The Handbook of Rationality

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14.3 Rationality and the Public Understanding of Science

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Summary

Science[1] and rationality are strongly linked. Therefore, the *public understanding of science*[2] is crucial for rationality as an everyday mode of reasoning. However, the knowledge provided by science is distinct from everyday thinking to a large degree, and at least nonscientists' understanding of it is limited. This chapter will provide an overview of the tension between the significance of science as a source for rational reasoning and the boundedness of nonscientists' understanding of science. It will be argued that *trust* is a key concept for analyzing how people cope with this boundedness. It will be elaborated why asking *Whom to believe?* is a rational way for citizens to reason about the truth of scientific knowledge claims. Then, *motivated reasoning* and *knowledge* as psychological conditions for judging what to believe and whom to trust will be discussed. Finally, the question about rationality within the public's understanding of science will be placed into the context of controversies between normative and descriptive accounts of rationality.

1. The Nexus between Science and Rationality

Rational inferences as well as rational beliefs are deemed valid because their validity has been established by scientific methods. Why is it justified to evaluate a Bayesian inference about the probability of an event as a rational inference? Why is it justified to evaluate the belief that objects move at a constant speed as a rational belief? In both cases, these justifications have been established by the scientific community as *scientific* knowledge (Bayes' theorem, Newton's first law). Rational decisions about the acceptance or rejection of such inferences and beliefs are therefore embedded in the acceptance of scientific background knowledge. In this regard, science is a source for establishing normatively what is "rational." Conversely, the production and justification of knowledge is accepted as *scientific* only if it can be described as rational.

The relationship between science and rationality is strong, but they are not equivalent concepts: it is possible to make rational inferences without reference to scientific knowledge. Conversely, rationality is necessary for science but not a sufficient condition for science.[3] This can be illustrated by the problem of demarcating between science and pseudoscience (e.g., creationism, climate change denialism, homeopathy, flat-earth theories, chem-trail theories). Pseudoscientists claim to adhere to scientific criteria of truth, they provide supposedly supporting evidence, and they mimic scientific discourse, especially when attacking real science. In this regard, pseudoscience is different from conspiracy theories and mere superstition, although the boundaries between these kinds of belief frameworks are fuzzy, and belief in one is correlated with belief in the other. There is no set of precise necessary and sufficient criteria for the demarcation between pseudoscience and science, but it is possible to tell them apart because pseudosciences typically ignore some of the criteria of science, for example, the need for coherence among its theoretical propositions (Law, 2020; Mahner, 2013). The validity of scientific inferences is not guaranteed solely by their adherence to normative rules of rational reasoning. All rational reasoning refers to some background knowledge about the world (Chater & Oaksford, 2012). The problem of demarcating between pseudoscience and science illustrates that "rationality" is not just an issue of adhering to norms of reasoning but also an issue of adopting shared assumptions about the world. For example, the inference that the dilution of a pharmaceutical agent increases its potency (a basic tenet of homeopathy) could be deemed rational as long as it is consistent with background beliefs about a world including the capacities of substances to store and to transmit health-related information irrespective of molecular concentrations. Hence, there could be a *local* rationality within the worldview of pseudoscientists. Nevertheless, in a more global sense it is not rational, because these background beliefs can be justified only by selectively ignoring contradicting evidence and arguments.

The validity of this background knowledge about the world does not *have to* be established as scientific knowledge, but with regard to many domains of our lives, it *can*[4] only be established as scientific knowledge. The strong nexus between science and rationality follows from the fact that the understanding of the actual structure of our environment (the natural and the social world) is formed by science. Modern societies rely on all kinds of artifacts (technological as well as social) that have been developed by means of scientific knowledge. Moving successfully in this world requires at least a certain degree of understanding and acceptance of this scientific knowledge, although it is possible (for some people within some contexts) to live without such acceptance, as the case of pseudoscience believers shows. In this regard, rationality also rests on the (public) acceptance of what can be taken as "true" (in the sense of scientifically justified) worldviews, not only on the local adherence to certain rules of rational reasoning. This does not mean that such a public acceptance can be taken for granted; it has to be maintained continually, for example, via schooling and science communication. In other words, a "public understanding of science" (PUS) (in a sense that will be detailed below in this chapter) is crucial for rationality.

Because of this nexus, analyzing the public understanding of science could contribute to understanding rationality and its limitations among the general public. There are roughly three strands of research providing empirical insight into conditions and processes of citizens' understanding of science: (a) research on the emergence and fostering of *scientific literacy* (SL), typically focused on children and young adults in formal learning contexts; (b) studies about the processing and acceptance of scientific beliefs, typically focused on adults encountering scientific claims via the media; and (c) studies about the personal stances toward science held by different segments of the general public, typically based on representative surveys.

