness of the vaccination against dysomeria compared to the vaccination against verococci.	n.a.

Supplementary Table 7. Effects of topic rebuttal and technique rebuttal on changes in intentions after controlling for effects of covariates. Significant effects are shown in boldface for the significance level of 0.05. The effects are controlled for age, gender, education, relevance of internet (Experiments 2–6), relevance of radio, knowledge about vaccination (Experiments 1–4,6), knowledge about climate change (Experiment 5). Numbers in brackets denote degrees of freedom for the ANCOVA models (df_1,df_2).

	Experiment 1 n = 112; (1,102)			Experiment 2 n = 158; (1,147)			Experiment 3 n = 198; (1,187)			Experiment 4 n = 227; (1,216)			Experiment 5 n = 148; (1,137)			Experiment 6 n = 921; (1,910)		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**5.48**	**.021**	**.051**	0.02	.878	<.001	**11.74**	**.001**	**.059**	0.36	.549	.002	0.39	.536	.003	0.45	.500	<.001
Topic rebuttal*Time	3.34	.071	.032	2.74	.100	.018	**13.21**	**<.001**	**.066**	**5.76**	**.017**	**.026**	0.08	.782	.001	**23.93**	**<.001**	**.026**
Technique rebuttal*Time	**4.40**	**.038**	**.041**	**10.96**	**.001**	**.069**	1.21	.274	.006	2.32	.129	.011	0.89	.347	.006	**23.50**	**<.001**	**.025**
Technique rebuttal*Topic rebuttal*Time	0.64	.425	.006	0.47	.492	.003	1.62	.205	.009	0.80	.372	.004	0.25	.618	.002	**23.28**	**<.001**	**.025**
Knowledge*Time	**7.63**	**.007**	**.070**	**10.41**	**.002**	**.066**	**15.39**	**<.001**	**.076**	**21.25**	**<.001**	**.090**	1.74	.190	.013	**70.57**	**<.001**	**.072**
Source Relevance Radio*Time	0.26	.612	.003	1.23	.270	.008	0.07	.787	<.001	0.04	.847	<.001	<0.01	.933	<.001	**7.38**	**.007**	**.008**
Source Relevance Internet*Time	--	--	--	<0.01	.987	<.001	0.03	.861	<.001	0.03	.873	<.001	0.02	.894	<.001	<0.01	.967	<.001
Education low*Time	Ref.	--	--	Ref.	--	--	Ref.	--	--	Ref.	--	--	Ref.	--	--	Ref.	--	--
Education middle*Time	0.25	.619	.002	0.19	.660	.001	0.41	.521	.002	0.15	.698	.001	0.02	.883	<.001	0.68	.409	.001
Education high*Time	0.60	.439	.006	0.54	.464	.004	1.84	.177	.010	0.42	.520	.002	0.11	.741	.001	0.56	.454	.001
Gender*Time	2.39	.126	.023	1.06	.100	.018	1.42	.235	.008	0.42	.520	.002	0.20	.657	.001	0.10	.752	<.001
Age*Time	1.53	.219	015	**8.27**	**.005**	**.053**	0.01	.922	<.001	0.84	.361	.004	0.50	.479	.004	0.01	.972	<.001

Supplementary Table 8. Effects of topic rebuttal and technique rebuttal on changes in attitudes after controlling for effects of covariates. Significant effects are shown in boldface for the significance level of 0.05. The effects are controlled for age, gender, education, relevance of internet, relevance of radio, knowledge about vaccination (Experiments 2–4,6), knowledge about climate change (Experiment 5). Numbers in brackets denote degrees of freedom for the ANCOVA models (df_1,df_2).

	Experiment 2 n = 158; (1,147)			Experiment 3 n = 198; (1,187)			Experiment 4 n = 227; (1,216)			Experiment 5 n = 148; (1,137)			Experiment 6 n = 921; (1,910)		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**4.05**	**.046**	**.027**	**11.88**	**.001**	**.060**	1.60	.207	.007	0.19	.660	.001	0.428	.513	<.001
Topic rebuttal*Time	0.14	.711	.001	**11.46**	**.001**	**.058**	0.70	.403	.003	0.27	.603	.002	**14.98**	**<.001**	**.016**
Technique rebuttal*Time	3.12	.079	.021	1.81	.180	.010	1.49	.224	.007	**5.82**	**.017**	**.041**	**23.37**	**<.001**	**.025**
Technique rebuttal*Topic rebuttal*Time	0.01	.912	.000	1.22	.270	.006	0.12	.727	.001	0.26	.615	.002	**27.09**	**<.001**	**.029**
Knowledge*Time	**11.83**	**.001**	**.074**	**24.59**	**<.001**	**.116**	**21.11**	**<.001**	**.089**	0.13	.719	.001	**91.38**	**<.001**	**.091**
Source Relevance Radio*Time	**5.91**	**.016**	**.039**	1.46	.228	.008	0.03	.859	<.001	0.27	.606	.002	**13.48**	**<.001**	**.015**
Source Relevance Internet*Time	**5.07**	**.026**	**.033**	0.30	.585	.002	1.64	.201	.008	0.62	.434	.004	2.25	.134	.002
Education low*Time	Ref.	--	--	Ref.	--	--	Ref.	--	--	Ref.	--	--	Ref.	--	--
Education middle*Time	0.03	.854	<.001	1.58	.210	.008	0.03	.859	<.001	0.05	.768	.001	0.26	.608	<.001
Education high*Time	0.18	.676	.001	0.51	.476	.003	0.02	.877	<.001	0.18	.671	.001	0.34	.559	<.001
Gender*Time	0.26	.607	.002	2.85	.093	.015	0.28	.601	.001	0.38	.537	.003	0.15	699	<.001
Age*Time	1.12	.292	.008	0.10	.758	<.001	0.14	.711	.001	0.19	.662	.001	**5.43**	**.020**	**.006**

Supplementary Table 9. Planned contrast effects of *advocate absent versus rebuttal strategies* (-3 1 1 1) and *single strategies vs. combination* (0 -1 -1 2) on changes in intentions and attitude after controlling for effects of covariates. Significant effects are shown in boldface for the significance level of 0.05. The effects are controlled for age, gender, education, relevance of internet (Experiments 2–6), relevance of radio, knowledge about vaccination (Experiments 1–4,6), knowledge about climate change (Experiment 5). Numbers in brackets denote degrees of freedom for the ANCOVA models (df1,df2).

	Experiment 1 n = 112; (1,102)			Experiment 2 n = 158; (1,147)			Experiment 3 n = 198; (1,187)			Experiment 4 n = 227; (1,216)			Experiment 5 n = 148; (1,137)			Experiment 6 n = 921; (1,910)		
	F	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Advocate absent vs. rebuttal																		
Attitude	--	--	--	1.41	.237	.009	**10.91**	**.001**	**.055**	1.82	.179	.008	0.68	.410	.005	**62.33**	**<.001**	**.064**
Intention	**6.92**	**.010**	**.064**	**10.91**	**.001**	**.069**	**11.55**	**.001**	**.058**	**7.28**	**.008**	**.033**	0.18	.673	.001	**68.32**	**<.001**	**.070**
Single strategies vs. combination																		
Attitude	--	--	--	0.93	.337	.006	1.08	.299	.006	0.23	.591	.001	1.37	.243	.010	0.60	.440	.001
Intention	0.97	.327	.009	2.12	.147	.014	0.82	.367	.004	0.70	.404	.003	0.81	.370	.006	<0.01	.966	<.001

Supplementary Table 10. Descriptive data for overall change in intention and stratified by conditions and contrasts. Smaller numbers indicate a stronger influence of the science denier.

	Experiment 1			Experiment 2			Experiment 3			Experiment 4			Experiment 5			Experiment 6		
	Mean	*SD*	n	*Mean*	*SD*	n	*Mean*	*SD*	n	*Mean*	*SD*	n	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*
Overall	-10.62	19.22	112	-9.34	23.10	164	-8.29	18.99	201	-6.27	16.13	227	-0.13	7.36	148	-5.01	15.59	921
Conditions																		
Advocate absent	-19.90	22.38	30	-16.96	23.95	42	-15.51	20.89	48	-12.10	21.35	54	-0.54	8.94	44	-13.38	22.50	207
Topic rebuttal only	-9.01	11.65	24	-11.83	23.79	45	-2.75	16.31	44	-4.42	13.30	55	-0.71	6.89	37	-2.43	10.75	183
Technique rebuttal only	-7.61	15.58	26	-7.00	23.23	37	-10.55	22.23	54	-5.65	16.14	64	0.00	4.40	28	-2.64	10.42	190
Combination	-5.59	20.94	32	-0.71	18.44	40	-4.21	12.88	55	-3.03	10.68	54	0.79	7.67	39	-2.64	13.19	341
Main effects																		
Topic rebuttal	-7.05	17.52	56	-6.60	22.04	85	-3.56	14.45	99	-3.73	12.04	109	0.06	7.29	76	-2.64	12.26	531
No topic rebuttal	-14.20	20.32	56	-12.29	23.99	79	-12.88	21.65	102	-8.60	18.90	118	-0.33	7.47	72	-8.24	18.77	390
Technique rebuttal	-6.50	18.60	58	-3.73	20.98	77	-7.35	18.32	109	-4.45	13.92	118	0.46	6.48	67	-2.57	12.38	524
No technique rebuttal	-15.06	19.05	54	-14.30	23.87	87	-9.41	-19.80	92	-8.23	18.08	109	-0.62	8.02	81	-8.24	18.55	397
Planned contrast																		
Single strategies	-8.28	13.72	50	-9.65	23.52	82	-7.05	20.08	98	-5.08	14.84	119	-0.40	5.92	65	-2.54	10.57	373
Combination	-5.59	20.94	32	-0.71	18.44	40	-4.21	12.88	55	-3.03	10.68	54	0.79	7.67	39	-2.64	13.19	341

Supplementary Table 11. Descriptive data for overall change in attitude and stratified by conditions and contrasts. Smaller numbers indicate a stronger influence of the science denier.

	Experiment 2			Experiment 3			Experiment 4			Experiment 5			Experiment 6		
	Mean	*SD*	n	*Mean*	*SD*	n	*Mean*	*SD*	n	*Mean*	*SD*	*n*	*Mean*	*SD*	*n*
Overall	-10.06	21.10	164	-11.61	18.05	201	-8.63	20.15	227	-2.65	11.08	148	-6.62	15.85	921
Conditions															
Advocate absent	-12.50	21.64	42	-18.40	22.54	48	-12.65	29.04	54	-3.79	10.70	44	-14.81	22.66	207
Topic rebuttal only	-14.07	24.02	45	-7.39	14.84	44	-8.79	16.07	55	-5.63	10.95	37	-4.43	10.83	190
Technique rebuttal only	-8.11	20.08	37	-13.73	16.12	54	-7.68	20.37	64	-0.30	6.61	28	-3.23	11.07	183
Combination	-4.79	16.97	40	-6.97	15.86	55	-5.56	10.24	54	-0.21	13.45	39	-4.69	13.56	341
Main effects															
Topic rebuttal	-9.71	21.40	85	-7.15	15.34	99	-7.19	.13.54	109	-2.85	12.15	76	-4.60	12.64	531
No topic rebuttal	-10.44	20.91	79	-15.93	19.45	102	-9.96	24.73	118	-2.43	9.43	72	-9.38	19.05	390
Technique rebuttal	-6.39	18.48	77	-10.32	16.27	109	-6.71	16.50	118	-0.25	11.04	67	-4,18	12.75	524
No technique rebuttal	-13.31	22.78	87	-13.13	19.93	92	-10.70	23.38	109	-4.63	10.79	81	-9.84	18.71	397
Planned contrast															
Single strategies	-11.38	22.40	82	-10.88	15.80	98	-8.19	18.44	119	-3.33	9.64	65	-3.84	10.95	373
Combination	-4.79	16.97	40	-6.97	15.86	55	-5.56	10.24	54	-0.21	13.45	39	-4.69	13.56	341

Supplementary Table 12. Mediations of technique rebuttal on intention by perceived persuasiveness (of the denier Model 1a; of the advocate Model 2a) in Experiment 1. Significant effects are shown in boldface for the significance level of 0.05. Regression coefficients *B* are unstandardized and adjusted for age, gender, education, relevance of radio and knowledge about vaccination.

	Model 1a (n = 112)			Model 2a (n = 82)		
Experiment 1	Dependent variable: Perceived persuasiveness (denier) **R^2 = .209; F(8, 103) = 3.41, p = .002**			Dependent variable: Perceived persuasiveness (advocate) **R^2 = .324; F(8, 73) = 4.37, p < .001**		
	B [95%CI]	*SE*	*p*	*B* [95%CI]	*SE*	*p*
Direct effects						
Constant	**63.23 [37.03, 89.44]**	**13.21**	**< .001**	**41.19 [21.34, 61.05]**	**9.96**	**< .001**
Technique rebuttal (vs. no technique rebuttal)	-4.79 [-13.11, 3.54]	4.20	.257	0.22 [-6.95, 7.40]	3.60	.951
	Dependent variable: Intention **R^2 = .470; F(9, 102) = 10.07, p < .001**			Dependent variable: Intention **R^2 = .370; F(9, 72) = 4.69, p < .001**		
Direct effects						
Constant	-0.48 [-20.26, 19.31]	9.97	.962	**-37.34 [-59.30, -15.39]**	**11.01**	**.001**
Technique rebuttal (vs. no technique rebuttal)	**5.81 [0.09, 11.53]**	**2.89**	**.047**	2.76 [-4.38, 9.91]	3.58	.444
Perceived persuasiveness (denier)	**-0.48 [-0.61, -0.35]**	**0.07**	**< .001**	---	---	---
Perceived persuasiveness (advocate)	---	---	---	**0.38 [0.15, 0.61]**	**0.12**	**.002**
Indirect effects						
Technique rebuttal (vs. no technique rebuttal)	2.30 [-1.47, 6.83]	2.15	---	.086 [-1.96, 3.00]	1.25	---

Supplementary Table 13. Mediations of technique rebuttal on intention (Model 1a, Model 2a) and attitude (Model 3a, Model 4a) by perceived argument strength (of the denier Model 1a, Model 3a; of the advocate Model 2a, Model 4a) in Experiment 2. Significant effects are shown in boldface for the significance level of 0.05. Regression coefficients *B* are unstandardized and adjusted for age, gender, education, relevance of radio, relevance of internet and knowledge about vaccination.

Experiment 2	Model 1a (n = 158)			Model 2a (n = 117)		
	Dependent variable: Perceived argument strength (denier) **$R^2 = .213$; $F(8, 149) = 5.04$, $p < .001$**			Dependent variable: Perceived argument strength (advocate) **$R^2 = .213$; $F(8, 149) = 5.04$, $p < .001$**		
	B [95%CI]	*SE*	*p*	*B* [95%CI]	*SE*	*p*
Direct effects						
Constant	**51.41 [38.02, 64.79]**	**6.77**	**< .001**	**52.16 [38.54, 65.77]**	**6.87**	**< .001**
Technique rebuttal (vs. no technique rebuttal)	-1.86 [-7.64, 3.92]	2.92	.526	-2.23 [-8.34, 3.88]	3.08	.471
	Dependent variable: Intention **$R^2 = .342$; $F(9, 148) = 8.53$, $p < .001$**			Dependent variable: Intention **$R^2 = .251$; $F(9, 107) = 3.98$, $p < .001$**		
Direct effects						
Constant	**25.20 [7.83, 42.57]**	**8.79**	**.005**	**-30.08 [-52.56, -7.60]**	**11.34**	**.009**
Technique rebuttal (vs. no technique rebuttal)	**10.89 [4.51, 17.26]**	**3.23**	**.001**	**8.02 [-0.15, 16.19]**	**4.12**	**.001**
Perceived argument strength (denier)	**-0.56 [-0.74, -0.38]**	**0.09**	**< .001**	**0.49 [0.24, 0.75]**	**0.13**	**< .001**
Perceived argument strength (advocate)	---	---	---	---	---	---
Indirect effects						
Technique rebuttal (vs. no technique rebuttal)	1.04 [-2.27, 5.25]	1.88	---	-1.10 [-4.71, 1.43]	1.49	---
Experiment 2	Model 3a (n = 158)			Model 4a (n = 117)		
	Dependent variable: Attitude **$R^2 = .234$; $F(9, 148) = 5.03$, $p < .001$**			Dependent variable: Attitude **$R^2 = .258$; $F(9, 107) = 4.14$, $p < .001$**		
Direct effects						
Constant	1.45 [-15.55, 18.45]	8.60	.867	**-48.23 [-69.04, -27.42]**	**10.50**	**< .001**
Technique rebuttal (vs. no technique rebuttal)	5.26 [-0.98, 11.50]	3.16	.098	6.86 [-0.70, 14.42]	3.82	.075
Perceived argument strength (denier)	**-0.39 [-0.56, -0.21]**	**0.09**	**< .001**	---	---	---
Perceived argument strength (advocate)	---	---	---	**0.49 [0.25, 0.72]**	**0.12**	**< .001**
Indirect effects						
Technique rebuttal (vs. no technique rebuttal)	0.72 [-1.28, 3.90]	1.27	---	-1.10 [-4.56, 1.46]	1.47	---

Supplementary Table 14. Mediations of technique rebuttal on intention (Model 1a) and attitude (Model 2a) by persuasion knowledge in Experiment 3. Significant effects are shown in boldface for the significance level of 0.05. Regression coefficients *B* are unstandardized and adjusted for age, gender, education, relevance of radio, relevance of internet and knowledge about vaccination.

Experiment 3	Model 1a (n = 198)			Model 2a (n = 198)		
	Dependent variable: Persuasion knowledge **R^2 = .287; *F*(8, 189) = 2.11, *p* = .036**			Dependent variable: Persuasion knowledge **R^2 = .287; *F*(8, 189) = 2.11, *p* = .036**		
	B [95%CI]	*SE*	*p*	*B* [95%CI]	*SE*	*p*
Direct effects						
Constant	**57.59 [40.82, 74.37]**	**8.50**	**< .001**	**57.59 [40.82, 74.37]**	**8.50**	**< .001**
Technique rebuttal (vs. no technique rebuttal)	-4.71 [-11.63, 2.21]	3.51	.181	-4.71 [-11.63, 2.21]	3.51	.181
	Dependent variable: Intention **R^2 = .082; *F*(8, 189) = 2.11, *p* = .036**			Dependent variable: Attitude **R^2 = .132; *F*(9, 188) = 3.17, *p* < .001**		
Direct effects						
Constant	**-23.32 [-37.33, -9.31]**	**7.10**	**.001**	**-19.13 [-32.36, -5.90]**	**6.71**	**.005**
Technique rebuttal (vs. no technique rebuttal)	3.06 [-2.15, 8.27]	2.64	.248	3.26 [-1.69, 8.14]	2.49	.197
Persuasion knowledge	0.06 [-0.05, 0.17]	0.05	.260	0.00 [-0.10, 0.11]	0.05	.952
Indirect effect						
Technique rebuttal (vs. no technique rebuttal)	-0.29 [-2.09, .151]	.474	---	-0.01 [-0.90, 0.59]	0.33	---

Supplementary Table 15. Repeated measures binary logistic model for willingness to donate. The model is analysed using Generalized Estimating Equations (GEE). An unstructured covariance matrix was used for the model. Regression coefficients *B* are unstandardized. *OR* values are odds ratios.

