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Terje Aven

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Terje Aven

University of Stavanger, Stavanger, Norway

ABSTRACT

In society, there is often an 'official view' – a mainstream account – and alternatives to this view are seen as representing a disturbance and hampering this view's policy implementation. There is often considerable pressure to dismiss these alternatives. Reference to conspiracy theories is commonly used to ensure such dismissal. This paper discusses the issue of when an alternative hypothesis or theory can and should be dismissed. New insights are provided by taking a risk and uncertainty science perspective. This perspective clarifies the understanding of and relationships between fundamental concepts relevant to this discussion, such as plausibility, knowledge, uncertainty and probability (likelihood), and what are proper measurements and characterizations of these concepts. A set of criteria is developed to be used as a checklist for what aspects to consider when evaluating such alternatives.

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1. Introduction

Consider the controversy about the origin of the coronavirus. In February 2020, the renowned medical journal, *The Lancet*, published a letter signed by 27 researchers, who strongly condemned the idea that COVID-19 did not have a natural origin (Calisher et al. 2020). The letter referred to the idea as a conspiracy theory: 'We stand together to strongly condemn conspiracy theories suggesting that COVID-19 does not have a natural origin' (Calisher et al. 2020). The authors refer to scientists from multiple countries who have published and analyzed work with the conclusion that the coronavirus originated in wildlife. Arguments were provided for these claims. Several of the studies referred to in this letter concluded that it was improbable that the virus had a non-natural cause; it was likely or very likely that it originated from bats. In this way, the letter points to epistemic deficiencies. In several places, the letter refers to misinformation, further highlighting this aspect. The concept of misinformation is, however, value-laden; used together with terms like 'rumors', as in the letter by Calisher et al. (2020), the text can also be viewed as having elements of morally derogatory terms. The authors state that 'conspiracy theories do nothing but create fear, rumors, and prejudice'. A main concern of the authors is that this alternative explanation could jeopardize global collaboration in the fight against this virus.

This letter has spurred considerable debate, particularly regarding the authors' reference to conspiracy theories and the fact that some of the authors of the letter clearly had conflicts of

CONTACT Terje Aven terje.aven@uis.no University of Stavanger, Stavanger, Norway

interests but did not disclose these (see, e.g. Thacker 2021). The conspiracy statement contributed to a silencing effect on the wider scientific discussion, including among science journalists (van Helden et al. 2021). The key message from van Helden et al. (2021) and many other researchers and scientists was that scientific journals should open their columns to in-depth analyses of all hypotheses:

> As scientists, we need to evaluate all hypotheses on a rational basis, and to weigh their likelihood based on facts and evidence, devoid of speculation concerning possible political impacts. (van Helden et al. 2021) (1.1)

Following this way of thinking, the non-natural origins should not be ruled out; see the overview of different perspectives and reasoning in the *Nature* article by Maxmen and Mallapaty (2021). Questions were raised among many scientists. Dr. Anthony Fauci, the leading US health expert on infectious diseases, stated that he was not convinced the novel coronavirus developed naturally and called for an open investigation into its origins (TET 2021). He stated, however, that the most likely explanation is a natural evolution from an animal reservoir to a human: The evidence leaning toward the origin not being non-natural was strong (National Geographic 2020). It should be mentioned that even today (July 2023) there are uncertainties about the origin of the coronavirus, but the non-natural origin is now frequently pointed to as likely, based on strong evidence (e.g. COA 2023).

Arguing as in (1.1) is the scientific stand. The scientific process is to examine all hypotheses and theories and reach a conclusion based on scientific methods, also challenging the 'official view'. In the case of the origin of the coronavirus, there was such an 'official view', and *The Lancet* letter clearly aimed at contributing to dismissing the alternative non-natural origin theory. For the authors of the letter, the concern was clearly also politics, not only science. Similarly, it can be argued that there has been an official view on vaccination in general and in relation to COVID-19 recently: The vaccines are safe. All questions and concerns about the official view represent a disturbance which hampers the implementation of the related policies: getting people vaccinated.