2. What Is Meant by *Public Understanding of Science*? In Which Sense Is This Understanding *Bounded*?

Scientific literacy (SL) and the public's bounded[5] understanding of science are related but distinct concepts. According to a recent definition, covering widely shared notions of SL, a scientifically literate person has the competencies to "explain phenomena scientifically—recognise, offer and evaluate explanations for *a range of natural and technological phenomena*. Evaluate and design scientific enquiry—describe and appraise scientific investigations and propose ways of addressing questions scientifically. Interpret data and evidence scientifically—analyse and evaluate data, claims and arguments in a variety of representations and draw appropriate scientific conclusions" (OECD, 2016, p. 13, emphasis added). Based on this definition, international studies within the PISA project revealed a large variance in the degree of SL, between countries as well as between individuals. In this regard, it can be assumed that—at least for large parts of the general public—the individual understanding of science is limited.

However, there are further limitations. SL typically refers to knowledge items and to the kinds of scientific reasoning that are taught in schools (DeBoer, 2000). These knowledge items are in principle *understandable* for the general public without specialized science training. Furthermore, they contain knowledge that has been established as *certain*, at least within the pertinent scientific community. Understandability and certainty are conditions for including a piece of knowledge in the school curriculum. Therefore, only a narrow selection of all the scientific knowledge and all the kinds of scientific reasoning (Kind & Osborne, 2017) can be included. In contrast, everyday encounters with natural and technological phenomena are confined neither to *understandable* nor to *certain* scientific knowledge. Parents reason about the actual or supposed scientific evidence put forward in favor of certain educational practices, patients reason about contradictions between their doctors' arguments and what they read on the Internet, and citizens reason about contradicting arguments concerning the feasibility of carbon storage as a means of reducing global warming. In this regard, public understanding of science refers to a much broader spectrum of citizens' encounters with science than the concept of SL. Furthermore, which topics emerge within the public discourse is not limited to topics that are understandable or certain. Which topics are receiving attention by the general public reflects practical problems on a personal (Feinstein, 2011) as well as a societal level and—in a mutual relationship—the media coverage of certain topics (National Academies of Sciences, Engineering, and Medicine, 2017). Thus, neither understandability nor certainty of knowledge is a limiting factor for which topics emerge within the public discourse about science.

There are further epistemological as well as psychological reasons to conceive the boundaries of understanding science as a constraint on the public's encounters with science. One epistemological reason is the complexity of scientific knowledge. This refers to the possibly unlimited depth of scientific explanations (Keil, 2010).

Additionally, there are the epistemic, social, and technological complexities of the methods and procedures necessary to establish a scientific knowledge claim as a true belief about the world. Nowadays, the production of scientific evidence is based on an elaborate *division of cognitive labor*, which is mirrored in the disciplinary structure of science as well as in the volatility of this structure.

A further epistemological reason refers to the qualitative differences between the objects, models, and methods of science, which refer to a certain piece of the natural or the social world and the everyday experiences with this piece. The emergence of science in modern history has also been a history of separating a scientific understanding from an everyday understanding of the world (Wolpert, 1992). Many entities of science could not be experienced with the unaided senses. Even concepts that are well established in our everyday reasoning, like "bacterium," "virus," or "gene," refer to entities that we cannot experience without technology. Some processes can only be modeled mathematically, for example, in nuclear physics. Others extend the number and kinds of dimensions that make up our everyday experience of the world. Such models can be linked to everyday reasoning only by way of analogies (Boudry, Vlerick, & Edis, 2020).

Research on the psychological differences between scientific and everyday knowledge has found systematic misconceptions (from a normative, i.e., scientific, point of view) in several domains of knowledge (Shtulman, 2017). Such misconceptions are robust, and even after science instruction, they still coexist with elements of scientifically justified knowledge. Two prominent features of everyday thinking illustrate that these differences are not due to a void within individual knowledge structures (and should thus not be explained in terms of a deficit model) but due to the stability and local coherence of the already existing knowledge. Both features refer to ontological differences between the kinds of categories used in scientific modeling and in everyday thinking: everyday reasoning prefers explanations in terms of substances and their features, while scientific thinking requires an understanding of relationships. For example, concepts like mass, energy, and heat are—from a physics point of view—concepts about relationships, while in everyday reasoning, they are dealt with as features of objects (Slotta & Chi, 2006). Everyday reasoning accepts "essences" as sufficient causes for explaining phenomena. In this vein, genetic explanations are popular in everyday reasoning about developmental and behavioral patterns of humans because they causally link the essence-like genes with these outcomes (Heine, Dar-Nimrod, Cheung, & Proulx, 2017).

This boundedness of science understanding is not fixed, neither historically nor individually. Specialist knowledge can become part of the school curriculum, as has been the case with concepts from nuclear physics or molecular genetics. These are examples for historic shifts of the boundary between specialist knowledge and public knowledge, at least for well-educated citizens. Appropriate instructional environments (e.g., science education in schools, lab experiences in science museums) can increase individual scientific literacy. Well-designed information about health issues, nuclear physics, or climate change is available. It is possible to increase scientific knowledge about topics of public interest. This is what strategic public-understanding-of-science campaigns are aiming for.

Nevertheless, this does not nullify the constraining effect of the previously outlined boundaries of understanding science for nonscientists. Such boundaries matter especially when it comes to *conflicting* scientific knowledge claims. When citizens look up health-related information on the Internet (e.g., about the relationship between nutrition, body weight, and illnesses), they will come across claims that do not align with each other or with claims made by their medical specialist. Even when citizens look up evidence for the existence of climate change, they will come across contradictory voices. Hence, there are not only conflicts between claims put forward by different scientists but also—and practically more important—conflicts between the claims of scientists and those of actors who would not be conceived as members of the scientific community, for example, deliberate science deniers, quacks, preachers of esoteric belief systems, conspiracy theorists, and "merchants of doubt" (Oreskes & Conway, 2010).

