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ORIGINAL ARTICLE

How people decide who is correct when groups of scientists disagree

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Abstract

Uncertainty that arises from disputes among scientists seems to foster public skepticism or noncompliance. Communication of potential cues to the relative performance of contending scientists might affect judgments of which position is likely more valid. We used actual scientific disputes—the nature of dark matter, sea level rise under climate change, and benefits and risks of marijuana—to assess Americans' responses ($n = 3150$). Seven cues—replication, information quality, the majority position, degree source, experience, reference group support, and employer—were presented three cues at a time in a planned-missingness design. The most influential cues were majority vote, replication, information quality, and experience. Several potential moderators—topical engagement, prior attitudes, knowledge of science, and attitudes toward science—lacked even small effects on choice, but cues had the strongest effects for dark matter and weakest effects for marijuana, and general mistrust of scientists moderately attenuated top cues' effects. Risk communicators can take these influential cues into account in understanding how laypeople respond to scientific disputes, and improving communication about such disputes.

KEYWORDS
intrascience disputes, relative performance cues, trust

1 | INTRODUCTION

Recent studies in risk communication and other fields have highlighted experts' concern about misinformation and disinformation in social and legacy media (Han et al., 2021; Shu et al., 2020). However, an older literature about public reactions to uncertainty in science also has important implications for risk communication. These cover experts' qualitative acknowledgment of uncertainty in their forecasts (e.g., Kuhn, 2000; Nakayachi et al., 2018), ranges of risk estimates versus point estimates (e.g., Du et al., 2011; Johnson & Slovic, 1995, 1998), explicit uncertainty forecasts (e.g., "22% chance" of freezing temperatures; Joslyn & LeClerc, 2012), and disputes among scientists (e.g., Kuhn, 2000), among others. Outcomes of concern have included changes in trust (e.g., people might reject specific uncertain risk estimates as indicating scientists' incompetence, although others welcome knowing about the uncertainties and exhibit more trust; Johnson, 2004), erroneous beliefs about the topic (e.g., make poorer decisions if uncertainties are misunderstood or subject to motivated reasoning; Dieckmann et al., 2017; Joslyn & LeClerc, 2012), and bias in one's own risk estimates (e.g., Gustafson & Rice, 2020). Professionals can help people grasp and apply many other kinds of uncertainties, including for people low in numeracy (e.g., Dieckmann et al., 2012; Peters et al., 2007; Han et al., 2021).

Our focus here is on the kind of uncertainty evoked by disputes among scientists. These disputes can be much more troubling for lay audiences, as they seem to undermine science's perceived authority (e.g., Collingridge & Reeve, 1986; Jasanoff & Wynne, 1998). The layperson cannot independently assess most technical claims experts make, thus is "epistemically dependent" on experts (Hardwig, 1985; Collins & Evans, 2007; see exceptions in Irwin & Wynne, 1996). In other words, the dispute may threaten belief in the value of science overall rather than just in the value of the specific science being disputed. A dispute may be even more threatening when among large groups of scientists on each side, rather than (say) one individual scientist versus another. However, concealing disputes could be equally problematic (e.g., Beatty, 2006; De Melo-Martin & Intemann, 2013; Halfon, 2006; Miller, 2016; Solomon, 2007).

Our goal here is to explore which cues people use to determine which side in a dispute among many scientists to believe. This question concerns relative performance of the contending groups, and relative-performance cues are the heuristic signals which may guide people to favor one of the debated positions over the other. These findings can help guide risk communicators for productive discussions with the public on how to effectively grapple with the existence of intrascientific disputes.

2 | BACKGROUND

We review the nature of the disputes of concern and why they should be of interest for risk communication. We also discuss the wider literature on information processing, and the specific literatures on public response to intrascience disputes and cues that people might use to interpret those disputes.

2.1 | Scientific disputes

Most scholarly studies of scientific disputes have emphasized their causes within science and its social context, and their consequences for science itself (e.g., Campbell, 1985; Lysaght & Kerridge, 2012; Yearley, 1994). That scientists disagree among themselves on many issues is widely known to experts, if not always perhaps to the general public. This is exemplified by contemporary disputes over such things as the causes of pine beetle infestation, potential benefits and risks of nanotechnology or of genome editing (Johnson, 2018), definitions of "processed food" and its effects on health (Sadler et al., 2022), and on the scale, trends, and factors in recent United Kingdom life expectancy (Hiam et al., 2023). The default assumption among both scientists and scholars of science practice is that disagreements among scientists *can* contribute to the progress of scientific knowledge by subjecting any claim to testing and counterarguments (e.g., Merton, 1973; Sarewitz, 2011). However, neither scientific disputes nor scientific consensus are *guaranteed* to advance scientific knowledge (e.g., Kuhn, 1962; Mauskopf, 1979).

Far less attention has been devoted to studying how laypeople respond to disputes among groups of scientists. In fact, more attention has been devoted to disputes between scientists on one side and nonscientists on the other (e.g., climate change; vaccination). However, several studies have been conducted on why laypeople think expert disputes occur, such as incompetence, bias, or the complexity of the topic (e.g., Dieckmann & Johnson, 2019; Dieckmann et al., 2017; Johnson & Dieckmann, 2018; Kajanne & Pirttilä-Backman, 1999; Sprecker, 2002; Thomm & Bromme, 2016; Thomm et al., 2015; Thomm et al., 2017). A very rough summary—given variance in explanations, measures, and sampling across these studies—is that self-interest and incompetence have been relatively common lay explanations for disputes, with the inherent complexity and uncertainty of the world less frequent. Much research on lay responses to intrascience disputes remains to be pursued, including how, and how often, laypeople notice and engage with scientific disputes generally in their daily lives.

2.2 | Risk communication and scientific disputes

Why should risk communicators care about scientific disputes, or about how the general public processes such disputes? As noted above, the primary concern is that "[c]onflict and disagreement among professionals could sow doubts" not only about specific topics (e.g., Sadler et al., 2022), but even perhaps undermine the authority of science overall, including the authority of risk science (Zehr, 2000; Stilgoe, 2007; Aven & Thekdi, 2021). One literature review concluded that communication about disagreements among scientists never has positive outcomes, while communications about other kinds of uncertainty, such as error ranges and probabilities, only have positive or null effects (Gustafson & Rice, 2020). Disagreements among scientists over nonpoliticized issues reduced attention to science news, acceptance of particular science issues, and trust in scientists and scientific methods generally (Chinn & Hart, 2022). By contrast, only among women less knowledgeable about research did scientists' trustworthiness about mammography drop as hypothetical conflict among scientists increased (Shi et al., 2022). High school students had difficulty grappling with researcher disagreements portrayed in a narrative about juvenile thyroid cancer incidence after the 2011 Fukushima Daiichi nuclear incident, although simultaneously they largely granted that disputes were a basic property of science (Hamza et al., 2022). Although concerns about alleged declines in trust in science may be overwrought—for example, see O'Neill (2002) on general problems with alleged declines in trust, and Gundersen et al. (2022) on the validity of questioning scientific claims—the potential for intrascientific disputes to produce undesirable societal outcomes demands attention from risk communicators.