The issue is about the challenge of balancing the need for healthy skepticism of mainstream scientific accounts and due scientific processes, on the one hand, and the need for concentration on policy implementation for the sake of obtaining efficient risk handling, on the other. The latter need puts some pressure on alternative theories (hypotheses) to be dismissed. The present paper aims at contributing to the discussion on what is required for a theory to be dismissed. Many approaches can be used for this purpose; the focus in this paper is scientific criteria. Science provides general principles and guidance for how to think in relation to this issue, accepting or rejecting hypotheses and theories. The present paper seeks to obtain new insights by adopting a risk and uncertainty science perspective as summarized in recent documents from the Society for Risk Analysis (SRA) (SRA 2015, 2017) and related scientific work (see e.g. summary in Aven and Thekdi 2022). This perspective provides a framework and a rationale for explaining fundamental concepts important for discussing this issue – including plausibility, likelihood, uncertainty and knowledge, and their relationships. By drawing on risk and uncertainty science, some potential criteria are discussed regarding when to dismiss a hypothesis/theory, following up the guidance (1.1) from van Helden et al. (2021).

The paper is organized as follows. First, in Section 2, we give a brief review of fundamentals about scientific analysis, clarifying key concepts such as theory and hypothesis, and reviewing basic generic criteria for evaluating theories and hypotheses. Section 3 presents the announced risk and uncertainty perspective and the potential criteria that can be used to dismiss a hypothesis or theory. Section 4 provides some conclusions.

The cases looked into in this paper, such as the origin of the coronavirus, are just examples to illustrate the risk and uncertainty science discussion in the paper. The aim has not been to add new knowledge on these examples as such, but to use them to support and motivate the argumentation provided, in particular in Section 3. For the purpose of the paper, it is not critical to provide extensive case details.

The present paper takes a risk and uncertainty view to obtain new knowledge concerning the issue of when to dismiss an alternative hypothesis or theory. Science benefits from different perspectives and approaches, and it is acknowledged that to study this issue, a risk and uncertainty view is only one out of several that could be taken. For example, the origin of the coronavirus discourse is to large extent about politization of science, which calls for studies from a social science perspective. However, the present paper is not about the social science aspects of the issue, but topics central in risk and uncertainty science, in particular the understanding and use of and relationship between concepts like plausibility, likelihood/probability and knowledge. The paper addresses conspiracy theories, but the discussion is limited to the risk and uncertainty science topics referred to above.

2. How science evaluates the appropriateness of a theory or hypothesis

When referring to a hypothesis and a theory, the interpretation is as follows (following Cutler 2003):

> A hypothesis is an idea or proposition about the world, whereas a theory is an explanation or a model of aspects or features of the world. A theory is more certain (the justification for its validity is stronger) than a hypothesis.

Science is founded on the generation of hypotheses that can be further studied and enhance our knowledge. The generation of hypotheses is a creative process, based on existing knowledge, observations, experience and intuition. A hypothesis is either true or not. Science is about testing and analyzing hypotheses to decide whether they are true or not.

The formulation and analysis of hypotheses is part of the scientific method, also referred to as the 'hypothetico-deductive method' (Wolfs 1996, Wolf 2018). When using the scientific method, the researcher/scientist develops a hypothesis, tests and analyzes it through various means, and then, depending on the outcome, modifies the hypothesis or potentially rejects it. If modified, the process repeats. From the insights gained through these processes, a theory can be developed.

A theory is updated/revised in view of new evidence and knowledge, and potentially discarded.

Knowledge in the narrow sense is defined as justified beliefs (SRA 2015), whereas knowledge in the broad sense is understood as covering both knowledge in the narrow sense and related evidence, i.e. (Aven & Flage 2023):

> Knowledge (broad sense) = Knowledge (narrow sense expressing justified beliefs) + Evidence (data, information, modeling results, test results, arguments, etc.)

To be able to evaluate the appropriateness of a hypothesis, we need to distinguish between the initial stage of the knowledge process and the later stages. Initially, one needs to be careful in dismissing a hypothesis, as this could hamper the research of potentially important ideas. The scientific analysis is to conclude on whether the hypothesis is justified or not. However, in practice, there are always limitations on which hypotheses to investigate. Often, natural hypotheses arise, generated from earlier scientific work, but there is also a value aspect involved. Various non-scientific factors can influence which hypotheses to study.

Following the scientific method, a hypothesis can be falsified according to defined procedures but not proved to be true. A typical statement would be to say that, based on the available evidence, the hypothesis cannot be rejected.