Often, the claims themselves and the reasoning by which they follow from the evidence are understandable. When they are presented well, they can be understood by nonexperts, even with a low level of SL. However, when reasoning about which of the conflicting knowledge claims is true and which is false, the abovementioned boundaries of public understanding matter. In a British survey (Castell et al., 2014), 70% of respondents agreed that there is so much conflicting information that it is hard to know what to believe.

3. Whom to Believe? The Role of Trust in Reasoning about Scientific Knowledge Claims

When coming across conflicting claims, one could evaluate these claims as more or less plausible and then accept one as a subjective belief. But with regard to many topics, most members of the general public are not able to decide by virtue of their own understanding of the relevant topic *which* scientific knowledge claim should be adopted as a true belief (in the sense of being justified scientifically).

Another way of coping with the encounter of competing knowledge claims could be a shift from the question of the plausibility of the content ("What to believe?") toward the question of the trustworthiness of its respective sources ("Whom to believe?"). The latter question is both logically and empirically quite different from the former. *Trust* is a kind of willingness to depend on others. Whenever people are dependent on other agents (persons or organizations), and whenever they are willing to accept the risks that come along with this dependency, they (the "trustors"; Blöbaum, 2016) put trust into these agents (the "trustees"). In the context of science, the good that the trustee provides to the trustor is "knowledge," and the risk to the trustor is his or her vulnerability to a lack of truth or validity of that knowledge (Hendriks, Kienhues, & Bromme, 2016). This is called *epistemic trust* (Sperber et al., 2010). Judging the validity of a claim on the basis of an ascription of trustworthiness to the source has been called the "argument from authority" or "argumentum ad verecundiam." Its logical form is "According to person *A*, who is an expert on the issue of *Y*, *Y* is true. Therefore, *Y* is true." This is, from a classical logical perspective, a fallacious inference (Cummings, 2014), and it seems to be at odds with scientific reasoning and argumentation. A core principle of modern science is to *know* the truth instead of just trusting what you are told. "Historically, this individualistic stance could be seen as a reaction against the pervasive role in Scholasticism of arguments from authority" (Sperber et al., 2010, p. 361). Only a minority of philosophers and historians of science have emphasized the role of *trust* in science, and the ones who do focus mostly on how it relates to doing science and only to a lesser degree on science communication with the public (Hardwig, 1991; Irzik & Kurtulmus, 2019; Wilholt, 2013). However, the main argument for trust within science, the division of cognitive labor,[6] is the same reason why trust is essential in the general public's encounter with science (Bromme & Goldman, 2014; Levy, 2019).

Within informal reasoning, the argument from authority is a legitimate inference (Cummings, 2014; Keren, 2018). It is a shift of the *topic* of rational reasoning (from "What to believe?" to "Whom to believe?"), not the *denial* of rationality. Reasoning about "Whom to believe?" requires thinking about science, not as a cognitive structure, but as a social system.

Research has revealed that judgments about trust in scientists involve three dimensions (although the terminology is not consistent), which are in line with trust research in other domains: expertise, integrity, and benevolence (Cummings, 2015; Hendriks, Kienhues, & Bromme, 2015; Peters, Covello, & McCallum, 1997). *Expertise* refers to someone's amount of knowledge and skill. The dimension of expertise also encompasses the aspect of pertinence (Bromme & Thomm, 2016): the person must have the *relevant* expertise. *Integrity* refers to adherence to the rules of the profession and—in the context of science—to the intention to produce "true" (unbiased) knowledge. *Benevolence* refers to taking into account the interests of the trustor or (more generally) the goods of the scientist's work for society. Importantly, people recognize that a scientist can have his or her own interests in mind and still be benevolent (Critchley, 2008).

When do people shift from a "What to believe?" toward a "Whom to believe?" strategy? Recent research on the conditions under which people pay attention to source information to assess the quality of knowledge claims (Bråten, Stadtler, & Salmerón, 2017; Bromme, Stadtler, & Scharrer, 2018) has corroborated two main results: first, there is no *spontaneous* attention to sources, and thus perceived content quality is unaffected by source information. Second, people only actively process source information when encountering some kind of *discrepancy*. Such discrepancies can be perceived when claims are inconsistent, either *within the same* piece of information or *across two or more different* pieces of information or *between the piece of information and prior beliefs* held by the recipient. When such discrepancies occur and people turn to the source information to determine which claim is correct, both types of judgment inform each other: on the one hand, people make inferences about the trustworthiness of sources based on their willingness to accept the messages provided by these sources. On the other hand, assumptions about a source affect judgments about the plausibility of their claims (Hahn, Harris, & Corner, 2009; Lombardi, Seyranian, & Sinatra, 2014; Thomm & Bromme, 2016).