Divergent generic perspectives on risk communication also might share some interest in educational initiatives about scientific disputes, from understanding their general bases to how to interpret them for one's own purposes. These generic models aim to help the public understand scientific processes and results given such aims as to get people to "accept" a hazard, or to grasp organizational decisions or make informed decisions for themselves (Balog-Way et al., 2020; Fischhoff, 1995; Gregory & Lock, 2008; Kasperson, 2014), recruit individuals as "citizen scientists" (e.g., Conrad & Hilchey, 2011), foster community-based participatory research (e.g., Wallerstein & Duran, 2009), or tailor message content and presentation to audience expectations and behavior (e.g., Ledford et al., 2012; Logan, 2001). One example is the emergence of guides on how to assess individual scientific studies, or media reports on such studies (e.g., Alberts & McNutt, 2013; Collins & Weinel, 2011; Harvard School of Public Health, 2016; Sutherland et al., 2013). Besides the potentially negative societal consequences of erosion in trust in science referred to earlier, these examples show that there can be a variety of other substantive goals that could be undermined if risk communicators did not account for the consequences for public opinion of intrascientific disputes.

2.3 | Information processing and cues

The use of cues to performance has been a general issue for scholarship, not restricted to assessing scientists' collective trustworthiness when they disagree with another grouping of scientists. For example, the heuristic-systematic (HSM) and elaboration likelihood (ELM) models both arose about 40 years ago to explain how humans process persuasive messages and change attitudes (e.g., Chaiken, 1980; Chaiken et al., 1989; Eagly & Chaiken, 1993 on HSM; Petty & Cacioppo, 1984, 1986; Petty et al., 1981 on ELM). These two models differ somewhat on presumed motives for information processing (e.g., achieve accurate attitudes; resolve cognitive dissonance), or its immediate outcomes (e.g., message endorsement or rejection; attitude change). For present purposes, we emphasize their generally shared views of information processing itself. Information processing can be deliberate, detailed, and thinking-intensive (systematic or central route), or deploy simple rules of thumb or "heuristics" to evaluate information (heuristic or peripheral route). Systematic/central processing is more likely to focus on information content, such as its logical quality, although not exclusively so. The more common heuristic/peripheral processing tends to focus on noncontent (often referred in these literatures as "cues"), such as the information source's trustworthiness or attractiveness, or the information's production quality. Both models agree that beliefs and attitudes based on systematic/central processing are less likely to change and are more strongly linked to subsequent behavior. Both processing styles may be used simultaneously (e.g., Stiff, 1986).

Our use of the term "cues" here to refer to the information we offer to our respondents, or similar information that they might read or hear in their daily lives, should not be taken to imply that the subsequent processing of this information is necessarily "heuristic" rather than "systematic." Despite many publications referring to heuristic "cues," we do not directly measure how people process the information we offer them. Indirectly, some of our moderators—for example, how motivated people say they are to know which scientific position is more correct, or how knowledgeable they claim to be on the topic—might implicate heuristic or systematic information processing, and our chosen topics help contribute to variation in these moderators and other aspects of individuals' responses to our cues. However, this need not mean that the cues we offer here are inherently heuristic cues.

2.4 | Science relative-performance cues

Epistemic dependence means that in most cases lay observers will be unable to evaluate the quality of the respective technical arguments made by scientific disputants (Collins & Evans, 2007). As noted above, we cannot determine whether the available information (whether in our cues or in people's daily information environments) is processed systematically or heuristically, but for many scholars implicitly this epistemic dependence means they should focus upon seemingly heuristic cues to infer scientists' relative performance in a dispute. For example, political and social identity cues have been identified for such politicized topics as climate change and vaccine impacts (e.g., Hart & Nisbet, 2012; Jones-Jang & Noland, 2022). Messages from expert sources that are endorsed by trusted social groups can offset misinformation about genetically modified food (e.g., Wang, 2021), and graphs can be a cue to performance in assessing science-related texts that conflict (Isberner et al., 2013).

That said, we must be cautious about extrapolating from these more general cue schemes to those salient for intrascience disputes. First, unlike with expert-other disputes (e.g., climate change), an important HSM/ELM cue—source expertise (e.g., see Eagly & Chaiken, 1993, on the "experts' statements can be trusted" heuristic)—is much less useful when everyone in the dispute is an "expert" by at least some criteria (e.g., scientist; Ph.D.). Other HSM/ELM cues also may have less value in most intrascience disputes. For example, a focus on message processing may be irrelevant for disputes in which the contenders are not talking to public audiences, or only tangentially so (e.g., Slater & Rouner, 1996). Even such potentially salient cues as the number of arguments favoring a particular position ("the more arguments the better") may be difficult to apply given the complexity of most scientific arguments. Further, most relative-performance studies from the communications field include just one scientist or expert on each side, reflecting the "talking heads" or "balanced reporting" frames of modern journalism. Individual-focused cues include whether the disputants provide understandable and acceptable explanations (e.g., Anderson, 2011; Wagenknecht, 2015), how they react to challenges (e.g., Brewer, 1998; Gelfert, 2011; Matheson, 2005), or honesty and ethical behavior regarding both their own and opponents' claims (e.g., Fallis & Frické, 2002). It is unclear how to apply these cues to large groups of unorganized scientists. By contrast, the cue of which position gets the most "votes" from scientists logically cannot apply to a one-on-one dispute. We expect that cues to the relative performance of contending individual or group experts will overlap considerably, without being identical or necessarily having equal effect.

A different conceptual approach, given our emphasis here on whether and how cues influence people to determine which side in the dispute is more likely to be correct, is to use pre-existing taxonomies of factors in trust. These are diverse if overlapping (e.g., Johnson, 1999), but for convenience, we can cite the distinction between ability, integrity, and benevolence. These refer to the potential trustor's beliefs that the trustee—the person or organization that is being judged for trustworthiness—has, respectively, skills, competencies, and expertise regarding one or more topics or processes;

adherence to an acceptable-to-the-trustor set of principles, which may include honesty and fairness among other attributes; and wants to help the trustor (e.g., Mayer et al., 1995). To our knowledge, neither this nor other taxonomies of factors in trust have been used to address the question of how people grapple with disagreements among scientists.