In this paper, science is understood as the practice that provides us with the most reliable knowledge (i.e. the most epistemically warranted statements or most justified beliefs) that can be produced at the time on the subject matter (scope) covered by the relevant knowledge fields/disciplines (Hansson and Aven 2014). Depending on the justification, a theory can be viewed as more or less representing or being in line with this knowledge. In some cases, it is clear what is the most justified knowledge; in others, it is not. What is the best knowledge is contested. It is commonly expressed that science is a continuous 'battle' on what this knowledge is – it is about institutions and power. Different environments and schools of thought argue for their beliefs and try to influence and control the field (Bourdieu and Wacquant 1992).

Scientific papers are written adding new and improved concepts, principles, models, theories, approaches and models to the field's knowledge base. In this way science develops gradually over time. The development happens within different schools of thought and paradigms, but also across the established boundaries of these schools and paradigms. There are also more dramatic – revolutionary – changes in science, paradigm shifts, which means fundamental revisions of existing beliefs and practices, as explained by Thomas Kuhn in his pioneering work on science development (Kuhn 1970, SEP 2018). Science and what are the most justified knowledge are embedded in a social context, including worldviews, politics and economic issues (Lakatos 1978, Jagtenberg 1983, Wolters 1988). Science can be seen as a social construct - the rejection of a thesis is not a strict logical accomplishment. Risk and uncertainty science knowledge provides useful input to this construct by its clarifications of the meaning and use of key concepts such a plausibility, probability and knowledge, as will be discussed in the coming sections.

There are many schemes used to evaluate a theory. In addition to the falsifiability criterion mentioned above, common criteria are (Yadav 2010, Aven and Heide 2009):

- Solidness (conceptual clarity and internal consistency, reproducibility, precision and rationale)
- Validity (reflecting the degree to which the theory is able to represent what one would like it to represent) (explanatory power)
- Prognostic power

At the same time, it is attractive that the model is simple. Hence, there is a balance to be made, to accurately represent the relevant aspects of the world, on the one hand, while being simple enough to allow practical use of the theory, on the other.

Scientific work is also characterized by norms and standards, such as the four institutional imperatives: Universalism, Communality, Disinterestedness, and Organized Skepticism (Merton 1973, Hansson and Aven 2014).

Finally in this section, some words about 'conspiracy theories', which are commonly referred to in public and academic discourse. The labeling is theory, but there is often an associated hypothesis formulation, as in the coronavirus origin example: 'The coronavirus has a non-natural origin'. There could be many theories supporting this hypothesis. The term 'conspiracy theory' points to a conspiracy – an event happening as the result of a secret plot by powerful conspirators – however, the term is also used without reference to conspiracies (Napolitano and Reuter 2021). What is required is the perception of a bad theory or explanation – in the sense of being crazy or ridiculous but also unjustified, false and non-scientific. The former category of expressions involves morally derogatory terms, whereas the latter category relates to epistemic deficiencies.

3. A Risk and uncertainty science perspective

Risk is associated with an activity, for example the operation of a system, an investment, or life in a country or on the earth. This activity leads to some future consequences, which we denote by C, related to something that we value, for example, human lives and health, the environment and economic values. When speaking about risk, there is always at least one outcome that is considered negative or undesirable. The future consequences are uncertain, and risk is defined as the combination of C and associated uncertainties, U, expressed for short as (C,U). Often the focus is on events, A, which precede the outcomes, which leads to the alternative (A,C,U) conceptualization of risk, where C then refers to the conditional consequences, given the occurrence of A. As an example, think about A as the occurrence of a virus disease outbreak in a specific period of time. The consequences C then relate to effects on human health but also to economic, social and security types of implications.

In a risk assessment, the events and consequences are specified; we write A′ and C′ to distinguish between the actual events and consequences occurring and those that are identified and focused on in the risk assessment. Furthermore, the uncertainties are described using some measure Q ('measure' interpreted in a wide sense), typically probability P – precise or imprecise – with judgments of the strength of the knowledge (SoK) supporting the judgments. In general terms, the risk description takes the form (A′,C′,Q,K) or (A′,C′,P,SoK,K), where K is the knowledge that the judgments (A′,C′,Q) are based on, which also covers related data, information, analysis results, etc. (for short, denoted evidence).

Probability is a key concept in risk and uncertainty science, and is central in the coming discussion in this Section 3. To be able to adequately understand and communicate risk and uncertainties, the meaning of the probability concept is critical. In the above risk set-up, P is a subjective (judgmental, knowledge-based) probability, interpreted using a reference standard like an urn (Lindley 2006, SRA 2015, Aven 2020). Hence, if a probability equal to 0.10 is assigned, the assessor has the same uncertainty or degree of belief in the event occurring (or a statement being true) as randomly drawing a red ball out of an urn comprising 100 balls, where 10 are red. If the probability is imprecise, say maximum 0.10, the interpretation is similar, but then the number of red balls is not specified beyond saying that the number of red balls is maximum 10; the assessor is not willing to be more precise.