There is a preference for immediate judgments about the plausibility or believability of claims; people seem to be *epistemic individualists* (Levy, 2019). There are different approaches to explaining this default preference. It could be explained as a case of a general *overconfidence regarding one's own knowledge* (Atir, Rosenzweig, & Dunning, 2015), as a case of a more specific *illusion of explanatory depth*—confined to the assumed understanding of causal mechanisms (Mills & Keil, 2004)—or as a kind of fluency effect, called the *easiness effect*. Scharrer, Stadtler, and Bromme (2014) asked laypersons to read short texts containing medicine-related knowledge claims. In all conditions, judging the validity of the medical claims was clearly beyond laypersons' medical or biological knowledge, but the texts varied regarding their lexical simplicity (easiness). Subjects who read the easier (but still conceptually very difficult) texts reported a lesser need for further expert advice to judge the credibility of the claim. However, this *easiness effect* was mitigated when subjects were explicitly told about the epistemic complexity of the medical topic. Awareness of the epistemic complexity matters for people's beliefs about the explanatory power of science. It seems to be a condition for *deference to science as an epistemic authority.*

4. Conditions for Judging What to Believe and Whom to Trust: Motivated Reasoning and Knowledge

Recent research on the public understanding of science—especially within the abovementioned strands (b) (studies about the processing of scientific beliefs) and (c) (studies about the personal stances toward science held by different segments of the general public)—has put a strong emphasis on the public's personal *acceptance* of specific scientific claims, on their *general appreciation* of science, and on the public's *trust* in science and scientists (Hendriks et al., 2016; Rutjens, Heine, Sutton, & van Harreveld, 2017).

This research focuses more on *attitudes* about science rather than on the *understanding* of science in the sense of the abovementioned research strand (a), regarding scientific literacy. Nevertheless, since attitudes refer to beliefs about the world, they matter for reasoning about the world and hence for rationality. This shift in focus has been fueled by evidence about the weak and sometimes inverse relationship between knowledge *about* science and *acceptance* of scientific knowledge as valid beliefs. Additionally, it has been fueled by findings pointing to the impact of attitudes, religious and political beliefs, group norms, personal identity, self-concepts, and personal goals on the processing of science information. Recent research on public understanding of science conceptualizes such processing as *motivated reasoning* (Kunda, 1990), subsuming these personal goals and beliefs as "motivations" for (biased) reasoning in favor of results that align with these motivations. Both the impact of knowledge and that of such motivations on reasoning are crucial for rationality and will hence be discussed in the following.

Motivations matter for the *selection* of information as well as for its subsequent processing. Selective exposure and selective avoidance, respectively, can lead to so-called echo chambers, in which people only hear what they already believe. Regarding the relative importance of these processes, people's preference for belief-confirming information seems to be stronger than their avoidance of belief-disconfirming information (Garrett, 2009). Motivated reasoning[7] in general, and so-called defensive motivations in particular, could lead people to discount belief-disconfirming evidence by devaluating science in general or by doubting its ability to provide true knowledge about critical issues (Munro, 2010). For example, computer gamers disparage research on negative consequences of playing violent video games due to anger about the goal of this research and the stigmatization of gamers that they perceive to go along with it. This devaluation of the critical research findings generalizes to the entire research about video games (Nauroth, Gollwitzer, Bender, & Rothmund, 2014). Indeed, being a member of a certain social group, be it gamers, parents, or supporters of a certain political party, often provides motivations that affect reasoning. In the United States, Republicans and Democrats differed in their opinions on 16 socioscientific issues, from mandatory childhood vaccinations to climate change and the teaching of evolutionary theory (Blank & Shaw, 2015). In fact, that Democrats are more likely to accept the existence of anthropogenic global warming is the most extensively studied case of how political opinions affect science attitudes and trust.

Typically, the main focus of such controversies is rather political or cultural than scientific (Who will have to pay, in any sense, for human-caused climate change?), but citizens' beliefs about the validity of the implied scientific knowledge claims (e.g., about effects of carbon emissions on the mean temperature) are affected by these debates and by the political and ideological landscape of a society (Gauchat, 2012). For example, Lewandowsky and Oberauer (2016) have shown that beliefs in the importance of free markets are negatively correlated with the acceptance of human agency as the cause of climate change. Some researchers on PUS argue that the affiliation with a certain *culture* (a set of related political, ideological, and religious stances) is the main predictor for the appreciation of science and for the acceptance of scientific knowledge claims as valid (Kahan, Jenkins-Smith, & Braman, 2011). It is questionable if these patterns of beliefs and affiliations to social groups within a society are properly described as *cultures* (van der Linden, 2016), but there is enough evidence that such belief systems impact directly on the acceptance of scientific claims as true beliefs and on trust in science. Examples for the impact of belief systems are *framing effects* in reasoning. In a study in the United States, by simply substituting the term "climate change" for "global warming" on a survey questionnaire, Republicans were rendered more willing to indicate agreement with its existence (Schuldt, Roh, & Schwarz, 2015).