We know of no compendium of all possible relative-performance cues to the more credible side in a scientific dispute. Such a comprehensive list may not be feasible anyway, given that contextual attributes will alter which cues are viable in a specific dispute. Most cue studies have applied few cues, often just one (e.g., Bromme et al., 2015; Stadtler et al., 2016). Some cues are too local to be observable by most people (e.g., Jasanoff & Wynne, 1998; Wynne, 1989). We should not ignore these usually topic- or locality-specific cues, as they can be critical to the outcome of that issue, but they are not "ubiquitous" cues to which anyone might gain access (Collins & Evans, 2007). However, the dependent variable in the experiment here is the decision as to which side in the intrascience dispute is most likely to be correct. This might evoke an accuracy motivation among our respondents (e.g., Chaiken, 1980), or at least an expectation of an accuracy motivation arising among the disputing scientists (also see Johnson & Dieckmann, 2020). If so, we would expect for this dependent variable an emphasis on cues to ability, rather than to integrity or benevolence, in the Mayer et al. (1995) taxonomy of trust factors.

We rely here on a seven-class taxonomy proposed by Johnson (2019a), based on a literature review regarding credulity cues for intrascience intergroup disputes. This taxonomy included interests, shared values, credentials, performance, demographics, vote-counting, and research quality. This seems to be a minimalist approach, as it is hard to see how it could be reduced further without conflating disparate cues. More systematic work on taxonomies of cues that the general public might use to interpret intrascience disputes is warranted. Excluding demographics,[1] the experiment we report here manipulated cues from six of these classes (including two from the research quality class). We would argue that most of these cues focus on ability (Mayer et al., 1995): information quality, experience, replication, and degree source. The employer cue seems to evoke integrity instead, as it might imply greater attention by the scientists to the interests of their employer than to the public interest (Johnson & Dieckmann, 2021 found little effect of employer on perceived scientists' motivations, but their experiment was not topic-specific, so those findings might not generalize to the specific topics raised in the current experiment). The remaining two cues deployed here are difficult to classify within the Mayer et al. (1995) trust factor taxonomy.

[1] Humans' default in-group bias (e.g., Hammond & Axelrod, 2006; Molenberghs, 2013) may lead an observer to favor that side of a dispute which shares attributes with the observer (e.g., gender, age, ethnicity, nationality; Collins & Evans, 2007 note that scientists sometimes use nationality as a cue in evaluating colleagues). Nationality had a small effect on relative performance in a previous experiment (Johnson, 2019b), but most demographic cues are less salient (they both segment respondent samples and do not adequately characterize disputant groups of scientists), so are likely to yield weak effects. Thus, we omitted this category of cues.

The majority vote cue (how many scientists support this position) is not directly a measure of expertise, although it might be taken for one (as the area editor put it, "better students tend to get the same answer"). The reference group cue possibly could raise benevolence issues (Mayer et al., 1995)—that is, if organizations which share my values endorse the scientists favoring this position, then those scientists also are likely to share my values—but it is not a direct measure of shared values or any other benevolence attribute.

We discuss the literature supporting each of these seven cues in turn.

2.4.1 | Interests

This category of cues concerns the self-interest of various actors. This might include the scientists involved in the dispute themselves: for example, taking a given position may increase the scientist's ability to gain research grants, get a promotion, start a business, sell a patent, or earn prestige or influence. It also or instead might include interests of the employer (e.g., scientists' position on a scientific issue may affect the earnings, influence, or other attributes of the university, business, government, or nonprofit for which they work). Even interests of the lay observer of the dispute may be salient (e.g., this person might potentially receive material benefits—e.g., better or cheaper products, or more safety, environmental quality, or convenience—or nonmaterial benefits, such as apparent scientific endorsement of one's prior views).

The role of interests in science and of scientists has been a long-standing theme in the scholarly empirical literature. Examples include focus groups' admonition to "Follow the money!" (Johnson, 2019a), or that 80% of Americans deemed research on genetically engineered food at least sometimes affected by scientists' support from industry (Funk & Kennedy, 2016). Further examples include the assertion "that individuals are specifically attentive to source information associated with the commercial interests of the source" (Thomm & Bromme, 2016, p. 1632, citing Bråten et al., 2011; Critchley, 2008; Cummings, 2014), or an experimental manipulation of scientists' employer (university vs. industry) which shifted agreement toward the university scientist's claim (Gottschling et al., 2019). Lay perception of scientists' self-oriented motives (e.g., financial rewards, demonstrating skill or competence, gaining power in society; Benson-Greenwald et al., 2023) reduce trust in science and decrease willingness to allocate more research funding relative to the perception of other-oriented motives (e.g., helping society, working face-to-face with others). Other observational and experimental studies also point to the effect of perceived interests as affecting public reactions to conflict (e.g., Bubela et al., 2009; Collins & Evans, 2007; Goldman, 2001; Irwin & Wynne, 1996; Kutrovátz, 2010; Maxim & Mansier, 2014; but see Johnson & Dieckmann, 2020, 2021).

2.4.2 | Shared values

Trust in scientists or other groups can shape how one responds to scientific disputes. Temporarily putting aside ability as a factor in trust (Mayer et al., 1995), our focus here is on the antecedent for trust proposed by Earle and Cvetkovich (1995; also see Earle & Siegrist, 2006, 2008). Specifically, if people think that the target group or entity shares with them values relevant to the topic, they will find that target more credible (also see Besley et al., 2021; Hendriks et al., 2015; Schoorman et al., 2007). Another type of shared-values cue is that groups the observer trusts take the same position, or they announce that they trust the scientists who take that position (reference group cue). Wang (2021) found reference groups can affect reactions to misinformation on genetically modified food safety, with similar findings on other topics (e.g., Frické et al., 2005; Kuklinski et al., 1982).

2.4.3 | Credentials

Indirect ability cues can include degrees and awards (e.g., Nobel Prizes) and the size and prestige of the university granting a scientist's doctoral degree, which Collins and Evans (2007) cited as a cue sometimes used by scientists to evaluate their colleagues' work (also see nonempirical cue suggestions by Goldman, 2001 and Matheson, 2005). The HSM and ELM literatures have effectively used credentials (e.g., being a university professor) to shape which sources seem more credible, with expertise cited as one of the strongest performance cues derived from source characteristics (e.g., Wilson & Sherrell, 1993).