Experiment 5	Model 3 (n = 148) Dependent variable: Willingness to donate			
	B [95%CI]	*SE*	*p*	*OR* [95%CI]
Intercept	0.57 [-0.13, 1.27]	0.35	.108	1.77 [0.88, 3.55]
Time	0.04 [-0.24, 0.32]	0.14	.773	1.04 [0.79, 1.38]
Topic rebuttal	0.19 [-0.64, 1.03]	0.43	.650	1.21 [0.53, 2.80]
Technique rebuttal	0.17 [-0.66, 1.01]	0.43	.682	1.19 [0.52, 2.74]
Topic rebuttal*Time	-0.10 [-0.42, 0.23]	0.17	.548	0.91 [0.65, 1.25]
Technique rebuttal*Time	-0.20 [-0.48, 0.24]	0.17	.236	0.82 [0.59, 1.14]

Supplementary Table 16. Mediations of technique rebuttal on attitude by perceived argument strength (of the denier Model 1a; of the advocate Model 2a) in Experiment 5. Significant effects are shown in boldface for the significance level of 0.05. Regression coefficients *B* are unstandardized and adjusted for age, gender, education, relevance of radio, relevance of internet and knowledge about climate change.

Experiment 5	Model 1a (n = 148)			Model 2a (n = 104)		
	Dependent variable: Perceived argument strength (denier) $R^2 = .064$; $F(8, 139) = 1.18$, $p = .314$			Dependent variable: Perceived argument strength (advocate) **$R^2 = .211$; $F(8, 95) = 3.17$, $p = .003$**		
	B [95%CI]	*SE*	*p*	*B* [95%CI]	*SE*	*p*
Direct effects						
Constant	**44.21 [28.32, 60.09]**	**8.03**	**< .001**	**44.01 [23.02, 64.99]**	**10.57**	**< .001**
Technique rebuttal (vs. no technique rebuttal)	-3.78 [-9.14, 1.58]	2.71	.166	6.31 [-.392, 13.02]	3.38	.065
	Dependent variable: Attitude $R^2 = .076$; $F(9, 138) = 1.26$, $p = .266$			Dependent variable: Attitude **$R^2 = .163$; $F(9, 94) = 2.03$, $p = .044$**		
Direct effects						
Constant	5.14 [-6.76, 17.03]	6.02	.394	1.53 [-13.82, 16.88]	7.73	.844
Technique rebuttal (vs. no technique rebuttal)	**4.02 [0.36, 7.69]**	**1.85**	**.032**	.119 [-.018, .256]	.069	.088
Perceived argument strength (denier)	**-0.11 [-0.23, -0.00]**	**1.85**	**.032**	---	---	---
Perceived argument strength (advocate)	---	---	---	**0.12 [-0.02, 0.26]**	**0.07**	**0.09**
Indirect effects						
Technique rebuttal (vs. no technique rebuttal)	0.43 [-0.14, 1.64]	0.45	---	0.75 [-0.10, 2.80]	0.72	---

Supplementary Table 17. The effectiveness of the Combination as a function of the individuals' confidence in vaccination (Model 1 and Model 2) and the individuals' calculation values (Model 3 and Model 4). Significant effects are shown in boldface for the significance level of 0.05. Regression coefficients *B* are unstandardized.

Experiment 6	Model 1 (n = 714)			Model 2 (n = 714)		
	Dependent variable: Intention **R^2 = .043; F(3, 710) = 10.75, p < .001**			Dependent variable: Attitude **R^2 = .087; F(3, 710) = 22.71, p < .001**		
	B [95%CI]	*SE*	*p*	*B* [95%CI]	*SE*	*p*
Constant	**-9.18 [-16.22, -2.13]**	**3.59**	**.011**	**-11.63 [-18.73, -4.53]**	**3.62**	**.001**
Combination (vs.single strategies)	0.44 [-4.00, 4.88]	2.26	.844	-0.84 [-5.31, 3.64]	2.28	.714
Confidence	**0.09 [0.00, 0.18]**	**0.05**	**.046**	**0.16 [0.03, 0.21]**	**0.05**	**.016**
Confidence*Combination	-0.01 [-0.06, 0.05]	0.03	.826	0.00 [-0.05, 0.06]	0.03	.956
	Model 3 (n = 714)			Model 4 (n = 714)		
	Dependent variable: Intention R^2 = .001; F(3, 710) = 0.12, p = .948			Dependent variable: Attitude R^2 = .005; F(3, 710) = 1.14, p = .333		
Constant	-3.42 [-10.54, 3.70]	3.63	.346	-4.14 [-11.47, 3.19]	3.73	.268
Combination (vs.single strategies)	0.86 [-3.74, 5.45]	2.34	.714	0.97 [-3.76, 5.71]	2.41	.686
Calculation	0.01 [-0.08, 0.11]	0.05	.769	0.02 [-0.08, 0.11]	0.05	.740
Calculation*Combination	-0.01 [-0.07, 0.05]	0.03	.658	-0.03 [-0.09, 0.04]	0.03	.414

Article 3

Weight-of-Evidence Strategies to Counter Science Denialism in Public Discussions

Weight-of-Evidence Strategies to Counter Science Denialism in Public Discussions

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Abstract

Science deniers and scientific-consensus advocates' positions repeatedly are presented in a balanced fashion in mass media. This false balance increases the spread of misinformation under the guise of objectivity. Weight-of-evidence strategies are an alternative to this, in which journalists lend weight to each position equivalent to the amount of evidence that supports it. In public discussions, journalists can do this by inviting more advocates of scientific consensuses than science deniers (i.e., outnumbering) or they can use warnings about the false-balance effect prior to the discussion (i.e., forewarning). In three preregistered laboratory experiments, we tested the efficacy of outnumbering and forewarning as weight-of-evidence strategies to mitigate science deniers' influence. We further explored whether advocates' responses to science deniers (rebuttal) and the audience's issue involvement moderate these strategies' efficacy. A total of N = 887 individuals indicated their attitudes towards vaccination and their intention to vaccinate before and after watching a TV discussion. The presence and absence of forewarning, outnumbering and rebuttal were manipulated between subjects; participants also indicated their individual issue involvement. We found no evidence that outnumbering mitigated damage from denialism, not even when advocates served as multiple sources. However, forewarning about the false-balance effect mitigated deniers' negative effect. Moreover, the protective effect was independent of rebuttal and issue involvement. Thus, forewarnings can serve as an effective, economic and theory-driven strategy to counter science denialism in public discussions.

Keywords: false-balance effect; science denialism; forewarning; multiple-source effect; rebuttal; weight of evidence; vaccination

Objectivity is a maxim in journalism that aims to reduce bias in media reports by eliminating journalists' subjective interpretations (Boudana, 2016; Schudson, 2001). A frequently applied strategy to achieve objectivity is to balance media reports by contrasting two opposing positions on the same issue, leaving it to the audience to weigh the positions and draw conclusions about the subject matter. However, balancing can reduce bias only if both opposing positions are supported by an equal amount of evidence (Boudana, 2016; Dearing, 1995). If this assumption is violated, balancing can turn into a source of bias itself. For example, a wide consensus in scientific communities exists that human-made climate change is happening (Cook et al., 2016), that vaccines are beneficial (PRC, 2015) and that humans have evolved over time (PRC, 2009). However, some individuals reject these scientific consensuses (Hornsey & Fielding, 2017; Lewandowsky & Oberauer, 2016) and 'employ rhetorical arguments to give the appearance of a legitimate debate where there is none' (Diethelm & McKee, 2009, p. 2). That is, they represent a form of pseudoscience known as *science denialism* (Hansson, 2017). In mass media, science deniers' views and positions within scientific consensuses repeatedly are presented in a balanced fashion (climate change: Petersen, Vincent & Westerling, 2019; vaccination: Clarke, 2008; evolution: Mooney & Nisbet, 2005). In these instances, journalists ignore scientific consensuses' greater weight of evidence and apply a biased 50/50 weight to the presentation of contrasting positions, that is, they apply *false balance* (Brüggemann & Engesser, 2017; Dixon & Clarke, 2013; Koehler, 2016). Extant research shows that falsely balanced reports can distort positive attitudes towards behaviours that science favours and decrease individuals' intentions to perform these behaviours (Corbett & Durfee, 2004; Dixon & Clarke, 2013). Thus, false balance increases damage from science denialism messages under the guise of objectivity.

The issue of false balance is especially prevalent in public discussions that are broadcast on TV or radio. These discussions often are designed to highlight or induce conflict (Rubin & Step, 1997). Producers often invite people with opposing opinions or perspectives to challenge invited experts' opinions on social, political or personal issues. Scientific evidence thus stands one-on-one with personal opinions, statistical numbers next to emotional narratives (Livingstone & Lunt, 1994). To avoid potential damage to audiences from such falsely balanced public discussions (Dixon & Clarke, 2013), journalists either could refrain from broadcasting them or alter the environment in favour of evidence-based perspectives in discussions (Clarke, McKeever, Holton & Dixon, 2015; Dunwoody, 2005; Kohl et al., 2016). Here, we focus on the latter because we argue that the issue of false balance is not rooted in the very existence of an unscientific perspective, but in the inappropriate weight that this perspective receives in mass media (Boudana, 2016; Dearing, 1995). Thus, in the remainder of this paper, we will discuss several weighting strategies that journalists could use to support the voice of science while maintaining the freedom to broadcast public discussions that involve opposite opinions and contradictory scientific views, that is, maintain democratic discourse.

Weight-of-evidence strategies

An alternative to falsely balanced discussions, which potentially can alter the environment in favour of evidence-based perspectives, is weight-of-evidence reporting (Dunwoody, 2005; Kohl et al., 2016). A weight-of-evidence strategy 'calls on journalists not to determine what's true, but instead to find out where the bulk of evidence and expert thought lies on the truth continuum and then communicate that to the audiences' (Dunwoody, 2005, p. 90). Thus, weight-of-evidence strategies neither overestimate positions that are backed up with little evidence, nor do they neglect the existence of contrasting positions (Kohl et al., 2016). Instead, weight-of-evidence strategies provide each position in a public discussion with a weight corresponding to the amount of evidence that supports the position. Previous research shows that weight-of-evidence strategies in newspaper articles can mitigate damage to the audience's attitudinal beliefs from misleading reports (Clarke, Dixon, Holton & McKeever, 2015; Clarke, McKeever, et al., 2015; Kohl et al., 2016). Given these promising findings, it is now necessary to explore how weight-of-evidence strategies can be best applied in public discussions about science.

Outnumbering as a weight-of-evidence strategy

A variety of cues can be used as weights of evidence in public discussions. For instance, a journalist can counter false balance at a public forum by inviting more advocates for science than deniers, that is, the relative number of guests serves as weight of evidence. We refer to this strategy as *outnumbering*. Extant research in psychology supports the efficacy of such a strategy for two reasons. First, the number of discussants who are invited to represent each position may serve as a social cue (Wood, 2000). Psychological research repeatedly has proposed and demonstrated that individuals tend to align their own judgements with the majority opinion (Bond & Smith, 1996; Cialdini & Goldstein, 2004; McDonald & Crandall, 2015). Individuals either follow majorities to express conformity with others, or they use majorities as informational evidence of facts (McDonald & Crandall, 2015; Wood, 2000). In line with research on scientific consensus (Lewandowsky, Gignac & Vaughan, 2012; van der Linden, Clarke, & Maibach, 2015), using majorities as informational evidence seems especially reasonable when the majority comprises experts in the field under discussion.

Second, the number of discussants who are invited to represent each position can cause a multiple-source effect. Several studies have shown that arguments are more persuasive when presented by multiple sources rather than a single source (Harkins & Petty, 1987; Petty, Harkins & Williams, 1980). It has been suggested that this effect occurs because individuals invest their limited cognitive resources economically, that is, they prefer to process the most worthy information. Multiple sources are perceived as independent pools of knowledge that are likely to represent a wide variety of perspectives, while a single source's perspective is likely to be known after the first argument (Harkins & Petty, 1987). Thus, information from multiple sources 'is more worthy of diligent consideration than information from only one perspective' (Harkins & Petty, 1987, p. 267).

Due to the consistent theoretical and empirical persuasive advantage of having multiple discussants, we expect that the relative number of guests representing a certain position can serve as a weight-of-evidence strategy in a public discussion. Therefore, the *outnumbering hypothesis* predicts that when advocates for science outnumber, rather than balance, science deniers in a public discussion, damage from denial will be mitigated. This mitigation will be achieved either due to the fact that the relative number of advocates serves as a social cue (Experiments 1–3), or due to an additional multiple-source effect (Experiment 3).

Forewarning as a weight-of-evidence strategy

Another weight-of-evidence strategy is to warn the audience prior to the discussion. In line with inoculation theory (McGuire, 1961a, 1961b), individuals can activate their own immune responses against persuasive attempts prior to the persuasion episode when perceiving a threat from being the target of inappropriate persuasion. This pre-activation can reduce the biasing effect of misinformation, including science denialism messages (Cook, Lewandowsky & Ecker, 2017; Roozenbeek & van der Linden, 2019). A common psychological intervention that uses prior information to apply weight to subsequent information is forewarning (McGuire & Papageorgis, 1962; Quinn & Wood, 2003). For example, being warned about a source's persuasive intent before it is accessed can decrease the weight of the information that the source provides, thereby reducing its influence (Quinn & Wood, 2003). Due to falsely balanced public discussions' biased nature, we expect that forewarning about the false-balance effect can serve as a weight-of-evidence strategy in favour of the scientific position. Thus, the *forewarning hypothesis* expects that when individuals read a general explanation of the false-balance effect, denial messages' damage will be mitigated compared with a control group.

Issue involvement and rebuttal as moderators

Some extant findings challenge the idea that weight-of-evidence strategies are a universal approach to counter science denialism in public discussions. First, forewarnings are found to be more effective with highly involved audiences, but also have a greater chance of backfiring with these specific audiences (Albarracín & Handley, 2011; Quinn & Wood, 2003). Moreover, outnumbering can be classified as a peripheral cue. Dual process models suggest that peripheral cues should be more effective with less-involved audiences because peripheral cues do not require as much motivation as a central message feature to be persuasive (Petty & Cacioppo, 1986). On the contrary, the Unimodel argues that the required motivation increases with increasing complexity of a message feature and not just because a feature happens to be peripheral or central (Kruglanski & Thompson, 1999). Given the mixed assumptions, the *involvement-as-moderator research question* explores whether and how the audience's issue involvement will moderate weight-of-evidence strategies' efficacy.

Second, the two outlined weight-of-evidence strategies' efficacy may depend on whether an advocate responds to the denier's claim with a counter message, that is, whether or not a rebuttal is present. If science deniers present misinformation, and advocates respond with rebuttal messages (Schmid & Betsch, 2019), then weight-of-evidence strategies can decrease the misinformation's persuasiveness and/or increase the rebuttal's persuasiveness. In the absence of a rebuttal, weight-of-evidence strategies only can decrease the persuasiveness of deniers' misinformation. In a public discussion, a rebuttal may be absent if the science advocate is not given the chance to respond to the denier, he or she is not trained in rebuttals or he or she does not feel confident enough to demand speaking time (WHO, 2016). Thus, given the lack of previous research on the topic, the *rebuttal-as-moderator research question* explores whether and how weight-of-evidence strategies' efficacy will depend on rebuttal messages' presence. We refer to the failure to deliver a rebuttal as *advocate silent*.

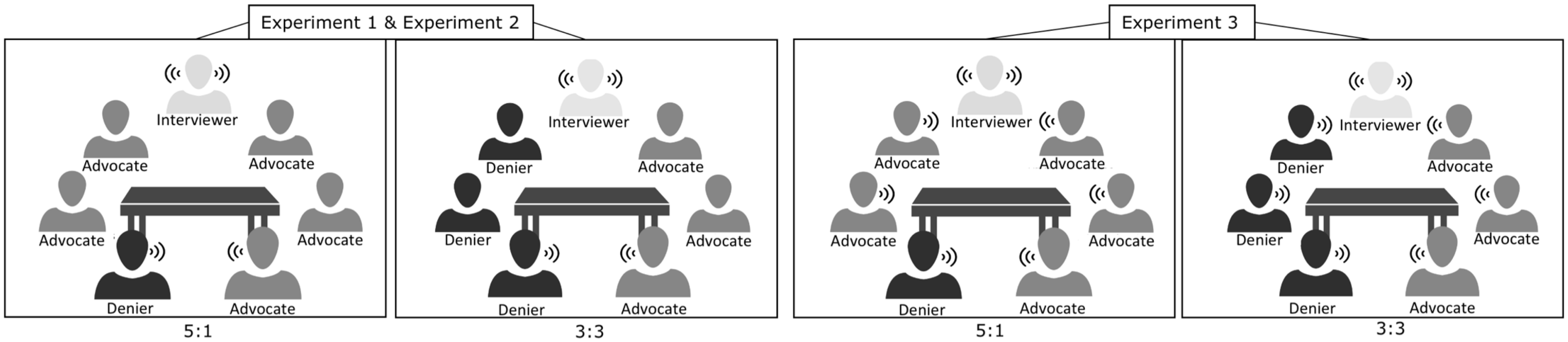
Overview

In three preregistered laboratory experiments, we tested the efficacy of outnumbering (Experiments 1 and 2) and forewarning (Experiments 2 and 3) to counter damage from science denialism in public discussions (Figure 1). We further explored whether these strategies' efficacy depends on the audience's issue involvement and on advocates' successful delivery of rebuttals. All experiments focussed on public discussions about vaccination as a content domain. Vaccination is a behaviour favoured by science that has been addressed repeatedly through science denialism and falsely balanced discussions (Dixon & Clarke, 2013). Thus, vaccination is an appropriate testing ground for interventions to counter misinformation. All studies used Schmid and Betsch's (2019) research scenario, in which participants read information about the fictitious disease dysomeria and learned that vaccination against the disease was available and recommended. Subsequently, participants watched a mock TV discussion between vaccine deniers and advocates for science, in which relevant independent variables were manipulated. Participants indicated their attitudes towards vaccination and the intention to get vaccinated against the fictitious disease before and after the discussion. The strategies' efficacy was judged based on how strongly deniers changed previous attitudes and intention. As described under the rebuttal as the moderator's research question, weight-of-evidence strategies could be effective because they decrease the persuasiveness of deniers' messages and/or increase the persuasiveness of the rebuttal message by providing each message with a weight equivalent to the amount of evidence that supports the position. Following this rationale, failure to detect any weight-of-evidence strategies' effects may be due to mere inefficacy of either the deniers' message or the advocates' rebuttal message in producing any persuasive effect. Thus, replicating the damaging effect from denial messages and the mitigating effect from rebuttal messages from Schmid and Betsch (2019) indicated successful manipulation in all subsequent experiments.