These belief systems and reasoning directed by them also modify the role of knowledge for the public's trust in science as well as for the acceptance of specific scientific claims. Early strategic endeavors for an improvement of the public understanding of science followed a coarse enlightenment heuristic: "If the public *understands* science, it will *believe* in science and support scientists." However, it rapidly became evident that this heuristic is flawed. There is a positive but small correlation between general knowledge about science and general trust in science (Allum, Sturgis, Tabourazi, & Brunton-Smith, 2008; Shi, Visschers, Siegrist, & Arvai, 2016). In contrast, when it comes to topics that are linked to political, religious, or cultural debates, the relationship between specific knowledge about the critical topic and trust in scientific evidence about this topic is mediated by the relevant belief systems: Kahan et al. (2012) found higher levels of science knowledge being related to increased polarization between Republicans and Democrats in regard to global warming belief. Similarly, accuracy of vaccination beliefs was most polarized among well-educated Americans (Joslyn & Sylvester, 2019). Broader science knowledge could enable people holding extreme beliefs (e.g., climate change deniers) to employ analytic reasoning strategies in order to reject belief-disconfirming evidence (Lewandowsky & Oberauer, 2016). Nevertheless, it is important to emphasize that these findings apply only to those who hold extreme beliefs about publicly debated topics and cannot be taken as a complete rebuttal of the abovementioned enlightenment heuristic. Carefully constructed and compelling counterarguments, such as the mechanistic explanation of global warming (Ranney & Clark, 2016), could lead to attitudinal change, as they are difficult to refute (Lewandowsky & Oberauer, 2016).

5. Public Understanding of Science as a Play and a Stage for the Tension between Normative and Descriptive Accounts of Rationality

The relationship between actual reasoning and normative models of reasoning is a core issue within controversies about the nature of rationality (see also the Introduction by Knauff & Spohn, chapter 1.1 by Sturm, and chapter 1.2 by Evans, all in this handbook), even if science communication and citizens' understanding of science are mostly not explicitly discussed in controversies about the nature of rationality. The boundedness of nonexperts' understanding of science points to a tension between the way in which science (as an ideal epistemic agent) reasons about the world and the way nonscientists do so in everyday contexts. In a sense, the public understanding of science is a case of this tension (merely a further play), just as reasoning within other domains of knowledge and of life are other plays. In another sense, the public understanding of science is also the overarching societal context (the *stage* for all these plays) for rationality, because—as was argued at the beginning of this chapter—there is a strong nexus between rationality and science. If it is true that science provides the means for discerning between different beliefs about the world on a rational basis, then the public's capability for rational reasoning is inevitably entrenched in its capability to understand science and its models of the world (i.e., scientific knowledge). When descriptive accounts of rationality aim to scrutinize the variance of rational reasoning in the general public, they do so on the stage of public understanding of science. Therefore, assessments of this variance (Stanovich, 2016) include subscales measuring scientific beliefs about the world.

Within the controversies about the nature of rationality, there have been several accounts arguing that the boundedness of reasoning (from a normative point of view) is no limitation for other kinds of rationality (see chapter 8.5 by Hertwig & Kozyreva and chapter 10.6 by Cosmides & Tooby, both in this handbook). Like others within research on the public understanding of science, we, too, argue in this vein. Judging the trustworthiness of researchers and of science in general is a rational strategy for overcoming the boundedness of a direct understanding of science. The topic of this reasoning about trustworthiness is science as a social system, not science as a cognitive structure with its unlimited depth of possible causal relations.

Citizens' capability to make such judgments is less bounded than their capability to judge which claims from a set of competing claims are true.[8] Science is a social subsystem of modern societies. Judgments about the trustworthiness of its actors require knowledge about this subsystem. Knowledge about the scientific consensus regarding a certain topic belongs to this knowledge. Knowledge about science institutions, about their affiliation with different (vested) interests, about reasons for dissent among scientists (Thomm, Hentschke, & Bromme, 2015), and about limitations and failures of science experts (Burgman, 2016) are further examples. The very fact that especially deniers of climate change underestimate the consensus about this topic (van der Linden, Leiserowitz, Feinberg, & Maibach, 2015), even if they have some understanding of its mechanisms, points to the role of this kind of knowledge for trust judgments. Of course, such knowledge must be acquired, and its acquisition is related to a wide range of educational experiences.[9] Nevertheless, this knowledge is more general than knowledge about specific science topics, because the criteria for judging the trustworthiness of different sources are less domain specific than the criteria for judging the validity of a specific knowledge claim. Furthermore, the social subsystem of science has common features with other subsystems within a society (education, health, industry) in which citizens have personal experience. Hence, knowledge about criteria for making rational judgments about the trustworthiness of science could be linked to these experiences. For example, a possible detrimental effect of vested interests on a source's epistemic trustworthiness could be experienced also in everyday contexts. Another example: consensus matters also for establishing what is true within other domains of rationality (Mercier & Sperber, 2017). This is not to argue that such reasoning is infallible and immune to the previously described effects of motivated reasoning. However, reasoning about science as a trustworthy source of knowledge contributes to maintaining a broad stage for rationality within society.

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Notes

1. "Science" is used here in the comprehensive sense of the German notion *Wissenschaft*, including the social sciences as well as the humanities.