2.4.4 | Performance

This class of ability cues includes scientists' prior accuracy, as in predicting future events or confirming a novel hypothesis (Bubela et al., 2009; Irwin & Wynne, 1996). This also can include general track records of repeated success or failure (Collins & Evans, 2007; Goldman, 2001), and length of experience, which could be general or refer to years spent in the particular subfield salient to the topic (Collins & Evans, 2007). Pertinent subfield experience may be a cue too subtle to be visible in most dispute information available to laypeople, yet experts are often quite willing to comment publicly on disputes where their area of expertise is of marginal relevance.

2.4.5 | Vote-counting

As noted earlier, the authority of science has been argued to stem in part from the notion that there is an underlying truth to the universe yielding agreement by most, if not all, competent scientists specializing in that topic area given the openness to criticism of scientists' claims. One heuristic cue from the HSM literature is that "consensus implies correctness" (Eagly & Chaiken, 1993, p. 327). There are several problematic aspects to these claims about scientific epistemology (e.g., consensus could reflect "group think and power"; see Coady, 2006; Goldman, 2001; Gundersen et al., 2022), although it has been argued that uninformed observers can estimate a weighted average of better than random opinions (Lehrer & Wagner, 1981, p. 20).

Empirically, this cue category could measure the proportion of scientists or scientific studies which support a given position. For example, one study found that as the hypothetical proportions of scientists supporting Position A versus B shifted from 100%–0% through 50%–50% to 0%–100%, perceived consensus also shifted, although the belief that one side was more correct was not affected by this shift (Johnson, 2018). In another study manipulating scientific agreement, perceived scientific certainty increased with greater agreement, particularly among those trusting science (Chinn et al., 2019; also see Johnson, 2019b). Although not directly relevant, as it focuses on disputes of scientists with nonscientists, a burgeoning literature on consensus messaging has largely found that a brief message that a very large majority of scientists favor a given viewpoint can influence public beliefs (Dixon, 2016; van der Linden et al., 2015a, 2019; Kerr & Wilson, 2018; Suldovsky & Akin, 2023; Kobayashi, 2018; Chinn et al., 2019 included less politically charged issues). The gateway belief model deems that consensus messages' main effect is on perceived consensus, with indirect and weaker effects on downstream variables as beliefs or policy support (van der Linden et al., 2015b). Critics argue that a focus on consensus is either irrelevant or of declining relevance to getting action on an issue and has limited effects or may backfire (Bolsen & Druckman, 2018; Dixon & Hubner, 2018; Cook & Lewandowsky, 2016; Cook, 2017; Suldovsky & Akin, 2023; Oreskes, 2017; Ma et al., 2019; also see Kahan et al., 2011).

A reviewer suggested that the majority-vote cue could be deemed to reflect descriptive norms, which by characterizing the behaviors of salient reference groups, such as members of one's social network, can signal to someone which actions are ones they should emulate (e.g., Lapinski et al., 2017). In other words, if most scientists think that a given position is correct, then they provide a norm that we laypeople should follow. However, descriptive norms are unlikely to apply here for most respondents, because scientists are not usually a salient reference group. A few people may want to be seen as complying with "scientific norms" because *their* salient reference group—people in their own social network—see this as desirable behavior, but rarely is this due to having scientists themselves in one's social network. Unfortunately, the term "descriptive norm" has been applied loosely in the research on scientific consensus (e.g., van der Linden et al., 2015b on the gateway belief model), when what may be going on here is more of an implicit appeal to authority (e.g., Lu, 2023). This does not mean that scientists cannot be a referent group for laypeople—on scientific issues, they may be deemed uniquely expert—only that scientists need not provide descriptive-norm information for lay observers.

We also note the parallel of an experiment in a national science survey, in which the belief that "the universe began with a huge explosion" was endorsed by far fewer Americans (38%) than when it was preceded by the clause "according to astronomers" (65%), indicating that people could recognize what scientists believe without necessarily endorsing that belief themselves (National Science Board, 2020). We are willing to believe that citizens *might* endorse a belief held by scientists, but not that they treat scientists' reputed majority view as a descriptive norm.

2.4.6 | Research quality

This category of cues purports to reflect the performance of "good science," highly salient cues to scientists themselves when they evaluate their own performance and that of their colleagues (Collins & Evans, 2007). The potential number of such cues is large given the complexity of scientific research both within and across disciplines. For example, consider just a few elements of what used to be called "the scientific method" before the sociology of science studies of laboratory practice revealed that "method" was not a single activity, and scientific findings were not a straightforward outcome of methodological choices (e.g., Knorr Cetina, 1981; Latour & Woolgar, 1979; Lynch, 1985). Such elements may include high-level research design choices, including whether scientists test alternative explanations in the same study or whether studies are replicated to yield convergent evidence (Maxim & Mansier, 2014). They also might include specific procedures, such as ensuring the best available data, data collection methods, or control groups are used (e.g., Johnson, 2019b; Maxim & Mansier, 2014). Then, there are more abstract, less researcher-defined elements, such as the uncertainty of findings in the field, which might reflect the topic's inherent complexity, the newness of the field, research design or data analyses that do not reduce uncertainty, among other factors (e.g., Dieckmann et al., 2017; Maxim & Mansier, 2014). As these research quality cues are largely less visible to and interpretable by nonscientists than other cues, we would expect their effect to be stronger for people who exhibit knowledge of scientific reasoning (Drummond & Fischhoff, 2017).

2.4.7 | Comparing cues' effects

The empirical literature on which cues have more influence on people's choices of relative validity comprises one study (Johnson, 2019b). It found that majority vote and relative experience, but not the quality of groups' doctorate-granting universities, influenced the choice between axions and neutralinos as the source of dark matter in the universe. For a wider set of topics, relative effects were strongest for information quality (recency of data collection and its methods), followed by majority vote, experience, degree source, grants (whether taking the position would bring the scientists more grants), nationality, and employer. Topic—perhaps driven by familiarity—and subjective topical knowledge were the only significant moderators of several tested. These experiments were limited in their focus, however. The first only assessed three cues' effects for a single topic, while the second tested three separate (siloed) sets of cues tested directly only against each other. Further, two cues in the second study were not represented as fully as they might be (replication, due to a programming problem; grants, due to an interpretive question).

2.5 | This study

Our main aim was to systematically assess relative cue effects on relative performance choices and potential moderators of these effects. We cover each of these topics in turn.