Experiment 1

In this experiment, we tested the outnumbering hypothesis by assessing whether a relatively higher number of advocates for science compared with deniers effectively reduces damage from science denialism. Experiment 1 uses the relative number of advocates present as a social cue, that is, while the relative number of advocates and deniers varies, only one person per group serves as a speaker (Figure 1). In addition, we examined involvement and rebuttal-as-moderator research questions for the outnumbering strategy, and we preregistered the experiment on aspredicted.org: http://aspredicted.org/blind.php?x=jp7az5.

Weight-of-evidence reporting: Outnumbering



Weight-of-evidence reporting: Forewarning

Experiment 2 & Experiment 3

Important note!

In the following program, opposing standpoints may be presented equally, although there is only scientific evidence for one standpoint. Since journalists are anxious to report as fairly as possible, in some cases this so-called false balance occurs. By implementing false balance journalists aim to equally weigh opposing perspectives on a topic. Thus, pro- and contra-arguments are presented to express different opinions. In debates about opinions this serves to increase fairness and is widely regarded as good journalism.

However, this becomes problematic in science reporting - because science is about facts and not opinions. In most cases, an advocate for science is invited and, in addition, someone who represents an unscientific standpoint. This may make the debate more exciting, but it also creates the false impression that both positions are of equal value. The most common example is climate change: about 97 percent of scientists agree that climate change is caused by humans. However, people who deny human-caused climate change are still being invited on television. The scientific facts are distorted by these falsely balanced reports.

We wish you good entertainment for the next programme.

Figure 1: Weight-of-evidence strategies in public discussions. The displayed materials represent the weight-of-evidence strategies *outnumbering* and *forewarning* as used in the respective experiments. Following the social-cue mechanism of outnumbering, the number of science advocates and deniers varied between conditions (3:3 vs. 5:1) in all experiments. Following the additional multiple-source mechanism, all guests in the discussion contributed as speakers in Experiment 3. The presented forewarning text is a translated version of the original German forewarning used in Experiments 2 and 3.

Method

Participants and design. A-priori power analyses using G*Power (Faul, Erdfelder, Buchner & Lang, 2009) revealed a minimum sample size of N = 100 to detect an effect size of $d = 0.34$ with a power of .80 in a repeated-measures ANOVA (four groups, two measurements, $\alpha = .05$). The chosen effect size of the power analysis was informed by effect sizes of previous research on the false-balance effect (Dixon & Clarke, 2013). Altogether, 101 psychology students at the University of Erfurt participated in this lab experiment in exchange for course credit. Participants received the invitation to participate via a mailing list, and each participant was assigned randomly to one of four conditions, resulting from the 2 (rebuttal vs. advocate silent; between subjects) × 2 (outnumbering 5:1 vs. equal proportion of guests 3:3; between subjects) × 2 (measurement before vs. after the debate; within subjects) mixed design.

Materials and Procedure. All materials were presented on a computer screen (Figure 1). Participants watched a mock TV discussion as part of a fictitious scenario. The TV discussion comprised videos that were designed specifically for the experiments. The videos depicted a public discussion, and the critical stimulus materials were voice recordings that Schmid and Betsch (2019) already have used. The videos indicated the number of participating guests and highlighted the current speaker, but contained few other details to minimise distraction and potential confounders. Figure 1 presents screenshots of the videos, all of which can be accessed at the Open Science Framework (Schmid, Schwarzer & Betsch, 2019). Depending on condition, science advocates in the videos either outnumbered the deniers (5:1) or were equal in number (3:3). The proportions of advocates and deniers that participated in the TV discussion were highlighted with different colours. An interviewer introduced the speakers for the TV discussion, during which one vaccine denier delivered the same two messages in all conditions. In these messages, the denier questioned the safety of vaccination against dysomeria, as well as health authorities' trustworthiness, by using the rhetorical techniques of impossible expectation and conspiracy theories. Depending on condition, one science advocate either refuted the denier's messages, or all advocates remained silent. Only one denier and one advocate delivered the messages, independent of the proportion of guests. Denial and rebuttal messages resembled those that Schmid and Betsch (2019) used in Experiment 1, where they are described in detail. A fully translated script of messages used in this study is available under Supplementary Method in the Supplementary Information. After the second measurement of primary outcomes, individuals' issue involvement, speakers' perceived credibility, additional control variables and demographic data were assessed.

Measures. Participants indicated their attitudes towards vaccination and intention to get vaccinated before and after the TV discussion (Table 1). The primary measures were identical to those that Schmid and Betsch (2019) used. In addition, we added a single item on individuals' willingness to donate to a fictitious anti-vaccination campaign. Willingness to donate was added for explorative purposes only and was dropped for Experiments 2 and 3. After completing the dependent measures, participants answered a single attention question about the discussion's content, individuals' issue involvement, speakers' perceived credibility, additional control variables and demographic information (Supplementary Table 1).

Data analyses. For all experiments, we used repeated-measures ANOVA models in IBM SPSS 25 for hypothesis testing. When adding a continuous moderator for the involvement-as-moderator research question, we used linear models on change scores in R. We used type 2 sum of squares and a 0.05 significance level for all models. All outcome measures were transformed into percentages of maximum possible scores from the original scales (POMP = $[(\textit{observed score}_{\textit{single case}} - \textit{minimum score}_{\textit{scale}})/(\textit{maximum score}_{\textit{scale}} - \textit{minimum score}_{\textit{scale}})] \times 100$; P. Cohen, Cohen, Aiken & West, 1999). The linear transformation of original scores into POMP scores allows for easy interpretation of outcome measures as all change scores range from -100 to 100 after transformation. The transformed scores indicate the change in attitudes towards vaccination and intentions to get vaccinated in percentages of the original scales. Thus, positive POMP values of change scores indicate percent increase in positive attitudes and intentions and negative POMP values of change scores indicate percent decrease in positive attitudes and intentions.

Results

Eighty percent of the full sample was female, with a mean age of 20.71 ($SD_{AGE} = 2.71$) for all participants. All participants correctly identified the hypothetical debate's content; thus, no participant was excluded from the analyses. No evidence of differences between conditions in prior attitudes towards vaccination or prior intention to get vaccinated was found (all ps $\geq .150$ in 2 × 2 ANOVAs). The Supplementary Information contains detailed descriptive data on all experiments (Supplementary Method).

Tables 2 and 3 and Figure 2 present the results from the 2 × 2 × 2 repeated-measures ANOVA models for individuals' attitudes and intention. Watching the public debate significantly damaged individuals' attitudes towards vaccination and their intention to get vaccinated, but the rebuttal successfully mitigated this damage. The mitigating effect was only marginally significant on intention to get vaccinated. These results indicate successful manipulation and replicate previous findings (Schmid & Betsch, 2019).

However, contrary to expectations on the outnumbering hypothesis, we found no evidence that the presence of a higher proportion of science advocates at the debate mitigated deniers' influence on individuals' attitudes or intention, main effects for outnumbering on attitude: $F(1, 97) = 0.11$, $p = .737$, $\eta^2_p = .001$, intention: $F(1, 97) = 0.19$, $p = .661$, $\eta^2_p = .002$. We repeated confirmatory analyses with preregistered control variables, and the pattern of results did not differ (Supplementary Tables 5 and 6).

Further examination of the rebuttal-as-moderator research question (Table 2; Figure 2) revealed a significant interaction effect from outnumbering and rebuttal on individuals' attitudes, $F(1, 97) = 4.68$, $p = .033$, $\eta^2_p = .046$. That is, inviting more advocates than deniers marginally reduced damage from deniers when a rebuttal was delivered, $F(1, 97) = 3.10$, $p = .081$, though this trend was reversed when the advocate remained silent, $F(1, 97) = 1.69$, $p = .196$. The interaction effect was only marginally significant concerning individuals' intention (Table 2).

Additional explorative analyses revealed no evidence that the outnumbering strategy's effects depend on the audience's issue involvement (Supplementary Table 7). Furthermore, we found no evidence that the willingness to donate to a fictitious initiative that supports anti-vaccination campaigns differed between either the rebuttal or outnumbering conditions (χ^2s < 1).

Discussion

Contrary to expectations on the outnumbering hypothesis, we found no evidence that inviting a greater number of advocates significantly mitigates science denialism's influence on the audience. However, in exploring the rebuttal-as-moderator research question, we found tentative evidence that outnumbering may be an effective weight-of-evidence strategy after all, but only if the advocate successfully delivers a rebuttal. Thus, in the following experiment, we converted our initial rebuttal-as-moderator research question into the preregistered *rebuttal-as-moderator hypothesis*. Furthermore, we tested the efficacy of forewarning as a new weight-of-evidence strategy.

Table 1. Overview of outcome measures. Reliability of multiple-item scales is indicated by Cronbach's alpha; numbers behind alphas relate to the respective experiments. All outcome measures were converted into percentages of maximum possible scores of the original scales (POMP), with higher values indicating a more positive attitude, greater confidence in vaccination and stronger intention.

construct	incl.	scale type	wording	source
attitude towards vaccination	Exp. 1–3	mean score of 5-point rating scales (α1pre = .72; α1post = .85; α2pre = .81; α2post = .86; α3pre = .84; α3post = .88)	Please indicate how much you agree with the following statements. 1. Vaccinating against dysomeria is necessary. 2. Vaccinating against dysomeria is a good idea. 3. Vaccinating against dysomeria is beneficial. (1 = I strongly disagree, 5 = I strongly agree)	(Schmid & Betsch, 2019)
intention to get vaccinated	Exp. 1–3	visual analog scale	If you had the opportunity to get vaccinated against dysomeria, what would you do? (1 = I will definitely not get vaccinated, 100 = I will definitely get vaccinated)	(Schmid & Betsch, 2019)
confidence in vaccination	Exp. 2–3	mean score of 5-point rating scales (α2pre = .71; α2post = .83; α3pre = .77; α3post = .85)	Please indicate how much you agree with the following statements. 1. Vaccination against dysomeria is effective. 2. I am completely confident that the vaccine against dysomeria is safe. 3. Regarding the vaccine against dysomeria, I am confident that public authorities decide in the best interest of the community. (1 = I strongly disagree, 5 = I strongly agree)	(Betsch et al., 2018)

Table 2. Weight-of-evidence strategies' effects on changes in attitude. The results presented in Tables 2–4 are based on a 2 (rebuttal vs. advocate silent; between subjects) × 2 (outnumbering 5:1 vs. equal proportion of discussants 3:3; between subjects) × 2 (forewarning vs. no forewarning) × 2 (measurement before vs. after the debate; within subjects) repeated-measures ANOVA (Type II sum of squares) for Experiments 1–3. Significant effects are shown in boldface for the significance level of < 0.05.

Attitude	Experiment 1 n = 101			Experiment 2 n = 390			Experiment 3 n = 396		
Effects	F	p	η^2_p	F	p	η^2_p	F	p	η^2_p
Time	**99.16**	**<.001**	**.506**	**165.42**	**<.001**	**.302**	**132.11**	**<.001**	**.254**
Rebuttal × Time	**10.01**	**.002**	**.094**	**24.13**	**<.001**	**.059**	**50.91**	**<.001**	**.116**
Outnumbering × Time	0.11	.737	.001	0.27	.605	.001	2.10	.148	.005
Forewarning × Time	--	--	--	**7.52**	**.006**	**.019**	1.11	.293	.003
Rebuttal × Outnumbering × Time	**4.68**	**.033**	**.046**	0.02	.883	<.001	2.83	.093	.007
Rebuttal × Forewarning × Time	--	--	--	0.47	.495	.001	0.16	.687	<.001
Outnumbering × Forewarning × Time	--	--	--	1.40	.239	.004	0.02	.886	<.001
Rebuttal × Outnumbering × Forewarning × Time	--	--	--	0.54	.462	.001	3.37	.067	.009

Table 3. Weight-of-evidence strategies' effects on changes in intention. Significant effects are shown in boldface for the significance level of < 0.05.

Intention	Experiment 1 n = 101			Experiment 2 n = 390			Experiment 3 n = 396		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**43.98**	**<.001**	**.312**	**156.64**	**<.001**	**.291**	**92.10**	**<.001**	**.192**
Rebuttal × Time	3.65	.059	.036	**32.37**	**<.001**	**.078**	**57.58**	**<.001**	**.129**
Outnumbering × Time	0.19	.661	.002	0.15	.703	<.001	2.44	.119	.006
Forewarning × Time	--	--	--	**14.75**	**<.001**	**.037**	**6.92**	**.009**	**.018**
Rebuttal × Outnumbering × Time	3.36	.070	.033	0.03	.868	<.001	0.03	.865	<.001
Rebuttal × Forewarning × Time	--	--	--	<0.01	.948	<.001	0.60	.441	.002
Outnumbering × Forewarning × Time	--	--	--	0.03	.864	<.001	1.11	.293	.003
Rebuttal × Outnumbering × Forewarning × Time	--	--	--	0.07	.790	<.001	0.25	.615	.001

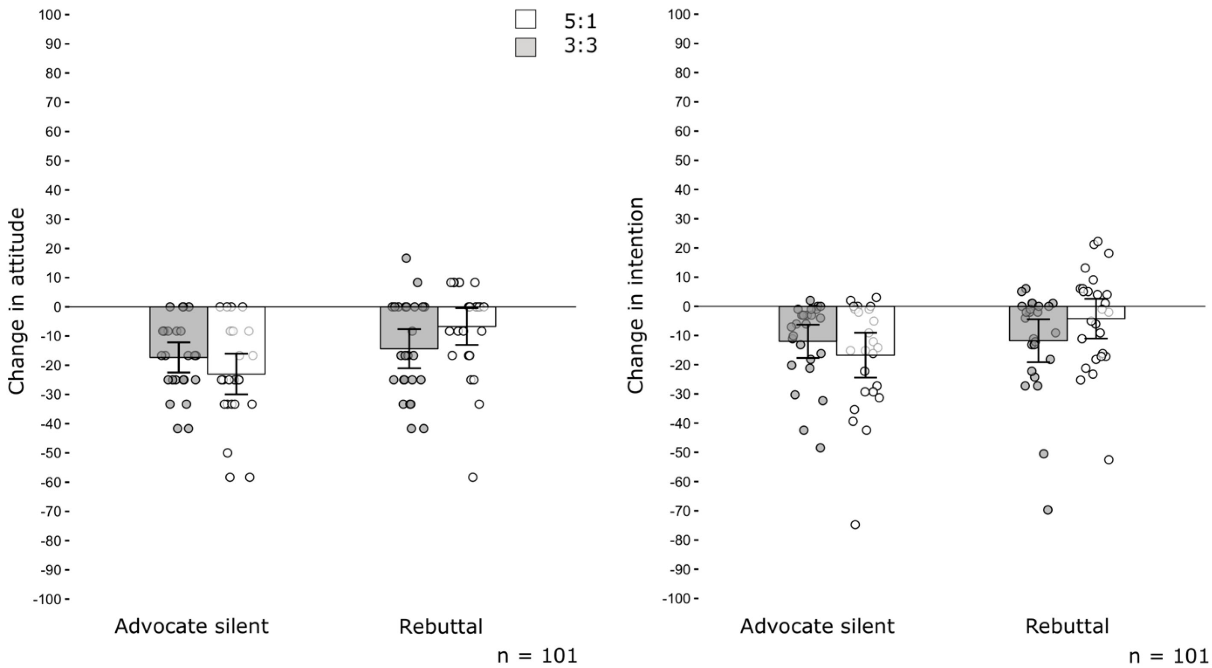


Figure 2: Effects from outnumbering on damage from science denialism in public discussions in Experiment 1. The results reveal that outnumbering mitigated the damage from denialism only if a rebuttal was delivered. The y-axes represent mean changes in attitude (left graph) and in intention (right graph) in POMP values. Descriptive data are provided in Supplementary Tables 2–4. The x-axes represent experimental conditions. Error bars represent 95% CIs. Dots indicate individual changes in individual participants' intentions.

Experiment 2

In this experiment, we tested the rebuttal-as-moderator hypothesis and the forewarning hypothesis. Thus, we expected that forewarning would decrease denialism messages' damage and that outnumbering is only effective when a rebuttal takes place and when no forewarning was implemented. The latter restriction of the rebuttal-as-moderator hypothesis was included because the forewarning was assumed to knock out any false-balance effect. In addition, we explored the rebuttal-as-moderator research question for forewarning and the involvement-as-moderator research question for both weight-of-evidence strategies. We preregistered the experiment on aspredicted.org: http://aspredicted.org/blind.php?x=ie3es8. However, the forewarning hypothesis was not preregistered.

Method

The experimental setup was almost identical to Experiment 1, with deviations described below.

Participants and design. A-priori power analyses using G*Power (Faul et al., 2009) revealed a minimum sample size of N = 368 to detect a minimum effect size of interest of d = 0.20, with a power of .80 in a repeated-measures ANOVA, including within-between interactions (eight groups, two measurements, α = .05). The effect size of the power analysis was chosen to detect conventionally small effect sizes (J. Cohen, 1977). Altogether, 390 undergraduate students at the University of Erfurt participated in this lab experiment. Subjects volunteered to participate during their university welcome week and did not receive any incentives. Each subject was assigned randomly to one of eight conditions, resulting from a 2 (rebuttal vs. advocate silent; between subjects) × 2 (outnumbering 5:1 vs. equal proportion of discussants 3:3; between subjects) × 2 (forewarning vs. no forewarning) × 2 (measurement before vs. after the debate; within subjects) mixed design. In contrast to Experiment 1, we did not preregister any exclusion criteria, but planned to stratify results based on individuals' attention.

Materials and procedure. The forewarning was implemented within the scenario. The participants were users of an online media centre that broadcasted the TV discussion. The control group read a neutral text about data protection for online users who access a media centre (Supplementary Method) while the experimental group read an explanatory text about false balance in media reports (Figure 1).

Measures. In addition to the measures in Experiment 1 (Table 1), participants indicated their confidence in the fictitious vaccination before and after the TV discussion. Confidence assesses one's beliefs in vaccination's safety and efficacy, as well as perceived trustworthiness of the institutions that deliver them (Betsch et al., 2018). Thus, it represents the audience's specific attitudinal beliefs towards the topics that science deniers target, that is, vaccination safety and trust in institutions. As an additional attention check, we asked participants in an open format about the number of advocates and deniers who were present during the discussion (Supplementary Table 1).

Results

Seventy-seven percent of the full sample was female, with a mean age of 19.96 (SD_{AGE} = 2.26) for all participants. All in all, 99.5% correctly answered the question about the debate's content, with 80% recalling the exact number of advocates and 82.3% recalling the exact number of deniers who were present at the debate. Thus, we repeated the primary analyses with a sample containing only those participants who recalled the correct information, with differences in the full sample reported below. No evidence of differences existed between conditions in prior attitudes, intention to get vaccinated or confidence (all ps ≥ .084 in 2 × 2 × 2 ANOVAs).

Tables 2–4 and Figure 3 present the results of the 2 × 2 × 2 × 2 repeated-measures ANOVA models for individuals' attitudes, confidence and intention. Replicating the results from Experiment 1, watching the public debate significantly damaged individuals' attitudes towards vaccination, including intention to get vaccinated and confidence in vaccination. However, the rebuttal mitigated this damage on all outcome measures, again indicating successful manipulation.