2. Here we use the *analytic* concept "public understanding of science," which embraces all kinds of citizens' encounters with science, while the *strategic* notion of "Public Understanding of Science" typically refers to educational attempts (e.g., campaigns, books, events) to improve the public appreciation of science or to deliberate marketing attempts for increasing the public's acceptance of science (Bromme & Goldman, 2014).

3. Peels (2020), in a critique of scientism, provides convincing arguments why it is not justifiable to claim that *only* scientific propositions could be deemed rational. Gottlieb and Lombrozo (2020) provide examples of, as well as reasons for, the *limits* of scientific explanations as well as people's intuitions about such limits.

4. The concept of *epistemic rationality* is even more strongly linked with science; it refers to "how well beliefs map onto the actual structure of the world" (Stanovich, 2012, p. 434), and beliefs about this *actual* structure could not be as arbitrarily established as beliefs about aliens.

5. The emphasis on the boundaries of the public's understanding of science should not be mistaken for the *deficit model* of science communication. This model assumes that it is just a lack of appropriate information that predicts people's rejection of science. Recent reports on PUS start with a stark rejection of this model, motivating a focus on other predictors like values and attitudes (e.g., National Academies of Sciences, Engineering, and Medicine, 2017; but see Suldovsky, 2016). Such predictors will be discussed below, but we would argue that the interplay between attitudes, values, and knowledge within reasoning could not be understood if the very fact that there are boundaries of understanding is downplayed.

6. Keren (2018) provides arguments (based on a social epistemology approach) why reliance on the experts' consensus is a rational way of reasoning for nonexperts, while it would be inappropriate for science as an epistemic community.

7. Druckman and McGrath (2019) argue that *all* reasoning is motivated and that these cases of denying scientific evidence are not due to a deliberate rejection of evidence but to different criteria for what counts as evidence.

8. Interestingly, representative democracy is based on a similar assumption. All citizens—as voters—are deemed to be able to make informed choices between different politicians (Goldman, 1999; critically Baurmann & Brennan, 2009). It is assumed that they have sufficient capability to judge rationally whom to trust for solving political problems, even when they could not solve these problems by virtue of their own capacities.

9. Recent educational approaches for analyzing and fostering citizens' capacity to deal with information found in the Internet put a strong emphasis on such trust judgments (Barzilai & Chinn, 2019; Stadtler, Bromme, & Rouet, 2018; Tabak, 2015).

References

Allum, N., Sturgis, P., Tabourazi, D., & Brunton-Smith, I. (2008). Science knowledge and attitudes across cultures: A meta-analysis. *Public Understanding of Science*, *17*(1), 35–54.

Atir, S., Rosenzweig, E., & Dunning, D. (2015). When knowledge knows no bounds: Self-perceived expertise predicts claims of impossible knowledge. *Psychological Science*, *26*(8), 1295–1303.

Barzilai, S., & Chinn, C. A. (2019). Epistemic thinking in a networked society: Contemporary challenges and educational responses. In Y. Kali, A. Baram-Tsabari, & A. Schejter (Eds.), *Learning in a networked society* (Vol. 17, pp. 57–77). Cham, Switzerland: Springer.

Baurmann, M., & Brennan, G. (2009). What should the voter know? Epistemic trust in democracy. *Grazer Philosophische Studien*, *79*(1), 157–186.

Blank, J. M., & Shaw, D. (2015). Does partisanship shape attitudes toward science and public policy? The case for ideology and religion. *Annals of the American Academy of Political and Social Science*, *658*(1), 18–35.

Blöbaum, B. (Ed.). (2016). *Trust and communication in a digitized world: Models and concepts of trust research*. Berlin, Germany: Springer.

Boudry, M., Vlerick, M., & Edis, T. (2020). The end of science? On human cognitive limitations and how to overcome them. *Biology & Philosophy*, *35*, 18.

Bråten, I., Stadtler, M., & Salmerón, L. (2017). The role of sourcing in discourse comprehension. In M. Schober, D. N. Rapp, & M. A. Britt (Eds.), *Handbook of discourse processes* (pp. 141–168). New York, NY: Taylor & Francis.

Bromme, R., & Goldman, S. R. (2014). The public's bounded understanding of science. *Educational Psychologist*, *49*(2), 59–69.

Bromme, R., Stadtler, M., & Scharrer, L. (2018). The provenance of certainty: Multiple source use and the public engagement with science. In J. L. G. Braasch, I. Bråten, & M. T. McCrudden (Eds.), *Handbook of multiple source use* (pp. 269–284). New York, NY: Routledge.

Bromme, R., & Thomm, E. (2016). Knowing who knows: Laypersons' capabilities to judge experts' pertinence for science topics. *Cognitive Science*, *40*(1), 241–252.

Burgman, M. A. (2016). *Trusting judgements: How to get the best out of experts*. Cambridge, England: Cambridge University Press.

Castell, S., Charlton, A., Clemence, M., Pettigrew, N., Pope, S., Quigley, A., . . . Silman, T. (2014). *Public attitudes to science 2014*. London, England: Ipsos Mori Social Research Institute.

Chater, N., & Oaksford, M. (2012). Normative systems: Logic, probability, and rational choice. In K. Holyoak & R. Morrison (Eds.), *The Oxford handbook of thinking and reasoning* (pp. 11–21). New York, NY: Oxford University Press.