A subjective probability P of an event A, P(A), is conditional on some knowledge K, as indicated when writing P(A|K). There is a gap between this knowledge and the probability P, reflecting a subjective judgment by the analyst. Using imprecise probability, the transformation from K to P is more objective, but this does not mean that P is objective or has strong support. The knowledge K could, for example, be based on one expert judgment.

Probability is also used as a measure of variation in large (in theory infinite) population of similar units – it is then referred to as a frequentist probability (or a propensity) and is to be viewed as a component of C′. A frequentist probability p is defined as the fraction of time the event considered will occur, if the situation studied could be repeated over and over again infinitely under similar conditions. The related propensity interpretation holds that the probability is to be thought of as a physical characteristic; a propensity of a repeatable experimental set-up which produces outcomes with frequentist probability p. The distinction between frequentist probabilities and subjective probabilities is important for the coming discussion, as the former interpretation means that the concept is used to represent an 'objective' feature of the world, whereas the latter expresses an assessor's subjective judgment about uncertainties concerning an aspect of the world.

This generic set-up on risk relates to future events and consequences, but we see from the above presentation that it is general and can also relate to the past, as long as A and C are uncertain. We refer to the assessment as a risk and uncertainty assessment, to emphasize that the study is general and not limited to only future events and consequences.

In this Section 3, a set of criteria for when a hypothesis/theory can be dismissed will be discussed. Table 1 summarizes the discussion. We focus on hypotheses/statements, which can be either true or not. Theories would commonly be defined by a set of statements and assumptions, which can be either true or not. The issue of dismissing a theory is a more complex issue

Table 1. Criteria for when a statement/hypothesis can be dismissed.

	Criterion	Potential dismissal	Comments
1	Judged unthinkable/inconceivable	Yes	Care must be shown because what is considered unthinkable/ inconceivable relates to one's knowledge, and surprises occur.
2	Very low probability/likelihood	No	A subjective probability judgment is not sufficient to dismiss a hypothesis, as the strength of the knowledge that supports the probability is not reflected. The criterion cannot be used for refutation because it remains in the realm of subjectivity. The same applies to estimates of frequentist probabilities. Uncertainties of the estimates also need to be taken into account.
3	Very strong evidence/knowledge supporting a statement	Yes	Care must be shown when dismissing a statement based on evidence, as the collecting and summarizing of evidence is not an objective activity, and knowledge is not objective facts but beliefs. Criterion 3 can be viewed as basically expressing the same as criterion 4, as very strong evidence/knowledge implies very low likelihood.
4	Very low probability/likelihood and strong SoK	Yes	Care must be shown when dismissing a statement based on these criteria, as the judgments are subjective (intersubjective).
5	Implausible	No	A statement is judged implausible, meaning that the likelihood is very low and there is some evidence/knowledge supporting this likelihood judgment. The evidence/knowledge does not need to be very strong – hence the statement/hypothesis should not be dismissed on the basis of an implausibility judgment.
6	Rejection by large majority of experts	No	The message can be strong if experts from different disciplines and areas agree. It is to be expected that analysts and researchers from the same 'school of thought' agree on fundamental questions. That the majority of experts agree does not necessarily mean they are right. New knowledge is produced by challenging current beliefs.
7	References to non-scientific issues	No	Science should be the main argument for dismissing a statement.

than just making a judgment about one specific statement. One aspect of the theory, for example one assumption, could lack support, but that would not necessarily make the theory as a whole uninteresting if it provides explanations on other aspects. It is acknowledged that the theory is a type of a model of the world and, as all models are simplifications of the reality, not an exact representation of it. A model can be useful, despite having some weakness in accurately representing the world.

To illustrate the analysis, we will refer to two statements following up the discussion in previous sections:

a. COVID-19 does not have a natural origin
b. A specific vaccine is not safe

These examples have been claimed to be conspiracy theories in specific contexts. The justification of this is, however, not the issue here. The focus is on the question of potential dismissal of the hypothesis/theory, based on epistemic and scientific argumentation.