Experiments can establish whether exposure to a cue supporting Position B leads laypeople to favor Position B significantly more often than Position A. When laypeople see more than one cue simultaneously, supporting the same or different positions, we can then determine cues' relative influence. In contrast to Johnson's (2019b) silo approach, we deployed a planned-missingness design, in which any one respondent saw only three cues but all 35 possible combinations of the seven cues (see Table 1, top) were tested across the sample. For replication purposes, these cues overlapped with those in Johnson (2019b). The replications cue was included to address a weakness in the earlier experiments, and the earlier study's grants and nationality cues were omitted for their ambiguity (grants) and weak effects (both).

Based on the science-cue-specific and general literature reviewed above, plus Johnson's (2019b) results, we posit the following hypotheses and research questions for which cues would have stronger main effects overall on judgments of which of two conflicting positions is more likely to be correct.

- **H1**. *The majority vote cue will have strong effects*. As this cue does not require evaluating the arguments specific to each side, this cue should be influential as it was in Johnson (2019b).
- **H2**. *Cues of research quality (information quality; replication) will have relatively strong effects*. However, effective use of these cues may require an above-average understanding of scientific methods (see moderator discussion, below).
- **H3**. *Credential (degree source) and performance (experience) cues will have moderate effects*. These are source trustworthiness cues (in HSM/ELM labeling) that, like majority vote, do not require analysis of the contending arguments, yet as reflections of judged ability may be less diagnostic for relative performance than cues of salient shared values (e.g., Earle & Cvetkovich, 1995; Earle & Siegrist, 2006, 2008).
- **RQ1**. *What is the relative effect of interest (employer) and shared values (reference group) cues?* There is a tension between the bulk of the literature, which supports a strong effect of interest—and particularly of

TABLE 1 Cue and topic scenarios in instrument.

Cues	Scenario (varying whether Position A or B is cited)
Information quality	The information supporting Position B has on average been collected more recently with newer techniques
Majority vote	About 75% of the scientists with expertise on this topic support Position B
Experience	Scientists who support Position B average 7.5 more years of experience in doing this kind of research
Replication	Multiple studies, by scientists independent of each other, find evidence favoring Position B
Degree source	Scientists supporting Position B tend to have been awarded their PhDs by more elite universities, like Harvard and Stanford
Employer	The organizations employing the scientists supporting Position B expect to gain much more from that position than from Position A
Reference group	Organizations whose values you share announce they favor Position B
Topics	**Scenario**
Dark matter	About 85% of all matter in the universe is "dark matter" which scientists know is there due to its gravitational pull on visible matter, such as galaxies and radiation. We cannot see it and do not know what it is made of. Some scientists think dark matter is made of axions, one kind of subatomic particle; other scientists think dark matter is made of the lightest of the neutralinos, another set of subatomic particles. Until research can answer this question, scientists do not know what makes up most of the matter in the universe.
Sea level rise	Scientists agree that climate change is occurring, but disagree about the size of its impacts if current trends continue. Some scientists think Antarctica melting will be so slow that by 2100 the average global rise in sea level will be about 1.7–3.2 feet. It will be due mainly to water expanding when it warms and melting of glaciers. Other scientists think Antarctica will melt faster, so by 2100 the average global rise in sea level will be about 3.4–6.3 feet.
Marijuana	Scientists disagree about marijuana's risks and benefits. Some scientists think it produces cancer-causing substances when smoked, can damage thinking ability among children and young adults, and has fewer medical benefits than claimed. They also think it is addictive and leads people to more harmful drugs. Other scientists think researchers could identify more medical benefits if marijuana was not illegal nationally, and the evidence on cancer or harder drug use is not clear. They also say it is much less harmful than legal substances like alcohol and tobacco.

employment—on judgments of relative performance, and the weak effects found specifically for contending groups of scientists (Johnson, 2019a, b). The reference group cue had not been tested previously, so for it as well we are agnostic on relative effects on performance judgments.

The HSM and ELM have focused on motivations and/or capacity as potential moderating factors. If both are present at high levels, the systematic/central route is most likely, but without motivation, or without capacity to process the information carefully, the heuristic/peripheral route is more likely. As noted earlier, we are not directly assessing how people process this cue information, but our use of various moderators that tap motivation and capacity can help illuminate the degree to which these factors affect cue processing.

Motivation moderators can be quite varied. For example, a person may be genuinely interested because the issue is personally relevant or otherwise involving (e.g., Cheung et al., 2012; Huo et al., 2018), they have strong need for the information (e.g., Zha et al., 2016), need cognition (e.g., Lin et al., 2011; Putrevu et al., 2004; Zhang & Buda, 1999), or have accuracy, defense, or impression motives (e.g., Kim & Paek, 2009). Capacities also can be quite varied including that the person is not distracted or bored or short of time (e.g., Kim et al., 2017; Lee & Hong, 2021), mindfully approaches the information (e.g., Gao et al., 2021), has cognitive ability (e.g., Wang et al., 2022), or has salient experience or prior knowledge (e.g., Cheung et al., 2012; Kumar et al., 2021; Liu & Huang, 2017; Putrevu et al., 2004).

The topic of the dispute is one potential moderator, and the bottom of Table 1 shows our three topics of actual intra-science disputes that also were used by Johnson (2019b). As we move from the first of these topics to the last, we propose that both motivations and capacities increase, although motivations perhaps increase faster, meaning that cues (e.g., majority vote; experience; degree source) might be more effective for dark matter (low motivation and capacity) than for the other two. Sea level rise and marijuana are likely more engaging because they are more prominent in media and personal discussions, if not entailing potential personal impacts on one's behavior and/or beliefs. These topics also may prompt higher perceived if not actual capacity, because grappling with whether and how to deal with climate change, or experience with marijuana or its users may lead people to feel competent to evaluate scientists' arguments, although probably more so for marijuana. We also note that Johnson (2019b) found a similar relative relationship among topics:

H4. Cues' effects—particularly those for majority vote, degree source, and experience—will be strongest for dark matter and least for marijuana, with sea level rise intermediate.

We now step back to consider the role of specific motivation and capacity moderators other than the topic (Table 2).

TABLE 2 Moderator measures.