Contrary to the findings in Experiment 1 and contradicting the rebuttal-as-moderator hypothesis, no evidence existed that a higher proportion of advocates present in the debate mitigated deniers' influence on individuals' attitude towards vaccination $F(1, 382) = 0.27$, $p = .605$, $\eta^2_p = .001$, intention to get vaccinated $F(1, 382) = 0.15$, $p = .703$, $\eta^2_p < .001$ or confidence $F(1, 382) = 1.35$, $p = .246$, $\eta^2_p = .004$, not even when analysed as a function of whether or not a rebuttal was delivered (Tables 2–4). However, analyses revealed promising results on the forewarning hypothesis. A consistent mitigating effect was found when the audience was forewarned in writing about false balance prior to the discussion compared with the control condition on all outcome measures attitude: $F(1, 382) = 7.52$, $p = .006$, $\eta^2_p = .019$; intention: $F(1, 382) = 14.75$, $p < .001$, $\eta^2_p = .037$; confidence: $F(1, 382) = 10.44$, $p = .001$, $\eta^2_p = .027$.

Table 4. Weight-of-evidence strategies' effects on changes in confidence. Significant effects are shown in boldface for the significance level of < 0.05.

Confidence	Experiment 2 n = 390			Experiment 3 n = 396		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**96.20**	**<.001**	**.201**	**61.59**	**<.001**	**.137**
Rebuttal × Time	**46.15**	**<.001**	**.108**	**70.75**	**<.001**	**.154**
Outnumbering × Time	1.35	.246	.004	0.81	.369	.002
Forewarning × Time	**10.44**	**.001**	**.027**	**8.76**	**.003**	**.022**
Rebuttal × Outnumbering × Time	1.72	.190	.004	0.03	.853	<.001
Rebuttal × Forewarning × Time	2.27	.132	.006	0.04	.949	<.001
Outnumbering × Forewarning × Time	0.04	.849	<.001	1.14	.287	.003
Rebuttal × Outnumbering × Forewarning × Time	0.49	.485	.001	2.21	.138	.006

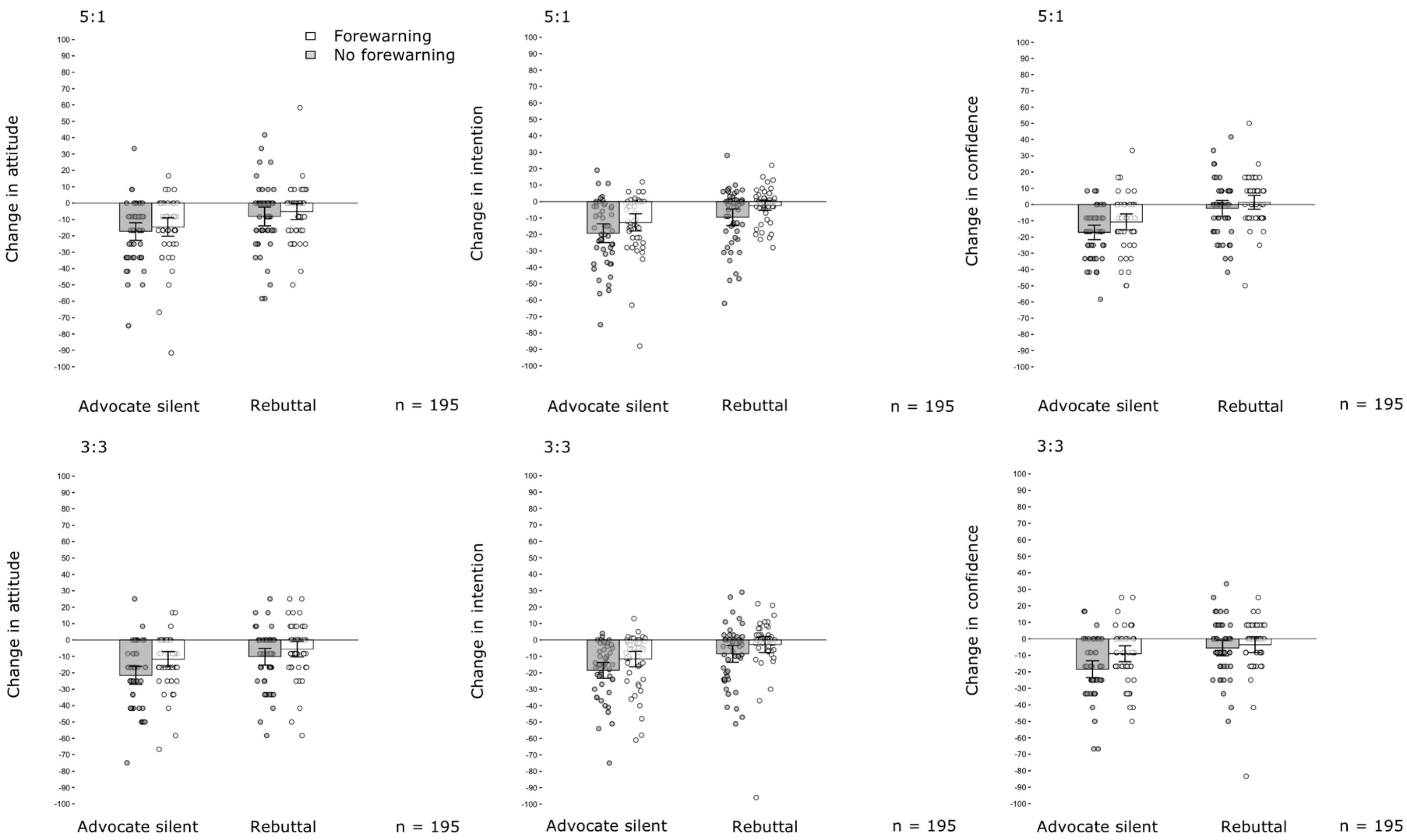


Figure 3: Effects from outnumbering and forewarning on damage from science denialism in public discussions in Experiment 2. The results reveal a significant mitigation in damage from denialism on all outcome measures when forewarning was used. The mitigating effect was not a function of whether the advocate uses a rebuttal or remains silent. Comparison of the lower (3:3) and upper (5:1) panels reveals no evidence that outnumbering mitigated the damage from denialism on any outcome measure. The y-axes represent mean changes in attitude (left graph), intention (centre graph) and confidence (right graph) in POMP values. Descriptive data are provided in Supplementary Tables 2–4. The x-axes represent experimental conditions. Error bars represent 95% CIs. Dots indicate individual changes in individual participants' outcome measures.

Confirmatory analyses were repeated with preregistered control variables (Supplementary Tables 5–6 and 8) and with a reduced sample containing only participants who recalled the encoded information correctly (Supplementary Table 9–11), obtaining the same patterns of results.

Further exploration of the ANOVA models revealed no evidence that forewarning's efficacy was a function of whether or not a rebuttal was delivered (Tables 2–4; Figure 3). We also found no evidence of a moderating effect from individuals' issue involvement on the efficacy of any of the two weight-of-evidence strategies (Supplementary Table 7).

Discussion

As in Experiment 1, we again found no evidence that outnumbering increases the audience's resistance to science denialism. Thus, in the third experiment, we aimed to increase outnumbering's persuasive power by adding another mechanism by which outnumbering potentially can work. Moreover, we aimed to replicate findings from Experiment 2 regarding the forewarning hypothesis.

Experiment 3

In the previous experiments, only one denier and one advocate spoke during the discussion, regardless of the relative number of guests present during the debate. Thus, outnumbering was expected to work as a social cue. In this experiment, we tested another possible mechanism: outnumbering by delivering multiple rebuttal sources. With this change, we aimed to test whether inviting a greater number of science advocates compared with deniers is an effective weight-of-evidence strategy when all participants take part in the conversation. This additional effect can be expected only when the advocates do not remain silent. Thus, we preregistered the rebuttal-as-moderator hypothesis. Moreover, we preregistered the forewarning hypothesis, explored the rebuttal-as-moderator research question for forewarning and explored the involvement-as-moderator research question for both weight-of-evidence strategies. We preregistered the experiment on aspredicted.org: http://aspredicted.org/blind.php?x=wk8nc8.

Method

The experimental setup was identical to Experiments 1 and 2, with deviations reported below.

Participants and design. A-priori power analyses using G*Power (Faul et al., 2009) revealed a minimum sample size of N = 368 to detect a minimum effect size of interest of *d* =

0.20 with a power of .80 in a repeated-measures ANOVA, including within-between interactions (eight groups, two measurements, α = .05). The effect size of the power analysis was chosen to detect conventionally small effect sizes (J. Cohen, 1977). Altogether, 369 undergraduate students from the University of Erfurt and RWTH Aachen University participated in this lab experiment in exchange for credit points (€4 or €5, depending on the laboratories' different payment policies). Due to a technical error, 13 students could not enter demographic data. The study design was identical to that of Experiment 2. Again, we did not preregister any exclusion criteria, but stratified results based on individuals' attention.

Materials and procedure. The number of advocates and deniers was equal to the number of speakers (Figure 1), that is, they served as multiple sources rather than a mere social cue. The arguments used in Experiments 1 and 2 were divided among all speakers. Thus, the total number of arguments remained constant across experiments. The forewarning used in this experiment was identical to the forewarning used in Experiment 2.

Measures. All measures were identical to Experiment 2 (Table 1).

Results

Sixty-seven percent of the sample was female, with a mean age of 22.96 years (SD_{AGE} = 4.72) for all participants. In the end, 99.5% of the sample passed the content question, 82.3% correctly recalled the number of advocates and 85.1% correctly recalled the number of deniers who were present at the debate. Thus, we again repeated the primary analyses with a reduced sample and reported differences to the full sample. No evidence existed of differences between conditions in prior intentions to get vaccinated or prior confidence in vaccination, all ps ≥ .160 in 2 × 2 × 2 ANOVA. However, a difference did exist between conditions in individuals' prior attitudes towards vaccination, as revealed through a significant three-way interaction $F(7, 388) = 4.08$, $p = .044$, $\eta^2_p = .010$, in the 2 × 2 × 2 ANOVA (all other ps ≥ .198). Details of the interaction effect are reported in Supplementary Figure 1. To increase the findings' robustness, the primary analysis of individuals' attitudes was repeated using postvalues at T2, controlled for values at T1, rather than difference scores. Differences are reported below.

Tables 2–4 and Figure 4 present the 2 × 2 × 2 × 2 repeated-measures ANOVA models for individuals' attitudes, confidence and intention. Again, attitudes, intention and confidence were damaged after watching the public discussion and the rebuttal mitigated this damage, confirming a successful manipulation.

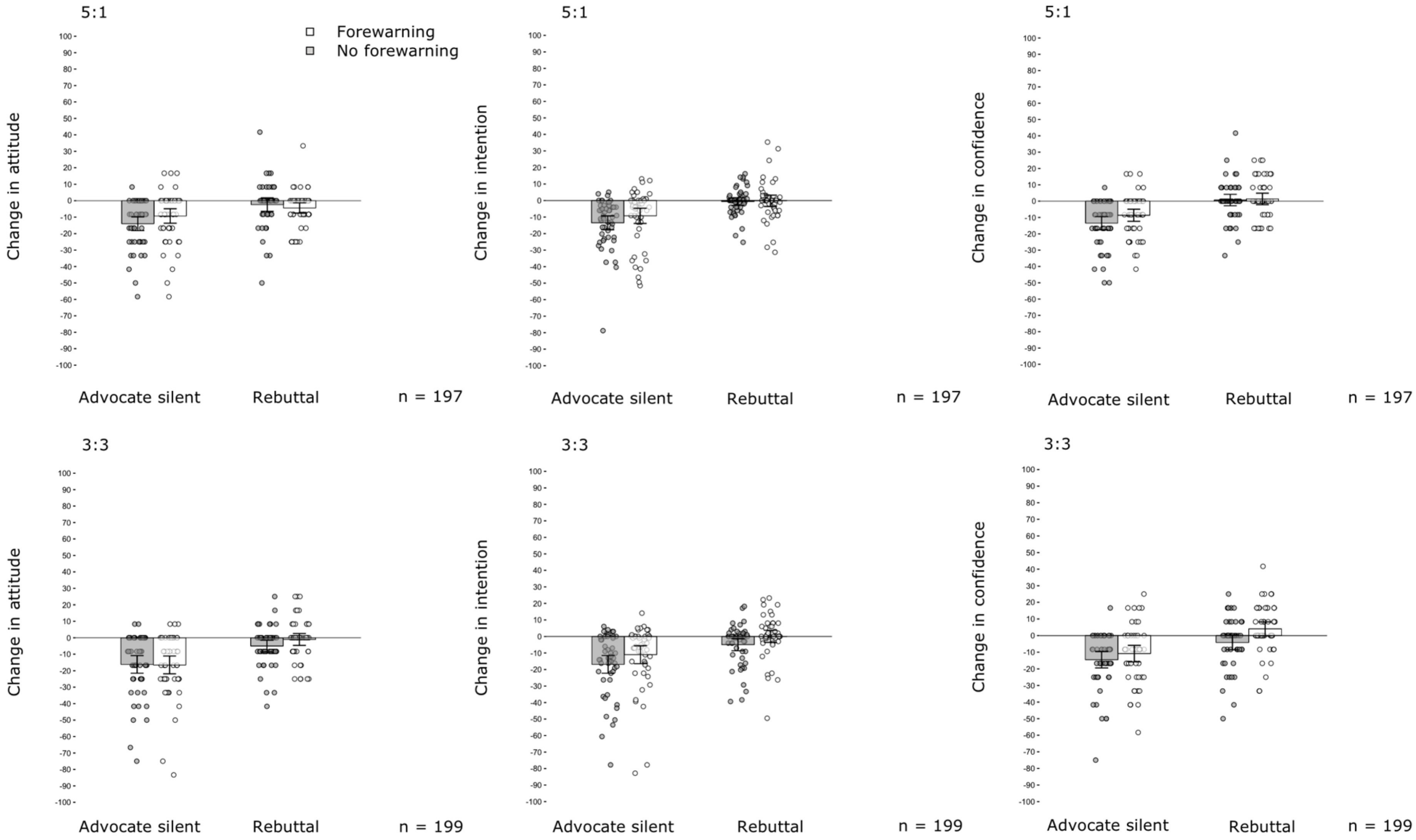


Figure 4: Effects from outnumbering and forewarning on damage from science denialism in public discussions in Experiment 3. Results reveal a significant mitigation of damage from denialism in individuals' intention to get vaccinated and confidence in vaccination when forewarning was used. The mitigating effect was not a function of whether the advocate uses a rebuttal or remains silent. Comparison of the lower (3:3) and upper (5:1) panels reveals no evidence that outnumbering mitigated the damage from denialism on any outcome measure. The y-axes represent mean changes in attitude (left graph), intention (centre graph) and confidence (right graph) in POMP values. Descriptive data are provided in Supplementary Tables 2–4. The x-axes represent experimental conditions. Error bars represent 95% CIs. Dots indicate individual changes in individual participants' outcome measures.

Even with all advocates speaking, we again found no evidence for the outnumbering hypothesis, nor for the rebuttal-as-moderator hypothesis: A higher proportion of advocates did not mitigate the denier's influence on individuals' attitudes towards vaccination, $F(1, 388) = 2.10$, $p = .148$, $\eta^2_p = .005$, intention to get vaccinated, $F(1, 388) = 2.44$, $p = .119$, $\eta^2_p = .006$, or confidence $F(1, 388) = 0.81$, $p = .369$, $\eta^2_p = .002$, not even when analysed as a function of rebuttal (Table 2–4). Again, we found confirming evidence for the forewarning hypothesis, as damage from denialism was reduced in the audience that was forewarned about false balance compared with the control group, intention: $F(1, 388) = 6.92$, $p = .009$, $\eta^2_p = .018$; confidence: $F(1, 388) = 8.76$, $p = .003$, $\eta^2_p = .022$. This trend also was observed with individuals' attitudes, but the benefit from using forewarning remained insignificant for this outcome, $F(1, 388) = 1.11$, $p = .293$, $\eta^2_p = .003$.

Confirmatory analyses were repeated with preregistered control variables (Supplementary Tables 5, 6 and 8) and a sample adjusted for failing attention (Supplementary Tables 9–11). In addition, and due to differences in initial attitude values between conditions, we repeated the ANOVA for individuals' attitudes using the attitude at T2 as a dependent variable controlling for attitude at T1, rather than difference scores (Supplementary Table 12). The patterns of results did not differ.

We found no evidence that forewarning's efficacy was a function of whether a rebuttal was delivered (Tables 2–4) or a function of individuals' issue involvement (Supplementary Table 7). We found individuals' issue involvement to be a significant moderator of the efficacy of outnumbering on individuals' attitudes towards vaccination. Less issue involvement led to greater damage from deniers when science advocates outnumbered deniers, while this damaging trend was reversed in the falsely balanced discussion (Supplementary Figure 2). This finding is difficult to interpret. In addition, we found no evidence of a moderation effect on individuals' confidence in vaccination or intention to get vaccinated (Supplementary Table 7).

In the preregistration, we also planned to analyse whether the effects from forewarning and rebuttal were mediated by the denier's perceived expertise. However, we accidentally did not ensure causal ordering because perceived expertise was measured after the dependent variables. We thus refrain from conducting this analysis.

Discussion

Again, the forewarning mitigated the damage from vaccine denialism messages on the audience's specific attitudinal beliefs, that is, vaccination safety and trust in institutions.

Moreover, it mitigated the damage to the audience's intention to vaccinate. Thus, forewarnings proved to be a helpful weight-of-evidence strategy against misinformation. As a limitation, and contrary to Experiment 2, we found no significant mitigating effect from forewarnings on the damage to the audience's general attitudes towards vaccination. Despite our efforts to increase the persuasive strength of inviting more advocates via the multiple-source mechanism, we again found no evidence that outnumbering mitigates science denialism damage from public discussions.

General Discussion

The results from these three experiments provide some new insights into how editors and journalists can support the evidence-based voice of science when they invite science advocates and deniers to a public discussion. The results also showed that it is necessary to use such measures consciously, as in all three experiments, the science denier damaged study participants' vaccination-related attitudes and intention, and reduced their confidence in vaccines' safety and efficacy. While the damage can be mitigated through clever rebuttals from the advocate (replicating Schmid & Betsch, 2019), it cannot always be guaranteed that rebuttals will be delivered successfully or at all (WHO, 2016).

In the light of the present findings, we expect that forewarnings about the false-balance effect should help reduce damage when screened prior to a falsely balanced discussion. The results from the present experiments reveal that such forewarnings are an effective weight-of-evidence strategy that can mitigate science denialism's influence, independent of whether a rebuttal is delivered and independent of audience characteristics. The results are consistent with an increasing body of evidence showing that using prior information as a prebunking is an effective strategy against damage from misinformation (Cook et al., 2017; Roozenbeek & van der Linden, 2019). The forewarning used here simply explained false balance and mentioned the possibility of being exposed to it in the subsequent public discussion. However, it did not specifically mention whether false balance was actually an issue in the subsequent discussion. Thus, it was up to the audience to identify whether the warning was applicable. This additional uncertainty might explain the rather small effect size of this weight-of-evidence strategy compared with previous findings on forewarnings' impact (Quinn & Wood, 2003). On the positive side, it also means that even rather generic forewarning is helpful in protecting audiences against misinformation. Furthermore, such generic forewarning offers a specific economic advantage. It can be used for multiple shows, for example, on an online media platform, and does not need to be revised for every single public discussion that is broadcast. Therefore, future studies should test the forewarning effect's duration and how specific or generic the warning may be in order to be effective.