3.1. Judged unthinkable or inconceivable

If a hypothesis is stated it cannot be 'unthinkable' or 'inconceivable'. However, this criterion refers to a judgement made by someone. The hypothesis is stated but judged unthinkable or inconceivable by others, meaning that it is considered impossible for it to occur or be true. What is considered impossible relates to one's knowledge. The events of September 11, 2001 were not reasonably conceivable according to Taleb (2007), but similar types of events had occurred, although on a much smaller scale, and the type of events had been identified in risk assessments. As discussed by Glette-Iversen and Aven (2021), 'The September 11th events were not conceivable using the approaches that were actually taken, but that does not make the event inconceivable per se; had the adequate tools and strategies been applied prior to the event, it could have been conceived'. In this case we can think about a risk analyst stating a hypothesis similar to what happened in 2001, but others in the analyst team dismissing it claiming it to be unconceivable.

Considerable work has been devoted to risks related to surprises and the unthinkable (black swans) in recent years. A key strategy has been to look for signals and warnings that can point to potential surprises occurring (Paté-Cornell 2012, Aven 2015). Such signals and warnings could be decisive for not dismissing an event or a hypothesis.

3.2. Very low probability/likelihood

Can we dismiss a hypothesis A based on judgments of probability/likelihood? Consider again the coronavirus origin hypothesis a), and suppose some experts claimed it should be dismissed because it is very unlikely. Can this be justified?

As far as the present author can see, the only meaningful interpretation that can be provided for a statement like this – that the non-natural theory is very unlikely – is by the use of subjective (judgmental, knowledge-based) probabilities, as referred to in the first part of this Section 3. The probability is a way of expressing the assessor's uncertainty or degree of belief. When people make this type of likelihood judgments in scientific papers or in the news, interpretations are almost always not provided, leaving the impression that the statement has a higher level of authority than the subjective judgment of the assessor. A subjective probability P can be written as P(A|K), expressing that the probability is a judgment of A conditional on some knowledge K ('|' is to be interpreted as 'given').

As experts, the probability judgment P has interest, but it is a subjective judgment and needs to be evaluated as such. Other experts can have other judgments. The judgment P does not express the strength of the evidence or the knowledge available. The knowledge K could, for example, be based on a key assumption which is highly uncertain. This would, however, then not be reflected in P. That some experts judge the probability as very low should consequently then not be used to dismiss a hypothesis. The justification is not strong enough, as this probability is just some experts' judgment about uncertainty, their beliefs expressed using the tool probability. Hence this criterion cannot be used for refutation because it remains in the realm of subjectivity.

Case b) is somewhat different, as here it is relevant to also consider frequentist type of probabilities.

Say, for example, that, in a population of 10,000, we know that maximum 1 person will experience health problems – and these will be minor – as a result of a vaccine. We could interpret this as saying that the probability of side-effects is 10^{-4}, which would normally be judged as a rather small risk contribution, from a public health perspective. The vaccine is considered safe. What is considered an acceptable level will depend on the effectiveness of the vaccine, i.e. the difference in risk related to contracting the disease, with and without the vaccine.

The problem with the above analysis is that uncertainty and hence risk have been ignored. We may have observations from a study that show a side-effect rate of $1/10^4$, but to what extent can we be sure that the future will be similar? What about long-term effects of the vaccines and differences in effects for some groups? The tests may include rather few people in each age group and be of limited duration. The conclusion about safety should also take into account such risk factors. In statistics, this challenge is addressed by making a clear distinction between the underlying unknown frequentist probability p and estimates of this probability, p*. In risk assessments, p is estimated, and the uncertainties analyzed and characterized, typically using some type of uncertainty interval. A confidence interval is used in traditional statistical analysis, whereas credibility intervals are applied when adopting a Bayesian analysis.

To dismiss the hypothesis, it is not sufficient to focus on p*; the uncertainties also need to be addressed.

3.3. Very strong evidence/knowledge supporting a statement

There is very strong evidence that the earth is not flat. The knowledge supporting the rejection of the statement that the earth is flat is strong. The evidence and knowledge are so strong that uncertainty is not an issue. The hypothesis/statement is dismissed.

In 2020, there was evidence supporting both the natural and the non-natural coronavirus origin explanations. The authors of the *The Lancet* letter focused on evidence supporting the former hypothesis. A judgment on the strength of the evidence and knowledge conducted by these authors themselves would clearly have resulted in the conclusion that there was strong evidence and knowledge supporting the rejection of the non-natural explanation. The example demonstrates that any such judgment is subjective (or inter-subjective) and hence needs to be evaluated as such by decision makers and other stakeholders. Clearly, in this case, the judgments made by these authors were not influenced only by scientific data and reasoning.