Label	Measure (scale)
	Scenario responses
Care	How much do you care about which group of scientists is correct on this topic? (1 *very little*, 5 *very much*)
Involvement	(3-item scale from Earle et al., 1990; 7-point semantic differential items) What does the issue described in this paragraph mean to you? *significant-insignificant, interested-interested, important-important*
	Attitudes to science
Dispute interest	[1 if heard of disputes and tried to decide relative validity, 0 otherwise]
Mistrust science	[6-item scale (Hartman et al., 2017); e.g.] Sometimes I think we put too much faith in science (1 *disagree very strongly*, 7 *agree very strongly*)
Positivism	[8 questions (Rabinovich & Morton, 2012; Steel et al., 2004); e.g.] Science provides objective knowledge about the world (1 *strongly disagree*, 5 *strongly agree*)
	Knowledge
Subjective topic knowledge	How much do you feel you know about this topic? (1 *no knowledge at all*, 5 *great deal of knowledge*)
Science facts	[9 true-false items (NSB, 2014); e.g.] The center of the Earth is very hot.
Scientific reasoning knowledge	[11 true-false items (Drummond & Fischhoff, 2017); e.g.] A researcher develops a new method for measuring the surface tension of liquids. This method is more consistent than the old method. True or False? The new method must also be more accurate than the old method.

Note: The four attention screeners also used as moderators are omitted here due to their length (Section 3.3).

As for *motivations*, our sample is faced with novelty in the choice task, not just the scenario. Given the distribution of media coverage of disputes involving science and technology, it is likely that disputes in which scientists appear primarily on one side (e.g., climate change, vaccination effects, evolution) are more familiar than intrascience disputes, regardless of their actual relative frequency (Friedman et al., 1999). Similarly, respondents are probably relatively unfamiliar with having to decide which of two groups of scientists disagreeing on a given topic is more likely to be correct. Our cue presentation was also quite repetitive, with each person seeing the same three cues eight times in succession, with just minor changes to cue content across the repeated triplets (i.e., whether a given cue favored one position or the other in this dispute). Thus, we should expect motivation to be a potential problem for our respondents, and therefore, the relative strength of cue effects may be moderated by motivation-related variables. Specifically, we took into effect the respondent's (1) attention score, the number of correct answers to misleading questions (i.e., instructions on the only acceptable answer are buried late in the question), to control for the possibility that people lose their concentration while going through the different cue triplets (e.g., Berinsky et al., 2014); (2) how engaged or involved one is in the topic of the dispute, which has been argued is a critical element in evaluating risk communications (Earle et al., 1990); (3) how much one cares about which side of the dispute is correct; and (4) whether one is interested in intrascience disputes, either at all or enough to try to decide which side was correct in a dispute that had come to one's attention in daily life. We expected that higher levels of these four motivation-related measures could enhance cue influence, although two might have the opposite effect. Both high involvement and caring about which side is correct could in fact reduce cues' effects if that involvement and caring have already generated strong opinions on the topic.

H5. Cues' effects will be stronger among people who (a) pay high attention to the survey questions, (b) are highly involved in the dispute topic, (c) care about which side of the dispute is correct, and (d) are interested in intrascience disputes.

For *capacity* moderators, we focused on various types of attitudes toward science and knowledge. We expect mistrust of science will attenuate cue effects, as it will lead people to disregard cues' specific content. However, empirical findings are mixed: for example, trust in science increased vaccine confidence, moderated by societal consensus about trust in science (Sturgis et al., 2021), while mistrust made unvaccinated African Americans more likely to be persuaded by a narrative about changing one's mind about COVID-19 vaccines (Huang & Green, 2022).

Having a positivist view of science may also moderate the impact of cues. We expect that the mere existence of the intrascience dispute will threaten positivists' view that science works by reaching consensus on the truth (compare Garte, 1995 to Gilmer, 1995). Thus, we expect both less reliance upon the cues provided, and perhaps more reliance on other influences, such as religion or nationalism. Prior research on public inference of reasons for scientific disputes found that believers in positivism were more inclined to support reasons like incompetence and bias, although also surprisingly, more likely than others to support the reason that the world is complex and thus difficult to decipher (Dieckmann & Johnson, 2019; Johnson & Dieckmann, 2018). Positivism also increased the belief that scientists are motivated by extrinsic (e.g., money, fame, helping employer) and intrinsic (e.g., helping society and others, enjoy challenge) incentives, and desire for scientists to be intrinsically motivated (Johnson & Dieckmann, 2020). Given the focus of positivism on science as an objective process that successfully builds knowledge, we expect that cues emphasizing expertise or consensus will amplify effects on positivists' choice of the more valid position, while cues that challenge that positivist belief will be ignored.

Subjective knowledge (how much people *believe* they know) has enhanced systematic processing in at least one study (Liu & Huang, 2017). In this context, we expect that people with high subjective knowledge about the topic will choose the "more likely to be correct" position on the topic based on their prior beliefs, attenuating any effect of our manipulated cues (Kruglanski, 1996; Kunda, 1987, 1990).

H6. Cues' effects will diminish among people who mistrust science, believe in a positivistic view of science, or feel they have high subjective knowledge of the topic.

H7. Belief in scientific positivism will amplify effects of research quality (replication; information quality), consensus (majority vote), and researcher quality (experience, degree source) cues, and attenuate effects of bias (employer, reference group) cues.

Two other potential moderators–knowledge of science facts and of scientific reasoning—are expected to amplify (at least some) cues' effects on choice of the correct position. In learning science facts in school (e.g., whether the sun orbits the earth or vice versa; antibiotics do not kill viruses), people may have also imbibed enough familiarity with the putative "scientific method" to privilege research quality cues. A more direct test of this notion is to measure knowledge of scientific reasoning, such as the use of control groups or the difference between accuracy and consistency in measurement (Drummond & Fischhoff, 2017; Golumbic et al., 2022).

H8. Knowledge of scientific facts or of scientific reasoning will amplify effects of research quality cues (replication, information quality).

3 | METHODS

3.1 | Sampling

A random sample of 3150 Americans 18+ (30 people X 35 versions of the instrument to accommodate all possible combinations of the seven cues taken three at a time X 3 topics) was recruited November 17–21, 2017 from Survey Sampling International's (now Dynata) online panel.

3.2 | Instrument and measures

After the consent form, the instrument opened with demographic questions partly designed as recruitment screeners ("Sampling" above), partly to collect these data early in case the repetitious main task led people to quit before answering demographic items. After an initial attention screener (see below), people answered questions about their interest in scientific disputes, saw a short description of one of three scientific disputes (below), and asked for their involvement in the topic (see moderator measures in Table 2), how much they cared about which side in the dispute was correct, and their subjective topical knowledge.