In contrast to forewarnings' efficacy as a weight-of-evidence strategy, we find no evidence that inviting more science advocates than deniers mitigates science denialism messages' influence. The strategy of outnumbering science deniers had no success whatsoever, neither when silent advocates further served as a social cue representing the majority (Experiment 1–3), nor when lots of advocates served as multiple information sources (Experiment 3). Thus, the outnumbering strategy remained ineffective in the present experiments, even in audiences that, following dual-process theories, are likely to be persuaded by such peripheral cues.

The unexpected inefficacy of this weight-of-evidence strategy may be a result of the numeric relation between the majority and minority. Studies show that individuals are persuaded by a consensus when majorities become overwhelming (Lewandowsky et al., 2012). The numeric relation used in the present study (5:1) might fail to communicate such an overwhelming majority. However, Yousif, Aboody and Keil (2019) found that an even lower 4:1 distribution of positive vs. negative statements significantly influenced confidence in the majority's position compared with a 1:1 distribution of statements. Thus, the stimulus material used in this study seems adequate for detecting an effect from the distribution of speakers if such an effect exists in the context of public discussions.

Another potential concern with the materials used in this study is the dependence on multiple sources. One of the very first studies about the multiple-source effect by Harkins and Petty (1987) found that the advantage of having multiple sources is a function of the sources' independence, that is, multiple sources that can be attributed to the same origin are not more persuasive than a single source, while independent sources lead to the majority's expected persuasive advantage (Harkins & Petty, 1987). In the present study, science advocates were described as employees of the same agency, so they may have lost their persuasive advantage due to their shared employer. However, Yousif, Aboody and Keil (2019) found that information shared by multiple sources was more persuasive than information from a single source, even when statements from multiple sources depended on the same primary source. Thus, in light of current findings, we have no evidence to believe that a mere weighted distribution of speakers in a public discussion could mitigate science denialism's influence.

Limitations

One potential limitation of the study is that the studied populations were all undergraduate students, though this may be negligible concerning the presented results on science deniers' influence and rebuttal messages' efficacy because previous online experiments with heterogenous samples in Germany and in the U.S. report similar patterns of results (Schmid & Betsch, 2019). However, the outlined weight-of-evidence strategies in this study have not been tested before, so the findings may vary with different audiences. For example, forewarning about the false-balance effect might be less effective among less-educated audiences compared with generally highly educated undergraduates. Future studies will address this question. A second limitation is the presented scenario's fictitious nature. The choice to use these fictitious scenarios in studies about vaccination decisions in this and previous publications (Schmid & Betsch, 2019) primarily is based on ethical considerations. However, this choice may reduce the presented findings' external validity.

Conclusion

Given the present results, editors, journalists and other mass media outlets should invest some effort in providing forewarnings as an effective weight-of-evidence strategy. As no evidence was found that forewarning's efficacy depended on advocates' delivery of specific rebuttals in the discussion or the audience's issue involvement, we suggest that warning audiences about false-balance reporting prior to debates can serve as quite a generic, theory-driven, economic and effective weight-of-evidence strategy to support advocates for science in public discussions about scientific topics.

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Data Accessibility Statement. The materials, data and syntax supporting the findings of this study are archived in the Open Science Framework's public database and are available to anyone: https://osf.io/sefqu/?view_only=51f3d7d44a3e42b683ef9021a7f51fd9 *[A DOI referring to the data and material will be provided upon publication]*.

Conflict of interest statement. The studies included human subjects and were conducted in accordance with German Psychological Association guidelines. All participants provided written informed consent to use and share their data for scientific purposes without disclosure of their identities. The experiment was conducted at a German university, where institutional review boards or committees are not mandatory. The research is negligible-risk research, with no foreseeable risk of harm or discomfort other than potential inconvenience expected during participation. All participants were free to quit the study at any time without any consequences.

References

Albarracín, D., & Handley, I. M. (2011). The time for doing is not the time for change: Effects of general action and inaction goals on attitude retrieval and attitude change. *Journal of Personality and Social Psychology*, *100*(6), 983–998. https://doi.org/10.1037/a0023245

Betsch, C., Schmid, P., Heinemeier, D., Korn, L., Holtmann, C., & Böhm, R. (2018). Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. *PLoS ONE*, *13*(12). https://doi.org/10.1371/journal.pone.0208601

Bond, R., & Smith, P. B. (1996). Culture and conformity: A meta-analysis of studies using asch's (1952b, 1956) line judgment task. *Psychological Bulletin*, *119*(1), 111–137. https://doi.org/10.1037/0033-2909.119.1.111

Boudana, S. (2016). Impartiality is not fair: Toward an alternative approach to the evaluation of content bias in news stories. *Journalism*, *17*(5), 600–618. https://doi.org/10.1177/1464884915571295

Brüggemann, M., & Engesser, S. (2017). Beyond false balance: How interpretive journalism shapes media coverage of climate change. *Global Environmental Change*, *42*, 58–67. https://doi.org/10.1016/j.gloenvcha.2016.11.004

Cialdini, R. B., & Goldstein, N. J. (2004). Social Influence: Compliance and Conformity. *Annual Review of Psychology*, *55*(1), 591–621. https://doi.org/10.1146/annurev.psych.55.090902.142015

Clarke, C. E. (2008). A question of balance: The autism-vaccine controversy in the British and American elite press. *Science Communication*, *30*(1), 77–107. https://doi.org/10.1177/1075547008320262

Clarke, C. E., Dixon, G. N., Holton, A., & McKeever, B. W. (2015). Including "Evidentiary Balance" in News Media Coverage of Vaccine Risk. *Health Communication*, *30*(5), 461–472. https://doi.org/10.1080/10410236.2013.867006

Clarke, C. E., McKeever, B. W., Holton, A., & Dixon, G. N. (2015). The Influence of Weight-of-Evidence Messages on (Vaccine) Attitudes: A Sequential Mediation Model. *Journal of Health Communication*, *20*(11), 1302–1309. https://doi.org/10.1080/10810730.2015.1023959

Cohen, J. (1977). *Statistical Power Analysis for the Behavioral Sciences*. *Academic Press*. Academic Press. https://doi.org/10.2307/2529115

Cohen, P., Cohen, J., Aiken, L. S., & West, S. G. (1999). The problem of units and the circumstance for POMP. *Multivariate Behavioral Research*, *34*(3), 315–346. https://doi.org/10.1207/S15327906MBR3403_2

Cook, J., Lewandowsky, S., & Ecker, U. K. H. (2017). Neutralizing misinformation through inoculation: Exposing misleading argumentation techniques reduces their influence. *PLoS ONE*, *12*(5), e0175799. https://doi.org/10.1371/journal.pone.0175799

Cook, J., Oreskes, N., Doran, P. T., Anderegg, W. R. L., Verheggen, B., Maibach, E. W., … Rice, K. (2016). Consensus on consensus: A synthesis of consensus estimates on human-caused global warming. *Environmental Research Letters*, *11*(4), 048002. https://doi.org/10.1088/1748-9326/11/4/048002

Corbett, J. B., & Durfee, J. L. (2004). Testing public (Un)certainty of science: Media representations of global warming. *Science Communication*, *26*(2), 129–151. https://doi.org/10.1177/1075547004270234

Dearing, J. W. (1995). Newspaper coverage of maverick science: Creating controversy through balancing. *Public Understanding of Science*, *4*(4), 341–361. https://doi.org/10.1088/0963-6625/4/4/002

Diethelm, P., & McKee, M. (2009, October 16). Denialism: What is it and how should scientists respond? *European Journal of Public Health*. Oxford University Press. https://doi.org/10.1093/eurpub/ckn139

Dixon, G. N., & Clarke, C. E. (2013). The effect of falsely balanced reporting of the autism-vaccine controversy on vaccine safety perceptions and behavioral intentions. *Health Education Research*, *28*(2), 352–359. Retrieved from https://academic.oup.com/her/article-abstract/28/2/352/595490

Dunwoody, S. (2005). Weight-of-Evidence Reporting: What Is It? Why Use It? *Nieman Reports*, *59*(4), 89–91. Retrieved from https://niemanreports.org/articles/weight-of-evidence-reporting-what-is-it-why-use-it/

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses. *Behavior Research Methods*, *41*(4), 1149–1160. https://doi.org/10.3758/BRM.41.4.1149

Hansson, S. O. (2017). Science denial as a form of pseudoscience. *Studies in History and Philosophy of Science Part A*, *63*, 39–47. https://doi.org/10.1016/j.shpsa.2017.05.002

Harkins, S. G., & Petty, R. E. (1987). Information utility and the multiple source effect. *Journal of Personality and Social Psychology*. Retrieved from https://psycnet.apa.org/record/1987-15547-001

Hornsey, M. J., & Fielding, K. S. (2017). Attitude roots and jiu jitsu persuasion: Understanding and overcoming the motivated rejection of science. *American Psychologist*, *72*(5), 459–473. https://doi.org/10.1037/a0040437

Koehler, D. (2016). Can Journalistic “False Balance” Distort Public Perception of Consensus in Expert Opinion? *Journal of Experimental Psychology. Applied*, *22*(1), 24–38. Retrieved from https://psycnet.apa.org/record/2016-00600-001

Kohl, P. A., Kim, S. Y., Peng, Y., Akin, H., Koh, E. J., Howell, A., & Dunwoody, S. (2016). The influence of weight-of-evidence strategies on audience perceptions of (un)certainty when media cover contested science. *Public Understanding of Science*, *25*(8), 976–991. https://doi.org/10.1177/0963662515615087

Kruglanski, A. W., & Thompson, E. P. (1999). Persuasion by a single route: A view from the unimodel. *Psychological Inquiry*, *10*(2), 83–109. https://doi.org/10.1207/S15327965PL100201

Lewandowsky, S., Gignac, G. E., & Vaughan, S. (2012). The pivotal role of perceived scientific consensus in acceptance of science. *Nature Climate Change*, *3*(4), 399–404. https://doi.org/10.1038/nclimate1720

Lewandowsky, S., & Oberauer, K. (2016). Motivated Rejection of Science. *Current Directions in Psychological Science*, *25*(4), 217–222. https://doi.org/10.1177/0963721416654436

Livingstone, S. M., & Lunt, P. K. (Peter K. (1994). *Talk on television : audience participation and public debate* (1st ed.). London: Routledge. https://doi.org/10.4324/9780203131916

McDonald, R. I., & Crandall, C. S. (2015). ScienceDirectSocial norms and social influence. *Current Opinion in Behavioral Sciences*, *3*, 1–5. Retrieved from https://www.sciencedirect.com/science/article/pii/S2352154615000558

McGuire, W. J. (1961a). Resistance to persuasion conferred by active and passive prior refutation of the same and alternative counterarguments. *Journal of Abnormal and Social Psychology*, *63*(2), 326–332. https://doi.org/10.1037/h0048344

McGuire, W. J. (1961b). The Effectiveness of Supportive and Refutational Defenses in Immunizing and Restoring Beliefs Against Persuasion. *Sociometry*, *24*(2), 184. https://doi.org/10.2307/2786067

McGuire, W. J., & Papageorgis, D. (1962). Effectiveness of Forewarning in Developing Resistance to Persuasion. *Public Opinion Quarterly*, *26*(1), 24. https://doi.org/10.1086/267068

Mooney, B. C., & Nisbet, M. C. (2005). Undoing Darwin. *Columbia Journalism Review*, *44*(3), 30–39. Retrieved from http://www.academia.edu/download/30499477/cjr_september_october_2005_-_undoing_darwin.pdf

Petersen, A. M., Vincent, E. M., & Westerling, A. L. (2019). Discrepancy in scientific authority and media visibility of climate change scientists and contrarians. *Nature Communications*, *10*(1), 3502. https://doi.org/10.1038/s41467-019-09959-4

Petty, R. E., & Cacioppo, J. T. (1986). The Elaboration Likelihood Model of Persuasion. In *Communication and Persuasion* (pp. 1–24). New York, NY: Springer New York. https://doi.org/10.1007/978-1-4612-4964-1_1

Petty, R. E., Harkins, S. G., & Williams, K. D. (1980). The effects of group diffusion of cognitive effort on attitudes: An information-processing view. *Journal of Personality and Social Psychology*. Retrieved from https://psycnet.apa.org/record/1981-32766-001

Pew Research Center. (2009). *Scientific Achievements Less Prominent Than a Decade Ago: Public Praises Science; Scientists Fault Public, Media*. Retrieved from https://www.people-press.org/2009/07/09/section-5-evolution-climate-change-and-other-issues/

Pew Research Center. (2015). *Public and Scientists' Views on Science and Society*. Retrieved from https://www.pewresearch.org/science/2015/01/29/public-and-scientists-views-on-science-and-society/

Quinn, J. M., & Wood, W. (2003). Forewarned and forearmed? Two meta-analysis syntheses of forewarnings of influence appeals. *Psychological Bulletin*, *129*(1), 119–138. https://doi.org/10.1037/0033-2909.129.1.119

Roozenbeek, J., & van der Linden, S. (2019). Fake news game confers psychological resistance against online misinformation. *Palgrave Communications*, *5(1)*(12). Retrieved from https://www.nature.com/articles/s41599-019-0279-9

Rubin, A. M., & Step, M. M. (1997). Viewing television talk shows. *International Journal of Phytoremediation*, *14*(1), 106–115. https://doi.org/10.1080/08824099709388651

Schmid, P., & Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nature Human Behaviour*. https://doi.org/10.17605/OSF.IO/XX2KT

Schmid, P., Schwarzer, M., & Betsch, C. (2019). Material and Data: Weight-of-Evidence Strategies to Counter Science Denialism in Public Discussions. [A DOI referring to the data and material will be provided upon publication]. *Open Science Framework*. Retrieved from https://osf.io/sefqu/?view_only=51f3d7d44a3e42b683ef9021a7f51fd9

Schudson, M. (2001). The objectivity norm in American journalism. *Journalism*, *2*(2), 149–170. https://doi.org/10.1177/146488490100200201

van der Linden, S., Clarke, C. E., & Maibach, E. W. (2015). Highlighting consensus among medical scientists increases public support for vaccines: evidence from a randomized experiment. *BMC Public Health*, *15*(1), 1207. https://doi.org/10.1186/s12889-015-2541-4

Wood, W. (2000). Attitude Change: Persuasion and Social Influence. *Annual Review of Psychology*, *51*(1), 539–570. https://doi.org/10.1146/annurev.psych.51.1.539

World Health Organization. (2016). *Best practice guidance: How to respond to vocal vaccine deniers in public*. Copenhagen: World Health Organization,. Retrieved from http://www.euro.who.int/de/health-topics/disease-prevention/vaccines-and-immunization/publications/2016/best-practice-guidance-how-to-respond-to-vocal-vaccine-deniers-in-public-2016

Supplementary Information

Article 3

Weight-of-Evidence Strategies to Counter Science Denialism in Public Discussions

Supplementary Results. Descriptive data for participants

Experiment 1

Participants in Experiment 1 indicated a positive attitude towards vaccination against the fictional disease dysomeria ($M_{prior\_attitude} = 77.48$, $SD_{prior\_attitude} = 18.35$) and a rather high willingness to get vaccinated ($M_{prior\_intention} = 72.60$, $SD_{prior\_intention} = 24.12$) before watching the public discussion. On average, they reached 49.6% ($M_{knowledge} = 49.62$, $SD_{knowledge} = 24.52$) of the maximum possible knowledge score. Participants assigned low relevance to TV as an information source on vaccination ($M_{relevance\_TV} = 11.05$, $SD_{relevance\_TV} = 10.70$) and reported rather low involvement in vaccination in general ($M_{involvement} = 36.37$, $SD_{involvement} = 17.12$).

Experiment 2

Similar to Experiment 1, participants indicated a positive attitude towards vaccination against dysomeria ($M_{prior\_attitude} = 70.98$, $SD_{prior\_attitude} = 20.96$), a rather high willingness to get vaccinated ($M_{prior\_intention} = 68.34$, $SD_{prior\_intention} = 23.71$) and moderate confidence in vaccination against dysomeria ($M_{prior\_confidence} = 58.35$, $SD_{prior\_confidence} = 19.60$) before watching the public discussion. On average, they reached 45.6% ($M_{knowledge} = 45.64$, $SD_{knowledge} = 23.55$) of the maximum possible knowledge score. Participants assigned low relevance to TV as an information source on vaccination ($M_{relevance\_TV} = 9.73$, $SD_{relevance\_TV} = 9.88$) and reported rather low involvement in vaccination in general ($M_{involvement} = 36.37$, $SD_{involvement} = 17.12$).

Experiment 3

Similar to the previous experiments, participants indicated a positive attitude towards vaccination against dysomeria ($M_{prior\_attitude} = 70.98$, $SD_{prior\_attitude} = 20.96$), a high willingness to get vaccinated ($M_{prior\_intention} = 68.34$, $SD_{prior\_intention} = 23.71$) and rather high confidence in vaccination against dysomeria ($M_{prior\_confidence} = 70.98$, $SD_{prior\_confidence} = 20.96$) before watching the public discussion. On average, they reached 55.1% ($M_{knowledge} = 55.10$, $SD_{knowledge} = 24.37$) of the maximum possible knowledge score. Again, participants assigned low relevance to TV as an information source on vaccination ($M_{relevance\_TV} = 11.01$, $SD_{relevance\_TV} = 10.65$) and reported rather low involvement in vaccination in general ($M_{involvement} = 32.70$, $SD_{involvement} = 15.53$).

Supplementary Material 1. Messages delivered by deniers and advocates for all conditions and experiments. Note: original materials were in German.

Experiments 1 and 2

Rebuttal: Advocate silent
Outnumbering: 5:1

1. Video

Florian Hantzsch (Interviewer): 'Welcome, ladies and gentlemen. Today, we are talking about the vaccine against the viral disease dysomeria. I am delighted to welcome my six guests: Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics and Mrs. Natalia Holderman, Mr. Domenik Rehde, Mr. Martin Schober, Mr. Peter Witting and Mr. Jürgen Schmidt from the Health Office in Neustadt.
I would like to start right away with my first question:
Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics, how safe is the vaccine against dysomeria?'

Stefan Müller (Science Denier 1): 'The lack of safety is an important issue with the dysomeria vaccine. The side effects and risks of the vaccine are incalculable. As a patient, you do not know how the body reacts to the vaccine before administration. Even if you feel healthy immediately after the shot, harmful substances may have entered your body. Doctors cannot guarantee in advance that there will not be any complications. In my opinion, you cannot expect any fellow citizens to vaccinate as long as the vaccine is not 100% safe. Surely, it is not too much to ask that a product injected into a healthy human body be 100% safe.'

2. Video

Florian Hantzsch (Interviewer): 'Vaccines protect against diseases; however, pharmaceutical companies also make money from producing vaccines. A question arises: Who actually benefits from vaccination, Mr. Müller?'