Different systems have been proposed for evaluating the strength of the evidence and knowledge (e.g. Berkman, Lohr, and Ansari 2008, IPCC 2010, Flage et al. 2014). Two examples are presented below.

The Intergovernmental Panel on Climate Change (IPCC) uses three categories of evidence strength: limited evidence, medium evidence and robust evidence (IPCC 2010). Generally, evidence is considered robust 'when there are multiple, consistent independent lines of high-quality evidence' (IPCC 2010). The evidence strength is combined with judgments of expert agreement, to provide a measure of 'confidence' in findings (statements), using five qualifiers: very low, low, medium, high, and very high. Here is an example of an IPCC statement (IPCC 2022, 1096): 'Climate change is projected to exacerbate malnutrition' (high confidence).

This means that there is high confidence that the statement 'Climate change is not projected to exacerbate malnutrition' is false. Hence, statements indicating that climate change would not exacerbate malnutrition could be dismissed. Against such a conclusion, it can be argued that relevant contradicting data/information could have been overlooked or given too little attention. The point made is generic: collecting and summarizing evidence is not an objective undertaking. In the case of medium or limited evidence, there is not a basis for dismissing the statement.

The second system is based on knowledge strength judgments (Flage et al. 2014, Aven and Flage 2018). The following criteria are used to evaluate the strength of knowledge:

- The reasonability of the assumptions
- The amount and relevancy of data and information
- The degree of agreement among experts
- The degree to which the phenomena and processes involved are understood and accurate models exist
- The degree to which the knowledge has been thoroughly examined (for example, with respect to 'unknown knowns': i.e. others, but not the analysis group, have the knowledge).

Different types of qualitative scoring systems have been suggested based on these criteria (e.g. Aven and Flage 2018, Aven 2020), with typical categories of strong, medium and weak strength of knowledge. If there is a strong knowledge judgment supporting a statement A, it indicates that the opposite statement could be dismissed. Care must be shown, as knowledge is not objective facts but beliefs. We will discuss this category in more detail in the coming Section 3.4. We argue that the criterion 'very strong evidence/knowledge' discussed in this Section 3.3 in fact basically expresses the same as the criterion considered in Section 3.4. Tacitly, 'very strong evidence/knowledge' supporting a statement implies very low likelihood/probability of this statement being false.

3.4. Very low likelihood/probability and strong supporting knowledge

Risk science points to theory expressing the link between confidence in a statement, and the combined use of subjective (precise or imprecise) probabilities and associated knowledge strength judgments (e.g. Aven and Renn 2015, Aven 2019). A low judged probability/likelihood P of a hypothesis based on strong knowledge K, means confidence that the hypothesis is not true and hence it can be dismissed. However, care must be shown. The analysts may consider K to be strong, but it could conceal uncertainties, and others could judge the strength differently. Even if there is broad consensus about the validity of some beliefs or assumptions, there is a potential for surprise. Making judgments about the knowledge and evidence strength is not objective. Knowledge can be more or less strong and also erroneous. This fact makes the assessment of statements and hypotheses challenging – the judgment could have strong elements of subjectivity and also be influenced by values, as seen in relation to the coronavirus origin case.

3.5. Implausibility

Authors commonly use the terms 'plausible' and 'implausible' in relation to statements and hypotheses, for example in climate change risk settings. The terms capture a combined judgment of probability (typically imprecise and qualitative) and judgments of the strength of the knowledge supporting the probabilities (Glette-Iversen, Aven, and Flage 2022). Hence, if a statement is judged implausible, it can be interpreted as stating that the likelihood is very low and there is some evidence/knowledge supporting this likelihood judgment. However, the evidence/knowledge does not need to very strong. Hence, the statement/hypothesis should not be dismissed on the basis of an implausibility judgment.