At this point, they saw the following paragraph:

> Now, we are going to provide you with information about the two groups of scientists on each side of this dispute. We have randomly labeled one side as Position A, the other as Position B; this has nothing to do with which side is "correct" (we don't know yet), but is merely an arbitrary step to make referring to each side easier. Next, we will present you with a series of "facts" about these two sides. Each set of facts is independent, and we want you to answer the questions following each set of facts as if you've never seen different facts before.

They were shown the first cue combination, randomly ordered, and asked which of the two positions was more likely to be correct, followed by the reminder that "The next page will show a different set of information, and the questions that follow it should be answered as if you've never seen similar information about this dispute before. Please read the information carefully." Each person judged the relative validity (choice of Position A or Position B as most likely correct) eight times (2^3 iterations given exposure to three cues at a time, each favoring one of two positions).

The survey ended with science beliefs and attitudes (Table 2)—scientific positivism, mistrust of science, knowledge of scientific facts, knowledge of scientific reasoning—and with a question on their degree of education in "natural, social or behavioral sciences."

3.3 | Attention screeners

As noted earlier, the repetitious nature of this task might foster respondent fatigue, distraction, and inattention, potentially reducing data quality. We followed Berinsky et al. (2014) in interspersing throughout the instrument four questions designed to measure to what degree people were paying attention. For example, one item (immediately following the demographic questions and preceding the dispute interest questions) began with "Before we proceed, we have a question about how you are feeling," with an ending instruction to "Please check all words that describe how you are currently feeling." Buried in a dense paragraph inserted between these two instructions was the instruction to check only the "none of the above" option. Other screeners were inserted between the subjective topical knowledge and first cue information;

between the last cue information and the first scientific belief (positivism) questions; and between the factual science knowledge and scientific reasoning questions. The number of attention questions answered correctly (0–4) was used as a covariate in multivariate analyses.

3.4 | Analyses

Data were analyzed in Mplus version 6.12 in a two-level regression for a binary outcome using Monte Carlo integration with randomly varying intercepts and slopes. Maximum likelihood estimation with robust standard errors was used with 5000 iterations. An omnibus model was first fit with all seven cues at the within-person level. Covariance coverage was set to 0 to accommodate parameter estimation in this planned-missingness design. Between-person level predictors included topic condition (dark matter, climate change, or marijuana), four science attitude/belief variables (scientific positivism, mistrust of science, knowledge of scientific facts, knowledge of scientific reasoning), an attention score index, and four variables regarding interaction with scientific disputes (involvement in the topic, interest in disputes, subjective knowledge of the topic, and how much one cares about which group of scientists are correct). This model was run twice, with and without covariates, to examine the effect of covariates on overall cue rankings and identify which of the 10 covariates had statistically significant moderator effects.

Binary interactions among the cues, within-person, were tested in 21 separate models. Cross-level interactions between statistically significant covariates and each of the seven cues were tested in separate models.

The interpretation of model results was focused on odds ratio (OR) effect sizes. To put these values into context, Chen et al. (2010) suggested that OR = 1.68, 3.47, and 6.71 are, for epidemiological analyses assuming an incidence of the harm of 1% in the nonexposed population, equivalent to Cohen's (1988) suggested thresholds $d = 0.02$ (small effect), 0.5 (medium), and 0.8 (large), respectively. Our data are not epidemiological, but this 1% rate is a conservative approach, so we use it here to give readers a sense of the absolute magnitude of an effect, with the caution that all such rules of thumb are arbitrary.

4 | RESULTS

4.1 | Respondents

This sample was older, and more female, white, and educated, than the average adult in the United States. They were less politically conservative but similarly political liberal as the average American (there were more moderates in this sample than in the adult population). They were 58.5% female (51.3% in the American Community Survey estimate for July 1, 2017 by the U.S. Census) and 79.8% (63.5%) of non-Hispanic white ethnicity, with 53.8% (32.0% among Americans 25+ years old) having a college degree or more (science education responses were highly correlated with general education responses). Age was high (M = 51.2, SD = 17.0, median = 54 [U.S. median = 38.1, including children], 65+ 26.5% [20.2%], range 18–95). Slightly under a third each were strong or leaning conservative (30.9%) or liberal (29.5%), compared to 36% and 27% for U.S. adults in a May 3–7, 2017 survey (Pew Research Center, 2017).

4.2 | Attention checks

Half (50.6%) got all four checks correct, with another 18.6% getting three correct; 11.7% got no checks correct.

4.3 | Dispute interest

Some 57.0% had heard of scientific disputes, with 53.6% of the sample saying they had tried to decide which group of scientists was more likely correct. However, the proportion assenting to both questions, our definition here of dispute interest, was only 37.7%, unvarying by topic (37% dark matter, 37% marijuana, and 39% sea level rise).

4.4 | Topic views

One-way ANOVAs indicated that all intertopic differences in reported caring, involvement, and subjective knowledge (full phrasing of measures appears in Table 2) were significant at $p < 0.0005$ except for that between marijuana and SLR for involvement (marijuana M = 5.26, SD = 1.60, SLR M = 5.31, SD = 1.65, $p = 0.736$). Marijuana evoked more caring about the correct answer (M = 3.68, SD = 1.10) and more subjective knowledge (M = 3.16, SD = 1.04) than did sea level rise, which in turn evoked more caring (M = 3.47, SD = 1.26), more subjective knowledge (M = 2.86, SD = 1.03), and more involvement in the topic than did the nature of dark matter (caring, M = 2.80, SD = 1.27; subjective knowledge, M = 2.14, SD = 1.18; involvement, M = 4.25, SD = 1.88). Although based on these results we could have focused on topic as a potential influence on cue effects in subsequent analyses, we included all four measures (topic, caring, subjective knowledge, and involvement) as covariates in later models to allow us to see whether there were unique contributions of topic alone when controlling for these other measures.

4.5 | Main and interaction effects

Main effects of cues appear in Table 3 (top). When each cue favored Position B over Position A, the person exposed to that cue was more likely to favor Position B, with varying strength. Without covariates, the rankings by odds ratios

TABLE 3 Odds ratios of main cue effects and interactions on choice of perceived "correct" position.