Critchley, C. R. (2008). Public opinion and trust in scientists: The role of the research context, and the perceived motivation of stem cell researchers. *Public Understanding of Science*, *17*(3), 309–327.

Cummings, L. (2014). The "trust" heuristic: Arguments from authority in public health. *Health Communication*, *29*, 1043–1056.

Cummings, L. (2015). *Reasoning and public health: New ways of coping with uncertainty*. Heidelberg, Germany: Springer.

DeBoer, G. E. (2000). Scientific literacy: Another look at its historical and contemporary meanings and its relationship to science education reform. *Journal of Research in Science Teaching*, *37*(6), 582–601.

Druckman, J. N., & McGrath, M. C. (2019). The evidence for motivated reasoning in climate change preference formation. *Nature Climate Change*, *9*(2), 111–119.

Feinstein, N. (2011). Salvaging science literacy. *Science Education*, *95*(1), 168–185.

Garrett, R. K. (2009). Echo chambers online? Politically motivated selective exposure among Internet news users. *Journal of Computer-Mediated Communication*, *14*(2), 265–285.

Gauchat, G. (2012). Politicization of science in the public sphere: A study of public trust in the United States, 1974 to 2010. *American Sociological Review*, *77*(2), 167–187.

Goldman, A. (1999). *Knowledge in a social world*. Oxford, England: Oxford University Press.

Gottlieb, S., & Lombrozo, T. (2020). What are the limits of scientific explanations? In K. McCain & K. Kampourakis (Eds.), *What is scientific knowledge? An introduction to contemporary epistemology of science*. (pp. 260–273). New York, NY: Routledge.

Hahn, U., Harris, A. J. L., & Corner, A. (2009). Argument content and argument source: An exploration. *Informal Logic*, *29*(4), 337–367.

Hardwig, J. (1991). The role of trust in knowledge. *Journal of Philosophy*, *88*(12), 693–708.

Heine, S. J., Dar-Nimrod, I., Cheung, B. Y., & Proulx, T. (2017). Essentially biased: Why people are fatalistic about genes. In J. Olson (Ed.), *Advances in experimental social psychology* (Vol. 55, pp. 137–192). Cambridge, MA: Academic Press.

Hendriks, F., Kienhues, D., & Bromme, R. (2015). Measuring laypeople's trust in experts in a digital age: The Muenster Epistemic Trustworthiness Inventory (METI). *PLoS ONE*, *10*(10), e0139309.

Hendriks, F., Kienhues, D., & Bromme, R. (2016). Trust in science and the science of trust. In B. Blöbaum (Ed.), *Trust and communication in a digitized world: Models and concepts of trust research* (pp. 143–159). Berlin, Germany: Springer.

Irzik, G., & Kurtulmus, F. (2019). What is epistemic public trust in science? *British Journal for the Philosophy of Science*, *70*(4), 1145–1166.

Joslyn, M. R., & Sylvester, S. M. (2019). The determinants and consequences of accurate beliefs about childhood vaccinations. *American Politics Research*, *47*(3), 628–649.

Kahan, D. M., Jenkins-Smith, H., & Braman, D. (2011). Cultural cognition of scientific consensus. *Journal of Risk Research*, *14*(2), 147–174.

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.

Keil, F. C. (2010). The feasibility of folk science. *Cognitive Science*, *34*(5), 826–862.

Keren, A. (2018). The public understanding of what? Laypersons' epistemic needs, the division of cognitive labor, and the demarcation of science. *Philosophy of Science*, *85*(5), 781–792.

Kind, P., & Osborne, J. (2017). Styles of scientific reasoning: A cultural rationale for science education? *Science Education*, *101*(1), 8–31.

Kunda, Z. (1990). The case for motivated reasoning. *Psychological Bulletin*, *108*(3), 480–498.

Law, S. (2020). How can we tell science from pseudoscience? In K. McCain & K. Kampourakis (Eds.), *What is scientific knowledge? An introduction to contemporary epistemology of science* (pp. 100–116). New York, NY: Routledge.

Levy, N. (2019). Due deference to denialism: Explaining ordinary people's rejection of established scientific findings. *Synthese*, *196*(1), 313–327.

Lewandowsky, S., & Oberauer, K. (2016). Motivated rejection of science. *Current Directions in Psychological Science*, *25*(4), 217–222.

Lombardi, D., Seyranian, V., & Sinatra, G. M. (2014). Source effects and plausibility judgments when reading about climate change. *Discourse Processes*, *51*, 75–92.

Mahner, M. (2013). Science and pseudoscience: How to demarcate after the (alleged) demise of the demarcation problem. In M. Pigliucci & M. Boudry (Eds.), *Philosophy of pseudoscience: Reconsidering the demarcation problem* (pp. 29–43). Chicago, IL: University of Chicago Press.

Mercier, H., & Sperber, D. (2017). *The enigma of reason: A new theory of human understanding*. Cambridge, MA: Harvard University Press.

Mills, C. M., & Keil, F. C. (2004). Knowing the limits of one's understanding: The development of an awareness of an illusion of explanatory depth. *Journal of Experimental Child Psychology*, *87*, 1–32.