3.6. Rejections by a large majority of experts

The fact that the vast majority of researchers are convinced of something does not mean that they are necessarily right. Within risk science, the present author has often been quite alone in arguing for seeing risk as more than probabilities and expected values. If one had taken a survey among a large number of risk analysts and researchers, my position would, in many cases, be neglected if one were to form one vote based on the entire sample. A conclusion could be reached, built on high 'confidence'. From my point of view, however, such a conclusion would be completely misleading as a characterization of risk science knowledge. Many similar examples can be presented showing the problem of using the majority of researchers as the reference for the truth about a scientific matter. We know that science is very much about challenging current beliefs. New knowledge is gained by questioning current ideas and perspectives. Analysts and scientists commonly belong to 'schools of thought' – building on the same stands on key concepts, principles and methods. It is thus to be expected that there is unity among many scientists and scholars within specific disciplines and areas. If agreement among experts can be obtained beyond the disciplines, the message is considerably stronger.

3.7. References to non-scientific issues

In the coronavirus example, the authors of *The Lancet* article used not only epistemic arguments but also derogatory terms – by reference to conspiracy theories, to discredit and reject alternative explanations. The conspiracy term is used as a discursive weapon. There are reasons to believe that the aim of the authors of *The Lancet* letter was to contribute to a dismissal of the non-natural origin theory.

Some authors, like Douglas and Sutton (2015), state that conspiracy theories are dangerous. These authors refer to literature which associates conspiracy theories with factors such as uncertainty, feelings of powerlessness, political cynicism, magical thinking, and errors in logical and probabilistic reasoning. In relation to climate change, these authors state that these theories 'present a significant challenge for governments and environmental organizations that are attempting to convince people to take action against global warming'.

This type of attitude to conspiracy theories is common. It puts a broad spectrum of theories – and associated people – into one category: theories which per definition are wrong, unjustified and also harmful. Concerns, for example that a vaccine is not safe or that climate change is not an apocalyptic threat, are raised by different groups of people, lay people but also experts, with very different beliefs about the magnitude and form of conspiracies. For many, the main concern is the epistemic issue, not the conspiracies; yet, they meet claims that they are conspiracy theorists. The attitude reflected in the second paragraph of this section contributes to this, as there is an official view – that the vaccine is safe and we should all be vaccinated, and that climate change is an apocalyptic threat and dramatic and urgent actions are needed - following some defined beliefs on how to obtain the desired results. All questions and concerns about the official views represent a disturbance which hampers the implementation of the related policies: getting people vaccinated and taking strong action against global warming. If the policy implementation of the official stand is the main focus, such a broad categorization of alternative perspectives could be seen as beneficial. For the sake of obtaining efficient risk handling, it is seen as acceptable to limit scientific debates about 'technicalities' and 'minor issues'.

As used today, the term 'conspiracy theory' is largely a political concept (Cassam 2019). The motivation for labeling theories 'conspiracy theories' is not easily separated from the analysts' political and ideological stands, for example on how individual freedom should be balanced against public safety. If the society as a whole is the most important thing, people that strongly emphasize individual freedom represent a challenge or a threat, and vice versa. If the analysts are themselves actively supporting the official public perspective, there is a risk that nuances in alternative perspectives are ignored or distorted, also by intention. What matters is discrediting certain ideas to obtain a political goal.

If, however, the perspective is improved risk understanding, rather than policy implementation, the conspiracy term is difficult to use. It is a derogatory term that hampers proper scientific studies, which continuously and in a setting of open and honest debate challenge existing beliefs and explanations, to obtain new and better insights. Science can be seen as threatened by conspiracy theories, but it can also be argued that the use of this term threatens science. Science needs to rationally assess all hypotheses and assess risk and uncertainties according to the best knowledge available, in line with the ideas discussed above.

4. Conclusions

Science is concerned with searching for the truth, related to events A and consequences C, and improving the risk understanding. Science has an important role in society; however, it is not one voice telling us the truth (about A and C) but one giving judgments about the truth, in the form of (A',C',Q,K). We should always question these judgments. Generating and studying alternative ideas and perspectives challenging current beliefs are essential elements of the scientific process, and caution must be shown in dismissing hypotheses too early. In principle, a hypothesis can be dismissed if it is judged very unlikely and the knowledge (in the narrow or wide sense) supporting this judgment is very strong. However, even when this criterion can be applied, care must be shown in dismissing hypotheses, as knowledge is not objective. Beliefs and key assumptions can be wrong, even if they are justified. There are also risks that the science process is influenced by political agendas, making it critical to not close investigations of ideas which are not in line with the official views. Care must also be shown regarding the use of derogatory terms like 'conspiracy theory' in the scientific discourse. It can be a ruling technique which undermines proper scientific analysis. Meaningless and absurd ideas should be refuted by proper arguments.

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