Stefan Müller (Science Denier 1): 'At the end of the day, it is not about the health of the individual citizen. It is about the financial interests of large companies and government institutions. The pharmaceutical industry earns a huge annual profit from the sale of the vaccine against dysomeria. The government can multiply the profit tremendously with official vaccination recommendations. If we put two and two together, then anyone can see this perfidious collaboration between the responsible parties. In the end, all those who have something to say in this system are connected in a way, and only the ordinary citizen is left out – and is expected to do one thing: Stay silent and keep on vaccinating.'

Rebuttal: Advocate silent
Outnumbering: 3:3

1. Video

Florian Hantzsch (Interviewer): 'Welcome, ladies and gentlemen. Today, we are talking about the vaccine against the viral disease dysomeria. I am delighted to welcome my six guests: Mr. Domenik Rehde, Mrs. Natalia Holderman and Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics and also Mr. Martin Schober, Mr. Peter Witting and Mr. Jürgen Schmidt from the Health Office in Neustadt. I would like to start right away with my first question:
Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics, how safe is the vaccine against dysomeria?'

Stefan Müller (Science Denier 1): 'The lack of safety is an important issue with the dysomeria vaccine. The side effects and risks from the vaccine are incalculable. As a patient, you do not know how the body reacts to the vaccine before administration. Even if you feel healthy immediately after the shot, harmful substances may have entered your body. Doctors cannot guarantee in advance that there will not be any complications. In my opinion, you cannot expect any fellow citizens to vaccinate as long as the vaccine is not 100% safe. Surely, it is not too much to ask that a product injected into a healthy human body be 100% safe.'

2. Video

Florian Hantzsch (Interviewer): 'Vaccines protect against diseases; however, pharmaceutical companies also make money from producing vaccines. A question arises: Who actually benefits from vaccination, Mr. Müller?'

Stefan Müller (Science Denier 1): 'At the end of the day, it is not about the health of the individual citizen. It is about the financial interests of large companies and government institutions. The pharmaceutical industry earns a huge annual profit with the sale of the vaccine against dysomeria. The government can multiply the profit tremendously with official vaccination recommendations. If we put two and two together, then anyone can see this perfidious collaboration between the responsible parties. In the end, all those who have something to say in this system are connected in a way, and only the ordinary citizen is left out – and is expected to do one thing: Stay silent and keep on vaccinating.'

Rebuttal: Yes
Outnumbering: 5:1

1. Video

Florian Hantzsch (Interviewer): 'Welcome, ladies and gentlemen. Today, we are talking about the vaccine against the viral disease dysomeria. I am delighted to welcome my six guests: Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics and also Mrs. Natalia Holderman, Mr. Domenik Rehde, Mr. Martin Schober, Mr. Peter Witting and Mr. Jürgen Schmidt from the Health Office in Neustadt. I would like to start right away with my first question:
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Florian Hantzsch (Interviewer): 'Thank you, Mr. Müller. Mr. Jürgen Schmidt from the Health Office in Neustadt, how do you respond to that?'

Jürgen Schmidt (Science Advocate 1): 'Mr. Müller demands 100% safety from the vaccine against dysomeria. In science, this argument is called *impossible expectation*. It is an impossible expectation because science can never guarantee 100% safety for any medical product, neither for aspirin nor for heart surgery. Any treatment poses a residual risk of complications for patients either during or after treatment. The scientific evidence is clear: The vaccine against dysomeria is a safe way to avoid the disease. The risk of dysomeria by far exceeds the risk from vaccination. This is why we, the Health Office in Neustadt, recommend the vaccination against the DS virus for citizens of all ages. And please let me add the following regarding the safety of the vaccine: We follow a very strict protocol to ensure the high quality of vaccines in the Federal States. This also is demonstrated by the fact that every batch of the vaccine against dysomeria constantly is monitored and independently screened by official control laboratories.'

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Florian Hantzsch (Interviewer): 'Thank you, Mr. Müller. Mr. Jürgen Schmidt from the Health Office in Neustadt, how do you respond to that?'

Jürgen Schmidt (Science Advocate 1): 'Mr. Müller suspects a secret conspiracy behind the distribution of the vaccine against dysomeria. This perspective completely ignores that a large proportion of the research that demonstrates the benefits of vaccination for society and each individual is conducted by independent scientists all over the world. In addition, such conspiratorial claims discredit the prosocial motives of all our healthcare system's employees. Let's stay with the facts: In regions where the vaccine against dysomeria is used, people live a healthier life. This has been demonstrated several times. The major goal of governmental health institutions like our office is to maintain and improve the health of every single citizen in the country. I very much regret that Mr. Müller has lost trust in our institution and our effort. The Standing Committee on Vaccination, STIKO, which is responsible for vaccination recommendations in the Federal States, is composed of independent experts who are appointed for a period of three years. The members are an independent advisory group, and the meetings and protocols of the STIKO, as well as possible conflicts of interest among members, are open to the public and available via webcast. Whatever Mr. Müller is suggesting here, the fact is: The vaccine improves the health standard of all individuals, and that is why we recommend it for citizens of all ages.'

Rebuttal: Yes
Outnumbering: 3:3

1. Video

Florian Hantzsch (Interviewer): 'Welcome, ladies and gentlemen. Today, we are talking about the vaccine against the viral disease dysomeria.
I am delighted to welcome my six guests: Mr. Domenik Rehde, Mrs. Natalia Holderman and Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics and also Mr. Martin Schober, Mr. Peter Witting and Mr. Jürgen Schmidt from the Health Office in Neustadt.
I would like to start right away with my first question:
Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics, how safe is the vaccine against dysomeria?'

Stefan Müller (Science Denier 1): 'The lack of safety is an important issue with the dysomeria vaccine. The side effects and risks of the vaccine are incalculable. As a patient, you do not know how the body reacts to the vaccine before administration. Even if you feel healthy immediately after the shot, harmful substances may have entered your body. Doctors cannot guarantee in advance that there will not be any complications. In my opinion, you cannot expect any fellow citizen to vaccinate as long as the vaccine is not 100% safe. Surely, it is not too much to ask that a product injected into a healthy human body be 100% safe.'

Florian Hantzsch (Interviewer): 'Thank you, Mr. Müller. Mr. Jürgen Schmidt from the Health Office in Neustadt, how do you respond to that?'

Jürgen Schmidt (Science Advocate 1): 'Mr. Müller demands 100% safety from the vaccine against dysomeria. In science, this argument is called *impossible expectation*. It is an impossible expectation because science can never guarantee 100% safety for any medical product, neither for aspirin nor for heart surgery. Any treatment poses a residual risk of complications for patients either during or after treatment. The scientific evidence is clear: The vaccine against dysomeria is a safe way to avoid the disease. The risk of dysomeria by far exceeds the risk from vaccination. This is why we, the Health Office in Neustadt, recommend the vaccination against the DS virus for citizens of all ages. And please let me add the following regarding the safety of the vaccine: We follow a very strict protocol to ensure the high quality of vaccines in the Federal States. This is also demonstrated by the fact that every batch of the vaccine against dysomeria is monitored constantly and independently screened by official control laboratories.'

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Stefan Müller (Science Denier 1): 'At the end of the day, it is not about the health of the individual citizen. It is about the financial interests of large companies and government institutions. The pharmaceutical industry earns a huge annual profit with the sale of the vaccine against dysomeria. The government can multiply the profit tremendously with official vaccination recommendations. If we put two and two together, then anyone can see this perfidious collaboration between the responsible parties. In the end, all those who have something to say in this system are connected in a way, and only the ordinary citizen is left out – and is expected to do one thing: Stay silent and keep on vaccinating.'

Florian Hantzsch (Interviewer): 'Thank you, Mr. Müller. Mr. Jürgen Schmidt from the Health Office in Neustadt, how do you respond to that?'

Jürgen Schmidt (Science Advocate 1): 'Mr. Müller suspects a secret conspiracy behind the distribution of the vaccine against dysomeria. This perspective completely ignores that a large proportion of the research that demonstrates the benefits of vaccination for society and each individual is conducted by independent scientists all over the world. In addition, such conspiratorial claims discredit the prosocial motives of all our healthcare system's employees. Let's stay with the facts: In regions where the vaccine against dysomeria is used, people live a healthier life. This has been demonstrated several times. The major goal of governmental health institutions like our office is to maintain and improve the health of every single citizen in the country. I very much regret that Mr. Müller has lost trust in our institution and our effort. The Standing Committee on Vaccination STIKO, which is responsible for vaccination recommendations in the Federal States, is composed of independent experts who are appointed for a period of three years. The members are an independent advisory group, and the meetings and protocols of the STIKO, as well as possible conflicts of interest among the members, are open to the public and available via webcast. Whatever Mr. Müller is suggesting here, the fact is: The vaccine improves the health standards of all individuals, and that is why we recommend it for citizens of all ages.'

Experiment 3

Rebuttal: Advocate silent
Outnumbering: 5:1

1. Video

Florian Hantzsch (Interviewer): 'Welcome, ladies and gentlemen. Today, we are talking about the vaccine against the viral disease dysomeria. I am delighted to welcome my six guests: Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics and also Mr. Leon Holderman, Mr. Domenik Rehde, Mr. Martin Schober, Mr. Peter Witting and Mr. Jürgen Schmidt from the Health Office in Neustadt.
I would like to start right away with my first question:
Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics, how safe is the vaccine against dysomeria?'

Stefan Müller (Science Denier 1): 'The lack of safety is an important issue with the dysomeria vaccine. The side effects and risks of the vaccine are incalculable. As a patient, you do not know how the body reacts to the vaccine before administration. Even if you feel healthy immediately after the shot, harmful substances may have entered your body. Doctors cannot guarantee in advance that there will not be any complications. In my opinion, you cannot expect any fellow citizen to vaccinate as long as the vaccine is not 100% safe. Surely, it is not too much to ask that a product injected into a healthy human body be 100% safe.'

2. Video

Florian Hantzsch (Interviewer): 'Vaccines protect against diseases; however, pharmaceutical companies also make money from producing vaccines. A question arises: Who actually benefits from vaccination, Mr. Müller?'

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Rebuttal: Advocate silent
Outnumbering: 3:3

1. Video

Florian Hantzsch (Interviewer): 'Welcome, ladies and gentlemen. Today, we are talking about the vaccine against the viral disease dysomeria. I am delighted to welcome my six guests: Mr. Domenik Rehde, Mr. Leon Holderman and Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics and also Mr. Martin Schober, Mr. Peter Witting and Mr. Jürgen Schmidt from the Health Office in Neustadt.
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Mr. Stefan Müller from the Neustaedter Vaccine-Sceptics, how safe is the vaccine against dysomeria?'

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2. Video

Florian Hantzsch (Interviewer): 'Vaccines protect against diseases; however, pharmaceutical companies also make money from producing vaccines. A question arises: Who actually benefits from vaccination, Mr. Rehde?'

Domenik Rehde (Science Denier 2): 'At the end of the day, it is not about the health of the individual citizen. It is about the financial interests of large companies and government institutions. The pharmaceutical industry earns a huge annual profit from the sale of the vaccine against dysomeria. The government can multiply the profit tremendously with official vaccination recommendations.'

Florian Hantzsch (Interviewer): 'Thank you, Mr. Rehde. Mr. Holderman, what do you think?'

Leon Holderman (Science Denier 3): 'If we put two and two together, then anyone can see this perfidious collaboration between the responsible parties. In the end, all those who have something to say in this system are connected in a way, and only the ordinary citizen is left out – and is expected to do one thing: Stay silent and keep on vaccinating.'

Rebuttal: Yes
Outnumbering: 5:1

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Florian Hantzsch (Interviewer): 'Thank you, Mr. Müller. Mr. Jürgen Schmidt from the Health Office in Neustadt, how do you respond to that?'

Jürgen Schmidt (Science Advocate 1): 'Mr. Müller demands 100% safety from the vaccine against dysomeria. In science, this argument is called *impossible expectation.* It is an impossible expectation because science can never guarantee 100% safety for any medical product, neither for aspirin nor for heart surgery. Any treatment poses a residual risk of complications for patients either during or after treatment.'

Florian Hantzsch (Interviewer): 'Thank you, Mr. Schmidt. Mr. Holderman, what do you think?'

Leon Holderman (Science Advocate 2): 'The scientific evidence is clear; the vaccine against dysomeria is a safe way to avoid the disease. The risk of dysomeria by far exceeds the risk from vaccination. That is why we at the Health Office in Neustadt recommend the vaccination against the DS virus for citizens of all ages. And please let me add the following regarding the safety of the vaccine: We follow a very strict protocol to ensure the high quality of vaccines in the Federal States. This is also demonstrated by the fact that every batch of the vaccine against dysomeria is constantly monitored and independently screened by official control laboratories.'

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Florian Hantzsch (Interviewer): 'Thank you, Mr. Müller. Mr. Martin Schober from the Health Office in Neustadt, how do you respond to that?'

Martin Schober (Science Advocate 3): 'In science, this argument is called *secret conspiracy*. This perspective completely ignores that a large proportion of the research that demonstrates the benefits of vaccination for society and each individual is conducted by independent scientists all over the world. In addition, such conspiratorial claims discredit the prosocial motives of all our healthcare system's employees.'

Florian Hantzsch (Interviewer): 'Thank you, Mr. Schober. Mr. Witting, what do you think?'

Peter Witting (Science Advocate 4): 'Let's stick with the facts: In regions where the vaccine against dysomeria is used, people live a healthier life. That has been demonstrated several times. The major goal of governmental health institutions like our office is to maintain and improve the health of every single citizen in the country.'

Florian Hantzsch (Interviewer): 'Thank you, Mr. Witting. Mr. Rehde, what do you think?'

Domenik Rehde (Science Advocate 5): 'The Standing Committee on Vaccination STIKO, which is responsible for vaccination recommendations in the Federal States, is composed of independent experts who are appointed for a period of three years. The members are an independent advisory group, and the meetings and protocols of the STIKO, as well as possible conflicts of interest among the members, are open to the public and available via webcast. The fact is: The vaccine improves the health standard of all individuals.'

Rebuttal: Yes
Outnumbering: 3:3

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Florian Hantzsch (Interviewer): 'Thank you, Mr. Rehde. Mr. Holderman, what do you think?'

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Florian Hantzsch (Interviewer): 'Thank you, Mr. Schober. Mr. Witting, what do you think?'

Peter Witting (Science Advocate 3): 'The major goal of governmental health institutions like our office is to maintain and improve the health of every single citizen in the country. The Standing Committee on Vaccination STIKO, which is responsible for vaccination recommendations in the Federal States, is composed of independent experts who are appointed for a period of three years. The members are an independent advisory group, and the meetings and protocols of the STIKO, as well as possible conflicts of interest among the members, are open to the public and available via webcast. The fact is: The vaccine improves the health standard of all individuals.'

Supplementary Material 2. Forewarning received by control group in Experiments 2 and 3. Note: original materials were in German.

Note!

Data protection is very important to us; therefore, we take protection of your data very seriously. We always want you to feel safe when using our Internet services and to know exactly which data are stored and used. We follow the principles of data avoidance and data economy. The basis for this is the law applicable in Germany in the form of the Federal Data Protection Act and the EU's Basic Data Protection Regulation.

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Enjoy the show.

Supplementary Table 1. Overview of additional measures. Reliability of multiple-item scales is indicated by Cronbach's alpha; numbers behind alphas relate to the respective experiments.

Construct	Included in	Scale type and reliability*	wording	Source of items
Moderator variable				
Involvement	Experiment 1-3	mean score of 7-point semantic differentials ($\alpha 1 = .87$; $\alpha 2 = .83$; $\alpha 3 = .84$)	For me the subject vaccination is… (unimportant – important, relevant – irrelevant, essential – nonessential, fascinating – mundane, insignificant – significant, appealing – unappealing, boring – interesting)	Zaichkowsky (1985)
Control variables				
knowledge about vaccination	Experiment 1-3	mean score of correct/incorrect answers	Example item: Diseases like autism, multiple sclerosis, and diabetes might be triggered through vaccinations. (1 = yes, 2 = no, 3 = I do not know)	Zingg & Siegrist (2012)
5C – psychological antecedents of vaccination	Experiment 1-3	7-point rating scale	Please evaluate to what extent you disagree or agree with the following statements. (Confidence) I am completely confident that vaccines are safe. (Collective responsibility) When everyone is vaccinated, I don't have to get vaccinated, too. (Constrains) Everyday stress prevents me from getting vaccinated. (Complacency) Vaccination is unnecessary because vaccine-preventable diseases are not common anymore. (Calculation) When I think about getting vaccinated, I weigh benefits and risks to make the best decision possible. (1 = I strongly disagree, 5 = I strongly agree)	Betsch et al. (2018)
trust in information source	Experiment 1-3	7-point rating scale	How much do you trust the following sources of health information? example item: TV example item: internet (1 = do not trust at all, 7 = trust completely)	Haase et al. (2015)
frequence of using information source	Experiment 1-3	7-point rating scale	How often do you use the following sources to get health information? example item: TV example item: internet (1 = never, 7 = daily)	Haase et al. (2015)

Supplementary Table 1. (continued)

relevance of source	Experiment 1-3	product score of trust in information source and frequency of using information source		Haase et al. (2015)
Additional variables				
willingness to donate	Experiment 1	single item	Please indicate whether you would support the initiative and, if so, how much money you would donate. 1 = no support, 2 = 1 (Euro) 3 = 5, 4 = 10, 5 = 20, 6 = other amount	n.a.
speaker evaluation	Experiment 1-3	mean score of 7-point semantic differentials competence (α1denier = .90; α1advocate= .95; α2denier = .89; α2advocate= .87; α3denier = .90; α3advocate = .89) character (α1denier = .65; α1advocate= .97; α2denier = .61; α2advocate= .96; α3denier = .63; α3advocate = .96) sociability (α1denier = .61; α1advocate= .97; α2denier = .69; α2advocate= .67; α3denier = .68; α3advocate = .74)	Please rate name denier/name advocate. Example item competence: 1. qualified 7. unqualified Example item character: 1. selfish 7. unselfish Example item sociability: 1. friendly 7. unfriendly	McCroseky & Johnson (1975)
content filter 1	Experiment 1	Single item selection	What was the TV debate about? (1 = About the effectiveness of the vaccination against dysomeria compared to the vaccination against verococci; 2 = About the vaccination against dysomeria; 3 = About the vaccination record of Stefan Müller. 4 = About the vaccination against verococci.)	n.a.
content filter 2	Experiment 2-3	Open textbox	Please enter the correct number. 1. How many guests from [*denier group*] were present in the TV debate? 2. How many guests from [*advocate group*] were present in the TV debate?	n.a.

Supplementary Table 2. Descriptive data for change in attitude independent of condition (overall) and stratified by conditions and experimental groups. Values are presented as percentages of maximum possible scores of the original scales (POMP), with smaller numbers indicating greater influence from science deniers.