Munro, G. D. (2010). The scientific impotence excuse: Discounting belief-threatening scientific abstracts. *Journal of Applied Social Psychology*, *40*(3), 579–600.

National Academies of Sciences, Engineering, and Medicine. (2017). *Communicating science effectively: A research agenda*. Washington, DC: Academies Press.

Nauroth, P., Gollwitzer, M., Bender, J., & Rothmund, T. (2014). Gamers against science: The case of the violent video games debate. *European Journal of Social Psychology*, *44*(2), 104–116.

OECD. (2016). *PISA 2015 assessment and analytical framework: Science, reading, mathematic, financial literacy and collaborative problem solving*. Paris, France: OECD Publishing.

Oreskes, N., & Conway, E. M. (2010). *Merchants of doubt: How a handful of scientists obscured the truth on issues from tobacco smoke to global warming*. London, England: Bloomsbury.

Peels, R. (2020). Should we accept scientism? The argument from self-referential coherence. In K. McCain & K. Kampourakis (Eds.), *What is scientific knowledge? An introduction to contemporary epistemology of science* (pp. 274–287). New York, NY: Routledge.

Peters, R. G., Covello, V. T., & McCallum, D. B. (1997). The determinants of trust and credibility in environmental risk communication: An empirical study. *Risk Analysis*, *17*(1), 43–54.

Ranney, M. A., & Clark, D. (2016). Climate change conceptual change: Scientific information can transform attitudes. *Topics in Cognitive Science*, *8*(1), 49–75.

Rutjens, B. T., Heine, S. J., Sutton, R. M., & van Harreveld, F. (2017). Attitudes towards science. *Advances in Experimental Social Psychology*, *57*, 125–165.

Scharrer, L., Stadtler, M., & Bromme, R. (2014). You'd better ask an expert: Mitigating the comprehensibility effect on laypeople's decisions about science-based knowledge claims. *Applied Cognitive Psychology*, *28*(4), 465–471.

Schuldt, J. P., Roh, S., & Schwarz, N. (2015). Questionnaire design effects in climate change surveys: Implications for the partisan divide. *Annals of the American Academy of Political and Social Science*, *658*(1), 67–85.

Shi, J., Visschers, V. H. M., Siegrist, M., & Arvai, J. (2016). Knowledge as a driver of public perceptions about climate change reassessed. *Nature Climate Change*, *6*, 759–762.

Shtulman, A. (2017). *Scienceblind: Why our intuitive theories about the world are so often wrong*. New York, NY: Basic Books.

Slotta, J. D., & Chi, M. T. H. (2006). The impact of ontology training on conceptual change: Helping students understand the challenging topics in science. *Cognition and Instruction*, *24*, 261–289.

Sperber, D., Clément, F., Heintz, C., Mascaro, O., Mercier, H., Origgi, G., & Wilson, D. (2010). Epistemic vigilance. *Mind & Language*, *25*(4), 359–393.

Stadtler, M., Bromme, R., & Rouet, J.-F. (2018). Learning from multiple documents: How can we foster multiple document literacy skills in a sustainable way? In E. Manalo, Y. Uesaka, & C. A. Chinn (Eds.), *Promoting spontaneous use of learning and reasoning strategies: Theory, research, and practice for effective transfer* (pp. 46–61). London, England: Routledge.

Stanovich, K. E. (2012). On the distinction between rationality and intelligence: Implications for understanding individual differences in reasoning. In K. Holyoak & R. Morrison (Eds.), *The Oxford handbook of thinking and reasoning* (pp. 343–365). New York, NY: Oxford University Press.

Stanovich, K. E. (2016). The comprehensive assessment of rational thinking. *Educational Psychologist*, *51*(1), 23–34.

Suldovsky, B. (2016). In science communication, why does the idea of the public deficit always return? Exploring key influences. *Public Understanding of Science*, *25*(4), 415–426.

Tabak, I. (2015). Functional scientific literacy: Seeing the science within the words and across the web. In L. Corno & E. M. Anderman (Eds.), *Handbook of educational psychology* (3rd ed., pp. 269–280). London, England: Routledge.

Thomm, E., & Bromme, R. (2016). How source information shapes lay interpretations of science conflicts: Interplay between sourcing, conflict explanation, source evaluation, and claim evaluation. *Reading and Writing*, *29*(8), 1629–1652.

Thomm, E., Hentschke, J., & Bromme, R. (2015). The Explaining Conflicting Scientific Claims (ECSC) questionnaire: Measuring laypersons' explanations for conflicts in science. *Learning and Individual Differences*, *37*, 139–152.

van der Linden, S. (2016). A conceptual critique of the cultural cognition thesis. *Science Communication*, *38*(1), 128–138.

van der Linden, S. L., Leiserowitz, A. A., Feinberg, G. D., & Maibach, E. W. (2015). The scientific consensus on climate change as a gateway belief: Experimental evidence. *PLoS ONE*, *10*(2), e0118489.

Wilholt, T. (2013). Epistemic trust in science. *British Journal for the Philosophy of Science*, *64*(2), 233–253.

Wolpert, L. (1992). *The unnatural nature of science*. Cambridge, MA: Harvard University Press.

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