	Experiment 1			Experiment 2			Experiment 3		
Change in Attitude	*Mean*	*SD*	n	*Mean*	*SD*	n	*Mean*	*SD*	n
Overall	-15.26	16.29	101	-11.77	18.70	390	-8.67	16.00	396
Conditions									
Rebuttal & 3:3 & No Forewarning	-14.33	16.23	25	-8.17	20.31	50	-2.38	14.23	49
Rebuttal & 5:1 & No Forewarning	-6.73	15.64	26	-10.20	17.45	49	-5.03	12.24	48
Advocate silent & 3:3 & No Forewarning	-17.33	12.48	25	-17.35	18.62	49	-14.00	14.62	50
Advocate silent & 5:1 & No Forewarning	-23.00	16.89	25	-21.53	18.90	48	-16.17	18.70	50
Rebuttal & 3:3 & Forewarning	--	--	--	-5.21	16.63	48	-4.42	10.91	49
Rebuttal & 5:1 & Forewarning	--	--	--	-5.61	16.61	49	-1.02	12.57	49
Advocate silent & 3:3 & Forewarning	--	--	--	-14.58	19.33	48	-9.31	15.60	51
Advocate silent & 5:1 & Forewarning	--	--	--	-11.73	16.31	49	-16.50	18.93	50
Main effects									
Rebuttal	-10.46	16.23	51	-7.31	17.81	196	-3.21	12.55	195
Advocate silent	-20.17	14.97	50	-16.28	18.53	194	-13.97	17.18	201
3:3	-15.83	14.41	50	-11.32	19.27	195	-7.58	14.58	199
5:1	-14.71	18.10	51	-12.22	18.15	195	-9.77	17.27	197
Forewarning	--	--	--	-9.28	17.59	194	-7.87	15.85	199
No Forewarning	--	--	--	-14.24	19.47	196	-9.48	16.14	197

Supplementary Table 3. Descriptive data for change in intention independent of condition (overall) and stratified by conditions and experimental groups. Values are presented as percentages of maximum possible scores of the original scales (POMP), with smaller numbers indicating greater influence from science deniers.

	Experiment 1			Experiment 2			Experiment 3		
Change in Intention	*Mean*	*SD*	n	*Mean*	*SD*	n	*Mean*	*SD*	n
Overall	-11.12	17.21	101	-10.67	17.69	390	-7.11	15.87	396
Conditions									
Rebuttal & 3:3 & No Forewarning	-11.80	17.82	25	-9.60	17.69	50	-0.60	8.21	49
Rebuttal & 5:1 & No Forewarning	-4.23	16.81	26	-8.49	17.46	49	-4.99	12.58	48
Advocate silent & 3:3 & No Forewarning	-12.00	13.76	25	-19.24	19.80	49	-13.49	14.71	50
Advocate silent & 5:1 & No Forewarning	-16.73	18.62	25	-18.48	16.61	48	-16.89	18.78	50
Rebuttal & 3:3 & Forewarning	--	--	--	-2.42	10.22	48	-0.16	11.97	49
Rebuttal & 5:1 & Forewarning	--	--	--	-2.80	17.00	49	0.08	12.81	49
Advocate silent & 3:3 & Forewarning	--	--	--	-12.75	17.93	48	-9.29	16.43	51
Advocate silent & 5:1 & Forewarning	--	--	--	-11.65	16.25	49	-11.03	18.98	50
Main effects									
Rebuttal	-7.94	17.56	51	-5.86	16.14	196	-1.40	11.63	195
Advocate silent	-14.36	16.38	50	-15.53	17.89	194	-12.66	17.41	201
3:3	-11.90	15.76	50	-11.03	17.77	195	-5.96	14.33	199
5:1	-10.36	18.64	51	-10.31	17.64	195	-8.28	17.24	197
Forewarning	--	--	--	-7.40	16.27	194	-5.17	16.06	199
No Forewarning	--	--	--	-13.91	18.47	196	-9.08	15.47	197

Supplementary Table 4. Descriptive data for change in confidence independent of condition (overall) and stratified by conditions and experimental groups. Values are presented as percentages of maximum possible scores of the original scales (POMP), with smaller numbers indicating greater influence from science deniers.

	Experiment 2			Experiment 3		
Change in Confidence	*Mean*	*SD*	n	*Mean*	*SD*	n
Overall	-8.16	17.56	390	-5.77	15.98	396
Conditions						
Rebuttal & 3:3 & No Forewarning	-2.33	17.10	50	0.68	12.25	49
Rebuttal & 5:1 & No Forewarning	-5.61	16.35	49	-4.17	14.99	48
Advocate silent & 3:3 & No Forewarning	-17.18	15.44	49	-13.50	14.07	50
Advocate silent & 5:1 & No Forewarning	-18.40	17.53	48	-14.50	17.24	50
Rebuttal & 3:3 & Forewarning	1.39	14.92	48	1.36	12.31	49
Rebuttal & 5:1 & Forewarning	-3.57	16.58	49	4.08	14.56	49
Advocate silent & 3:3 & Forewarning	-10.76	16.84	48	-8.66	13.12	51
Advocate silent & 5:1 & Forewarning	-9.01	16.57	49	-10.83	17.44	50
Main effects						
Rebuttal	-2.55	16.33	196	0.51	13.79	195
Advocate silent	-13.83	16.96	194	-11.86	15.62	201
3:3	-7.22	17.55	195	-5.11	14.33	199
5:1	-9.10	17.57	195	-6.43	17.50	197
Forewarning	-5.50	16.81	194	-3.60	15.72	199
No Forewarning	-10.80	17.93	196	-7.95	15.98	197

Supplementary Table 5. Effects from rebuttal and weight-of-evidence strategies on changes in attitude after controlling for effects of preregistered covariates. All models are repeated-measures ANOVAs (Type 2 sum of squares) on change scores of individuals' attitudes. Significant effects are shown in boldface for the significance level of <0.05.

Attitude	Experiment 1 n = 98			Experiment 2 n = 389			Experiment 3 n = 382		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	2.70	.104	.030	0.19	.661	.001	**10.08**	**.002**	**.027**
Rebuttal × Time	**7.98**	**.006**	**.083**	**20.73**	**<.001**	**.052**	**47.00**	**<.001**	**.113**
Outnumbering × Time	0.12	.727	.001	0.65	.422	.002	1.46	.228	.004
Forewarning × Time	--	--	--	**7.06**	**.008**	**.018**	2.01	.157	.005
Rebuttal × Outnumbering × Time	**4.99**	**.028**	**.054**	0.02	.880	<.001	2.10	.148	.006
Rebuttal × Forewarning × Time	--	--	--	0.24	.627	.001	0.19	.661	.001
Outnumbering × Forewarning × Time	--	--	--	1.41	.236	.004	0.05	.824	<.001
Rebuttal × Outnumbering × Forewarning × Time	--	--	--	1.20	.273	.003	2.35	.126	.006
Knowledge × Time	**5.99**	**.016**	**.064**	**7.14**	**.008**	**.019**	**15.92**	**<.001**	**.041**
Source Relevance Television × Time	0.03	.875	<.001	2.17	.142	.006	1.99	.160	.005
Education low × Time	Ref.	--	--	Ref.	--	--	Ref.	--	--
Education middle × Time	0.02	.888	<.001	0.09	.762	<.001	1.21	.272	.003
Education high × Time	0.10	.759	.001	<0.01	.963	<.001	0.12	.726	**<.001**
Gender male × Time	Ref.	--	--	Ref.	--	--	Ref.	--	--
Gender female × Time	0.12	.733	.001	**4.34**	**.038**	**.011**	0.96	.327	.003
Age × Time	1.64	.204	.018	0.66	.418	.002	2.72	.100	.007

Supplementary Table 6. Effects from rebuttal and weight-of-evidence strategies on changes in intention after controlling for preregistered covariates' effects. All models are repeated-measures ANOVAs (Type 2 sum of squares) on change scores of individuals' attitudes. Significant effects are shown in boldface for the significance level of <0.05.

Intention	Experiment 1 n = 98			Experiment 2 n = 389			Experiment 3 n = 382		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	1.00	.319	.011	0.48	.488	.001	2.09	.150	.006
Rebuttal × Time	2.50	.117	.028	**29.06**	**<0.01**	**.072**	**62.06**	**<.001**	**.145**
Outnumbering × Time	0.39	.535	.004	0.02	.902	<.001	1.70	.194	.005
Forewarning × Time	--	--	--	**14.04**	**<.001**	**.036**	**10.26**	**.002**	**.027**
Rebuttal × Outnumbering × Time	3.91	.051	.042	0.03	.855	<.001	.001	.979	<.001
Rebuttal × Forewarning × Time	--	--	--	0.03	.864	<.001	0.39	.531	.001
Outnumbering × Forewarning × Time	--	--	--	0.06	.809	<.001	1.55	.215	.004
Rebuttal × Outnumbering × Forewarning × Time	--	--	--	0.29	.592	.001	0.08	.774	<.001
Knowledge × Time	2.08	.153	.023	**4.45**	**.035**	**.012**	**7.92**	**.005**	**.021**
Source Relevance Television × Time	0.18	.669	.002	0.86	.355	.002	6.25	.013	.017
Education low × Time	Ref.	--	--	Ref.	--	--	Ref.	--	--
Education middle × Time	0.16	.694	.002	0.32	.569	.001	0.17	.685	<.001
Education high × Time	0.02	.883	<.001	<0.01	.952	<.001	0.03	.873	<.001
Gender male × Time	Ref.	--	--	Ref.	--	--	Ref.	--	--
Gender female × Time	0.13	.716	.002	3.83	.051	.010	**4.41**	**.036**	**.012**
Age × Time	1.89	.172	.027	0.06	.812	<.001	1.01	.317	.003

Supplementary Table 7. The efficacy of outnumbering and forewarning as a function of the audience's issue involvement. All models are linear models (Type 2 sum of squares) on change scores of the respective outcome measure. Significant effects are shown in boldface for the significance level of <0.05.

Experiment 1	Model 1 Attitude n = 101			Model 2 Intention n = 101					
	F	p	η^2_p	F	p	η^2_p			
Rebuttal	**10.52**	**.002**	**.100**	**4.47**	**.037**	**.045**			
Outnumbering	0.10	.749	.001	0.22	.639	.002			
Involvement	0.85	.358	.009	0.24	.628	.002			
Rebuttal × Outnumbering	**5.21**	**.025**	**.052**	2.65	.110	.027			
Outnumbering × Involvement	0.52	.472	.005	1.00	.321	.010			
Experiment 2	Model 3 Attitude n = 390			Model 4 Intention n = 390			Model 5 Confidence n = 390		
	F	p	η^2_p	F	p	η^2_p	F	p	η^2_p
Rebuttal	**24.10**	**<.001**	**.060**	**31.89**	**<.001**	**.078**	**45.70**	**<.001**	**.108**
Outnumbering	0.22	.643	.001	0.15	.699	<.001	1.09	.296	.003
Forewarning	**7.60**	**.006**	**.020**	**14.26**	**<.001**	**.036**	**9.85**	**.002**	**.025**
Involvement	0.05	.824	<.001	0.28	.598	.001	**4.34**	**.038**	**.011**
Rebuttal × Outnumbering	0.02	.898	<.001	0.03	.857	<.001	1.88	.171	.005
Rebuttal × Forewarning	0.44	.509	.001	<0.01	.952	<.001	2.12	.146	.006
Outnumbering × Forewarning	1.45	.229	.004	0.04	.838	<.001	<0.01	.952	<.001
Rebuttal × Outnumbering × Forewarning	0.52	.471	.001	0.07	.791	<.001	0.44	.510	.001
Outnumbering × Involvement	0.58	.448	.002	<0.01	.944	<.001	0.27	.604	.001
Forewarning × Involvement	0.26	.611	.001	<0.01	.958	<.001	1.70	.193	.004
Experiment 3	Model 6 Attitude n = 396			Model 7 Intention n = 396			Model 8 Confidence n = 396		
	F	p	η^2_p	F	p	η^2_p	F	p	η^2_p
Rebuttal	**50.86**	**<.001**	**.120**	**63.50**	**<.001**	**.144**	**72.10**	**<.001**	**.162**
Outnumbering	1.25	.265	.003	1.42	.234	.004	0.48	.489	.001
Forewarning	2.10	.148	.006	**10.91**	**.001**	**.028**	**10.39**	**.001**	**.027**

Supplementary Table 7. (continued)

Involvement	0.10	.756	<.001	1.24	.266	.003	**4.17**	**.042**	**.011**
Rebuttal × Outnumbering	1.84	.175	.005	0.01	.937	<.001	0.02	.901	<.001
Rebuttal × Forewarning	0.04	.851	<.001	0.30	.587	.001	0.12	.727	<.001
Outnumbering × Forewarning	0.08	.773	<.001	2.62	.106	.007	1.72	.190	.005
Rebuttal × Outnumbering × Forewarning	3.01	.083	.008	0.22	.640	.001	2.31	.129	.006
Outnumbering × Involvement	**5.95**	**.015**	**.016**	2.75	.098	.007	1.32	.252	.004
Forewarning × Involvement	0.02	.881	<.001	0.02	.894	<.001	0.22	.637	.001

Supplementary Table 8. Effects from rebuttal and weight-of-evidence strategies on changes in confidence after controlling for preregistered covariates' effects. All models are repeated-measures ANOVAs (Type 2 sum of squares) on change scores of individuals' attitudes. Significant effects are shown in boldface for the significance level of <0.05.

Confidence	Experiment 2 n = 389			Experiment 3 n = 382		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**6.24**	**.013**	**.016**	**7.78**	**.006**	**.021**
Rebuttal × Time	**44.75**	**<.001**	**.107**	**68.63**	**<.001**	**.157**
Outnumbering × Time	2.14	.145	.006	0.57	.450	.002
Forewarning × Time	**9.29**	**.002**	**.024**	**11.56**	**.001**	**.030**
Rebuttal × Outnumbering × Time	0.62	.432	.002	0.03	.872	<.001
Rebuttal × Forewarning × Time	1.14	.286	.003	0.15	.698	<.001
Outnumbering × Forewarning × Time	<0.01	.991	<.001	1.49	.224	.004
Rebuttal × Outnumbering × Forewarning × Time	1.25	.263	.003	1.54	.215	.004
Knowledge × Time	**12.97**	**<.001**	**.033**	**12.74**	**<.001**	**.033**
Source Relevance Television × Time	0.06	.801	<.001	2.03	.156	.005
Education low × Time	Ref.	--	--	Ref.	--	--
Education middle × Time	0.10	.755	<.001	**4.29**	**.039**	**.012**
Education high × Time	0.01	.920	<.001	2.92	.088	.008
Gender male × Time	Ref.	--	--	Ref.	--	--
Gender female × Time	**5.03**	**.026**	**.013**	0.55	.460	.001
Age × Time	3.25	.072	.009	0.50	.482	.001

Supplementary Table 9. Effects from rebuttal and weight-of-evidence strategies on changes in attitude with a sample containing only those participants who recalled the correct information. All models are repeated-measures ANOVAs (Type 2 sum of squares) on change scores of individuals' attitudes. Significant effects are shown in boldface for the significance level of <0.05.

Attitude	Experiment 2 n = 280			Experiment 3 n = 299		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**127.96**	**<.001**	**.320**	**85.51**	**<.001**	**.227**
Rebuttal × Time	**16.75**	**<.001**	**.058**	**37.23**	**<.001**	**.113**
Outnumbering × Time	0.04	.848	<.001	0.03	.871	<.001
Forewarning × Time	**7.67**	**.006**	**.027**	2.04	.154	.007
Rebuttal × Outnumbering × Time	1.45	.230	.005	0.50	.479	.002
Rebuttal × Forewarning × Time	<0.01	.995	<.001	0.30	.584	.001
Outnumbering × Forewarning × Time	0.58	.446	.002	0.06	.811	<.001
Rebuttal × Outnumbering × Forewarning × Time	0.04	.847	<.001	**4.84**	**.029**	**.016**

Supplementary Table 10. Effects from rebuttal and weight-of-evidence strategies on changes in intention with a sample containing only those participants who recalled the correct information. All models are repeated-measures ANOVAs (Type 2 sum of squares) on change scores of individuals' attitudes. Significant effects are shown in boldface for the significance level of <0.05.

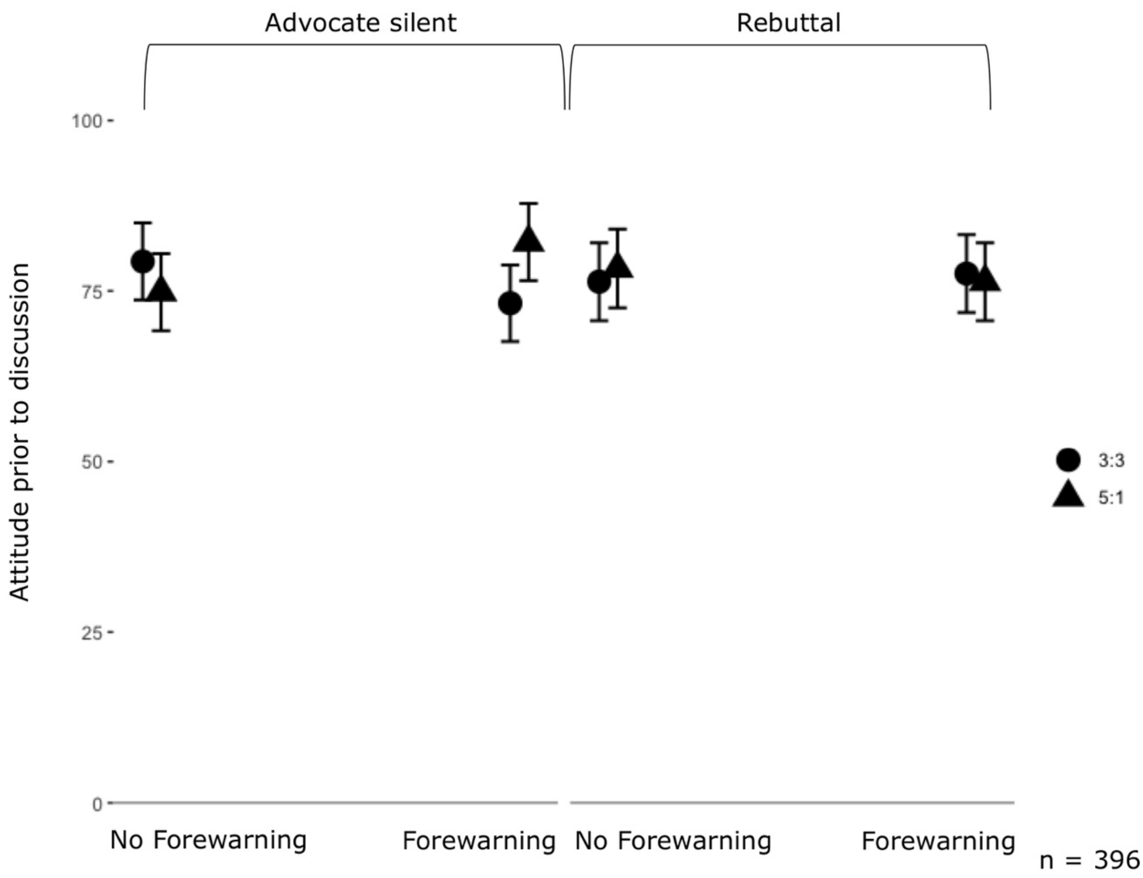
Intention	Experiment 2 n = 280			Experiment 3 n = 299		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**127.48**	**<.001**	**.319**	**52.26**	**<.001**	**.152**
Rebuttal × Time	**26.11**	**<.001**	**.088**	**37.08**	**<.001**	**.113**
Outnumbering × Time	1.14	.286	.004	0.30	.586	.001
Forewarning × Time	**18.73**	**<.001**	**.064**	**5.45**	**.020**	**.018**
Rebuttal × Outnumbering × Time	0.35	.555	.001	1.14	.286	.004
Rebuttal × Forewarning × Time	<0.00	.956	<.001	0.05	.827	<.001
Outnumbering × Forewarning × Time	0.10	.749	<.001	0.03	.853	**<.001**
Rebuttal × Outnumbering × Forewarning × Time	0.04	.852	<.001	2.38	.124	.008

Supplementary Table 11. Effects from rebuttal and weight-of-evidence strategies on changes in confidence with a sample containing only those participants who recalled the correct information. All models are repeated-measures ANOVAs (Type 2 sum of squares) on change scores of individuals' attitudes. Significant effects are shown in boldface for the significance level of <0.05.

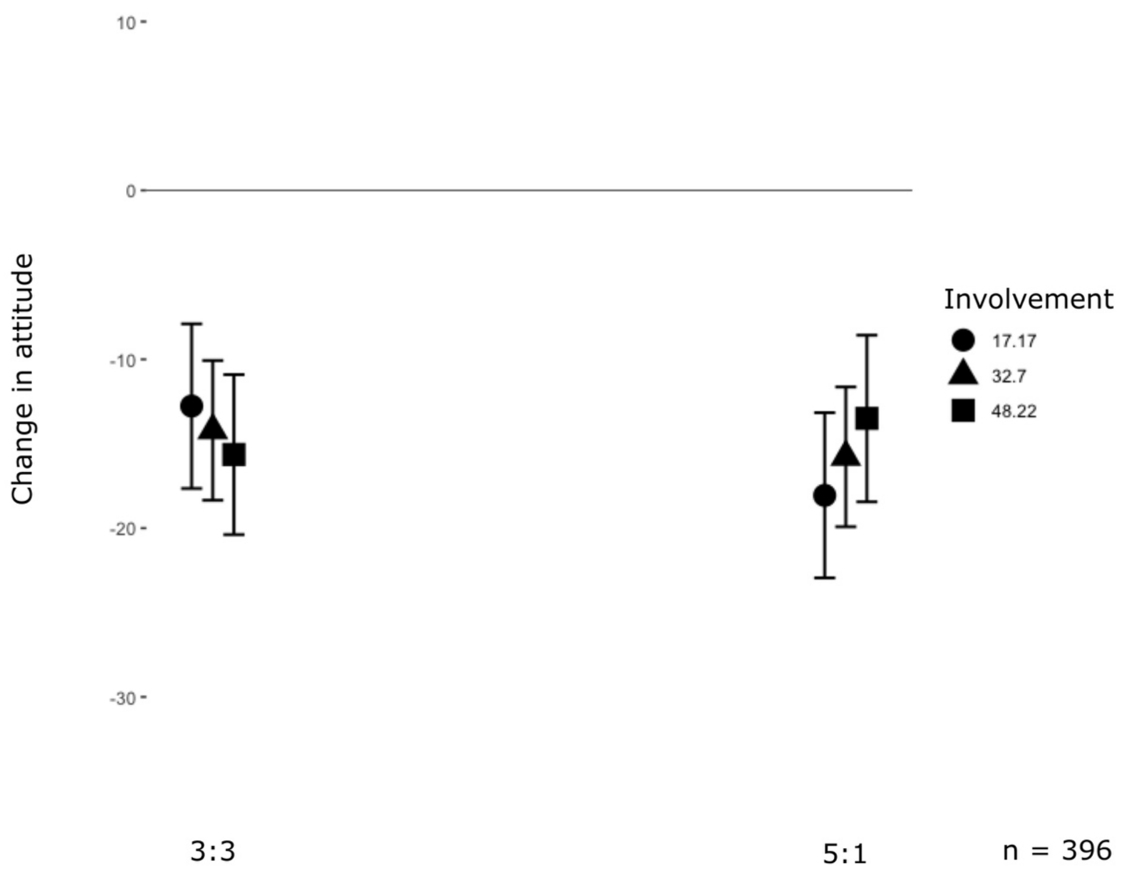
Confidence	Experiment 2 n = 280			Experiment 3 n = 299		
Effects	*F*	*p*	η^2_p	*F*	*p*	η^2_p
Time	**68.51**	**<.001**	**.201**	**24.04**	**<.001**	**.076**
Rebuttal × Time	**43.57**	**<.001**	**.138**	**58.10**	**<.001**	**.166**
Outnumbering × Time	0.16	.685	.001	0.02	.877	<.001
Forewarning × Time	**4.53**	**.034**	**.016**	**7.64**	**.006**	**.026**
Rebuttal × Outnumbering × Time	1.72	.191	.006	0.01	.910	<.001
Rebuttal × Forewarning × Time	0.81	.369	.003	0.57	.451	.002
Outnumbering × Forewarning × Time	0.16	.688	.001	0.02	.888	<.001
Rebuttal × Outnumbering × Forewarning × Time	0.02	.885	<.001	**7.04**	**.008**	**.024**

Supplementary Table 12. Effects from rebuttal and weight-of-evidence strategies on post-attitude values controlled for pre-attitude values. The model is a repeated-measures ANOVA (Type 2 sum of squares) on change scores of individuals' attitudes. Significant effects are shown in boldface for the significance level of <0.05.

Post values Attitude	Experiment 3 n = 387		
Effects	*F*	*p*	η^2_p
Intercept	**77.65**	**<.001**	**.616**
Prior Attitude	**563.18**	**<.001**	**.593**
Rebuttal	**52.02**	**<.001**	**.118**
Outnumbering	1.83	.177	.005
Forewarning	1.16	.282	.003
Rebuttal × Outnumbering	2.63	.106	.007
Rebuttal × Forewarning	0.20	.652	.001
Outnumbering × Forewarning	0.15	.704	<.001
Rebuttal × Outnumbering × Forewarning	2.25	.135	.006



Supplementary Figure 1. Evidence of a biased distribution of pre-values in Experiment 3. The figure visualises a three-way interaction of rebuttal × outnumbering × forewarning in an ANOVA model on individuals' attitude values prior to the discussion. Circles and triangles represent mean values. Error bars are 95% confidence intervals. Results from ANOVAs stratified by rebuttal revealed that the three-way interaction resulted from a significant two-way interaction from outnumbering × forewarning on individuals' attitudes in the advocate-silent condition, $F(1, 197) = 5.92$, $p = .016$, $\eta^2_p = .029$, and a reversed, but insignificant, pattern in the rebuttal condition, $F(1, 191) = 0.27$, $p = .607$, $\eta^2_p = .001$. Further exploration of simple effects in the advocate-silent condition revealed that the two-way interaction resulted from significantly lower pre-values of participants in the 5:1 condition (outnumbering) compared with participants in the 3:3 condition, $p = .028$, when participants were forewarned and a reversed, but insignificant, pattern in the no-forewarning condition, $p = .271$.



Supplementary Figure 2. Outnumbering increases damage from denialism with decreasing issue involvement from the audience. The figure visualises a two-way interaction of outnumbering × involvement in a linear model (Supplementary Table 7) on changes in individuals' attitude values in Experiment 3. Circles and triangles represent mean values. Error bars are 95% confidence intervals. Results on attitude changes for moderator levels stratified by outnumbering revealed that the damage from deniers increases with decreasing issue involvement, but only if the denier was outnumbered (5:1). The pattern is reversed for the falsely balanced discussion. The pattern contradicts a conditional benefit from outnumbering (5:1) compared with a falsely balanced discussion (3:3), as expected by previous research underlying the involvement as a moderator research question.

Supplementary References

Zaichkowsky, J. L. (1985). Measuring the involvement construct. *Journal of consumer research*, *12*(3), 341-352.

Zingg, A., & Siegrist, M. (2012). Measuring people's knowledge about vaccination: developing a one-dimensional scale. *Vaccine*, *30*(25), 3771-3777.

Betsch, C., Schmid, P., Heinemeier, D., Korn, L., Holtmann, C., & Böhm, R. (2018). Beyond confidence: Development of a measure assessing the 5C psychological antecedents of vaccination. *PloS one*, *13*(12), e0208601.

Haase, N., Betsch, C., & Renkewitz, F. (2015). Source credibility and the biasing effect of narrative information on the perception of vaccination risks. *Journal of health communication*, *20*(8), 920-929.

McCroskey, J. C., & Jenson, T. A. (1975). Image of mass media news sources. *Journal of Broadcasting & Electronic Media*, *19*(2), 169-180.

General Discussion

General Discussion

In light of the findings of the current dissertation, I recommend that science advocates should train in topic or technique rebuttal and that journalists should make use of forewarnings when broadcasting public discussions about scientific issues. All three approaches were shown to be effective in reducing the damage from science deniers in public discussions (Schmid & Betsch, 2019; Schmid, Schwarzer, & Betsch, 2019). Moreover, the presented results provide no evidence that the strategies cause unintended effects when used on vulnerable audiences (e.g., rebuttal: U.S. conservatives; forewarnings: individuals with low issue involvement). In contrast, we found no evidence that simply inviting more advocates for science to a public discussion or using complex combinations of topic and technique rebuttal is beneficial in countering science denialism (Schmid & Betsch, 2019; Schmid et al., 2019). This knowledge of effective and ineffective strategies improves advocates' toolboxes in the fight against misinformation.

Rebuttal and weight-of-evidence strategies are effective in countering science denialism messages. However, it would be naive to think that countering messages alone is sufficient to neutralise the global threat of science denialism in the post-truth era (Cook, 2019; Lewandowsky, Ecker, & Cook, 2017). Organisational science denialism (e.g., climate change denier) repeatedly interferes with policymaking and can damage science on a structural level beyond the reach of any psychological communication approach (Oreskes & Conway, 2011). For example, the Trump administration has drastically changed the course of the Environmental Protection Agency of the United States (EPA) by cutting the agency's budget, allowing lobbyists on the scientific advisory board and using executive orders to serve the interests of the industry rather than the ecological goals of the agency (Dillon et al., 2018). Moreover, new tools to manipulate image and video data, so-called *deepfakes* (Maras & Alexandrou, 2019), are on the rise and pose a new challenge for advocates for science because these deepfakes add further ways to spread misinformation and are becoming more and more difficult to detect. To counter these multifaceted challenges, large-scale approaches that promote societal (e.g., March for Science; Durnová, 2019), technical (e.g., algorithms that verify rumours; Vosoughi, Mohsenvand, & Roy, 2017) and political (e.g., making political advertising transparent; EC, 2019) developments are needed to support psychological communication approaches in the fight against misinformation. In line with this, a recent development in research relies on 'the combination of psychology, critical thinking, communication, and behavioural economics in the design of scalable, technological solutions' (Cook, 2019, p. 289) to counter misinformation, that is, *technocognition* (Cook, 2019;

Lewandowsky et al., 2017). The interdisciplinary approach of technocognition seems especially promising because attempts from social media corporations to fight misinformation alone have revealed a high need for improvement (Clayton et al., 2019; Zollo et al., 2017) while psychologists, communication scientists and behavioural economists need technical support to translate their knowledge about human behaviour into user-friendly and appealing applications.

New developments such as rebuttal or technocognition reveal the increased efforts of scientists to counter misinformation. Moreover, the general public and scientists are even marching in the streets to strengthen the evidence-based voice for science in the post-truth era (Durnová, 2019). Despite these positive trends, science advocates should monitor their own actions and be aware that their task is not to unreasonably dismiss any argument that opposes a scientific consensus. If factual errors are spread, then science advocates can use topic rebuttal to correct them. If logical fallacies are used within reasoning, then advocates can counter them with technique rebuttal. If a biased discussion is to be expected, then science advocates can implement forewarnings. But if an advocate lacks scientifically grounded counter-arguments, then he/she should refrain from using fallacious arguments him/herself just for the sake of defending a scientific position. Even though deceptive arguments may in fact turn out to be temporary effective in mitigating the damage of science denialism messages, they pose the risk of damaging the trustworthiness of advocates for science in the long run (Schweitzer, Hershey, & Bradlow, 2006) – not to speak of the ethical concerns of using fallacies to win an argument. For example, science advocates may misuse the term 'science denier', just as politicians have repeatedly misused the term 'fake news', to dismiss an argument from an opposing party (Brummette, DiStaso, Vafeiadis, & Messner, 2018; Frank, 2019). By doing this, advocates may miss reasonable ethical or even epistemic concerns that 'even if one disagrees, should not be dismissed as denialist' (Frank, 2019, p. 2). Moreover, to put an opposing argument or discussant 'into some odious category; even though the connection is only apparent, or else of a loose character' (Schopenhauer, 1830, p. 80) is bad reasoning. Thus, training rebuttal also implies that an advocate makes him/herself aware of the flawed reasoning in his/her own arguments and learns to separate the arguments of denial from reasonable concerns.

Limitations

The research presented in the current dissertation has some limitations. All empirical data are based on online or laboratory randomised control trials to ensure the internal validity of the findings. As a consequence, the current dissertation does not provide evidence about the evaluated strategies in a real-life setting, and concerns about the external validity of the findings can be raised. However, the experiments provided are the very first empirical evaluations of rebuttal and weight-of-evidence strategies to counter science denialism in public discussions Thus, focusing on internal valid experiments follows best practices of evaluation because ‘it does not make much sense to ask whether a result is valid outside the experimental circumstances unless we are confident that it does therein’ (Guala, 2003, p. 1198).

All experiments vary the advocates’ responses to a denier’s claim, but they do not entail the possibility that a denier can respond to rebuttal. That is, the experiments present an excerpt of a real-life setting that restricts the dynamics usually experienced in public discussions. Again, this limitation was accepted to answer the primary research question of whether rebuttal and weight-of-evidence strategies mitigate the deniers’ damage. The question of whether they remain effective in different contexts (e.g., different responses from deniers to rebuttal, different delays between the discussion and judgements) needs to be analysed by follow-up studies.

Finally, all experiments measured the behavioural intentions and attitudes towards a behaviour but not actual behaviour. Moreover, the participants received fictitious scenarios. However, both attitude and intention are theoretically sound and empirically strong predictors of actual behaviour (O’Keefe, 2002), and fictitious scenarios enable ethically appropriate research that avoids the spread of misinformation about real behaviours favoured by science (e.g., getting vaccinated against measles).

Conclusion

The presented articles in the current dissertation introduce and evaluate effective strategies to counter science denialism in public discussions. We found that uncovering faulty reasoning (i.e., technique rebuttal), correcting scientific content (i.e., topic rebuttal) and warning individuals about the false balance effect (i.e., forewarning) can mitigate the damage from science denialism messages. These strategies complement previous inoculation and debunking strategies and are now considered a ‘second-order line of defence’ (van der Linden, 2019, p. 890) in the fight against misinformation.

References

Brummette, J., DiStaso, M., Vafeiadis, M., & Messner, M. (2018). Read All About It: The Politicization of “Fake News” on Twitter. *Journalism and Mass Communication Quarterly*, *95*(2), 497–517. https://doi.org/10.1177/1077699018769906

Clayton, K., Blair, S., Busam, J. A., Forstner, S., Glance, J., Green, G., … Nyhan, B. (2019). Real Solutions for Fake News? Measuring the Effectiveness of General Warnings and Fact-Check Tags in Reducing Belief in False Stories on Social Media. *Political Behavior*. https://doi.org/10.1007/s11109-019-09533-0

Cook, J. (2019). Understanding and Countering Misinformation About Climate Change. In *Handbook of Research on Deception, Fake News, and Misinformation Online* (pp. 281–306). https://doi.org/10.4018/978-1-5225-8535-0.ch016

Dillon, L., Sellers, C., Underhill, V., Shapiro, N., Ohayon, J. L., Sullivan, M., … Wylie, S. (2018). The Environmental Protection Agency in the Early Trump Administration: Prelude to Regulatory Capture. *American Journal of Public Health*. https://doi.org/10.2105/AJPH.2018.304360

Durnová, A. (2019). Der ‚March for Science‘ als Schauplatz der gesellschaftspolitischen Polarisierung zwischen Elite und Volk: ein interpretativer Beitrag zur Analyse von Postfaktizität. *Zeitschrift Für Politikwissenschaft*. https://doi.org/10.1007/s41358-019-00186-3

European Comission. (2019). Tackling online disinformation. Retrieved from https://ec.europa.eu/digital-single-market/en/tackling-online-disinformation

Frank, D. M. (2019). Disagreement or denialism? “Invasive species denialism” and ethical disagreement in science. *Synthese*, 1–29. https://doi.org/10.1007/s11229-019-02259-w

Guala, F. (2003). Experimental Localism and External Validity. In *Philosophy of Science*. https://doi.org/10.1086/377400

Lewandowsky, S., Ecker, U. K. H., & Cook, J. (2017). Beyond Misinformation: Understanding and Coping with the “Post-Truth” Era. *Journal of Applied Research in Memory and Cognition*, *6*(4), 353–369. https://doi.org/10.1016/j.jarmac.2017.07.008

Maras, M. H., & Alexandrou, A. (2019). Determining authenticity of video evidence in the age of artificial intelligence and in the wake of Deepfake videos. *International Journal of Evidence and Proof*, *23*(3), 255–262. https://doi.org/10.1177/1365712718807226

O’Keefe, D. J. (2002). *Persuasion: Theory and Research* (2nd ed.). SAGE. https://doi.org/psycinfo/1990-97697-000

Oreskes, N., & Conway, E. (2011). Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming.

Schmid, P., & Betsch, C. (2019). Effective strategies for rebutting science denialism in public discussions. *Nature Human Behaviour*. https://doi.org/10.17605/OSF.IO/XX2KT

Schmid, P., Schwarzer, M., & Betsch, C. (2019). Weight-of-Evidence Strategies to Counter Science Denialism in Public Discussions. *Submitted*.

Schopenhauer, A. (1830). *The art of being right [Die Kunst, Recht zu behalten]* (2015 10th). Hamburg: Nikol Verlagsgesellschaft mbH & Co. KG.

Schweitzer, M. E., Hershey, J. C., & Bradlow, E. T. (2006). Promises and lies: Restoring violated trust. *Organizational Behavior and Human Decision Processes*. https://doi.org/10.1016/j.obhdp.2006.05.005

van der Linden, S. (2019). Countering science denial. *Nature Human Behaviour*. https://doi.org/10.1038/s41562-

019-0631-5

Vosoughi, S., Mohsenvand, M. 'Neo,' & Roy, D. (2017). Rumor gauge: Predicting the veracity of rumors on twitter. *ACM Transactions on Knowledge Discovery from Data*, *11*(4). https://doi.org/10.1145/3070644

Zollo, F., Bessi, A., Del Vicario, M., Scala, A., Caldarelli, G., Shekhtman, L., … Quattrociocchi, W. (2017). Debunking in a world of tribes. *PLoS ONE*. https://doi.org/10.1371/journal.pone.0181821