	Without covariates		With covariates	
Main effects	**Odds ratio**	**95% CI**	**Odds ratio**	**95% CI**
Majority vote	4.79***	4.21, 5.45	5.42***	4.66, 6.30
Replication	4.71***	4.13, 5.37	5.66***	4.85, 6.59
Information quality	3.28***	2.91, 3.70	3.67***	3.19, 4.21
Experience	2.66***	2.38, 2.97	2.71***	2.39, 3.08
Reference group	1.52***	1.38, 1.69	1.48***	1.32, 1.66
Employer	1.37***	1.24, 1.52	1.38***	1.23, 1.56
Degree source	1.30***	1.17, 1.44	1.30***	1.15, 1.47
Cue interactions				
Information quality * Reference group	1.28**	1.09, 1.51	1.39***	1.18, 1.64
Majority vote * Degree source	1.25**	1.06, 1.48	1.22*	1.04, 1.45
Majority vote * Employer	1.24*	1.05, 1.47	1.27**	1.07, 1.50
Replication * Reference group	1.23*	1.04, 1.46	1.21*	1.02, 1.45
Reference group * Degree source	1.23*	1.05, 1.44	1.27**	1.08, 1.48
Information quality * Experience	1.20*	1.02, 1.42	1.19*	1.01, 1.41
Replication* Degree source	1.19*	1.00, 1.40	1.19***	1.00, 1.41
Experience * Degree source	1.17	1.00, 1.38	1.26**	1.07, 1.48
Majority vote * Reference group	1.13	0.96, 1.33	1.11	0.94, 1.31
Employer * Reference group	1.12	0.97, 1.31	1.17	1.00, 1.37
Experience * Replication	1.10	0.94, 1.29	1.13	0.96, 1.33
Replication * Employer	1.07	0.91, 1.27	1.12	0.95, 1.34
Information quality * Degree source	1.06	0.89, 1.26	1.16	0.98, 1.38
Majority vote * Employer	1.05	0.89, 1.24	1.03	0.87, 1.23
Information quality * Experience	1.02	0.87, 1.21	0.97*	0.81, 1.14
Information quality * Majority vote	1.01	0.85, 1.20	1.05	0.88, 1.25
Information quality * Replication	0.99	0.84, 1.17	1.01	0.85, 1.19
Employer * Degree source	0.91	0.78, 1.06	0.89	0.77, 1.04
Experience * Reference group	0.90	0.76, 1.06	0.93	0.79, 1.11
Experience * Employer	0.87	0.74, 1.01	0.90	0.77, 1.05
Majority vote * Replication	0.76	0.64,0.90	0.75**	0.64, 0.90
Covariates				
Topic			0.73***	0.67, 0.79
Mistrust of science			0.73***	0.70, 0.78
Science facts			0.91**	0.85, 0.96
Scientific reasoning			0.94**	0.91, 0.98
Attention score			1.01	0.95, 1.06
Scientific positivism			0.75***	0.68, 0.83
Involvement			0.84***	0.80, 0.88
Subjective knowledge			1.12	0.97, 1.30
Care about correct			0.97	0.90, 1.05
Disputes interest			1.05	0.97, 1.14

Abbreviation: CI, confidence intervals.
*$p < 0.05$;
**$p < 0.01$;
***$p < 0.001$.

of cue effects had majority vote and replication at the top, both medium effects. Next were information quality and experience, both small effects. Weaker effects occurred for reference group, employer, and degree source. Thus, these main effects were consistent with H1 on the majority vote cue having the strongest effects, and with H2 on replication having relatively strong effects. H2 was less supported by information quality results, as they were the third strongest of the seven cues but exhibited only small effects. Experience's small effect size also was only partly supportive of H3 which posited "moderate" effects. Finally, credentials' failure to exhibit any effect was inconsistent with H3, and on RQ1 reference group and employer cues had less-than-small effects, although technically stronger ones than those offered by degree source (credentials).

We posited no hypotheses about the interaction among cues, but the middle of Table 3 shows that some of these were statistically significant if still of less-than-small effect. The positive odds ratios indicate that the combination of both cues pointing to Position B led to a stronger increase in respondent support for Position B as most likely correct than if only one of the cues pointed to Position B.

The results when controlling for covariates were identical, except that majority vote and replication switched places at the top; information quality also met the medium effect criterion; and two of the significant cue interactions were now negative (i.e., an odds ratio of less than 1.0), indicating that the combination (information quality X experience; majority vote X replication) reduced the tendency to choose Position B as the view most likely to be correct.

Finally, Table 3 (bottom) shows that most covariates reduce the effect of the cues, excluding three covariates that are nonsignificant (subjective knowledge, disputes interest, attention score). This list indirectly supports H4, in that topic has a statistically significant effect even when we control for the factors on which the topics differed significantly (involvement, caring about which side is correct, subjective knowledge; Section 4.4). But we need to turn to other data to fully test this and subsequent hypotheses.

4.6 | Moderator effects

We postulated that topic would be a moderator, with the three topics particularly distinguished by the effect of majority vote, degree source, and experience (H4). Table 4 shows contrasts across two topics at a time for each cue, to test this hypothesis. The odds ratio column indicates, relative to the reference topic shown in parentheses, how much the cue's effect changes for the focal cue. If the odds ratio is less than 1.0, then a cue has less effect on the choice of which side is correct in the focal than in the reference topic's dispute; the smaller (closer to zero) the odds ratio, the bigger the difference between the cue's effects on the two topics. If the odds ratio is greater than 1.0, the cue has more effect for the focal than the reference topic, with greater intertopic differences as the odds ratio gets larger. We presumed in Section 2.5 that cues would have most effect on the dark matter topic, and least effect on marijuana benefits and risks, due to varying topical involvement, caring about which side is correct, or subjective knowledge, an explanation confirmed in Section 4.4.

These expectations are largely confirmed in Table 4. The first comparison is between dark matter, for which we expected the strongest cue effects, and marijuana, for which we expected the least cue effects. All of the cues except degree source showed significantly weaker cue effects for marijuana, with the biggest gaps for information quality, majority vote, and replication, all small effect sizes. For the sea level rise comparison to dark matter, again we see the expected and statistically significant difference in cue effects for all cues but experience, but the higher odds ratios here compared to the marijuana−dark matter contrast indicate that the effect of topic as a moderator is weaker. Information quality, majority vote (both small effects), employer, and replication are the cues exhibiting the greatest gaps in effects across these two topics. Finally, the SLR−marijuana contrast shows that cues as expected again had more effect on the former, but only three of these cue gaps were statistically significant at $p < 0.05$: the strongest gap was for replication (small effect), followed by majority vote and experience. H4 postulated that majority vote, degree source, and experience would particularly feature large differences in effects across topic. The results support the majority vote part of the hypothesis for all three contrasts, the experience part only for the SLR−marijuana contrast, and the degree source part not at all.

To test the final hypotheses, we calculated cross-level interactions between covariates with statistically significant main effects in Table 3 and all seven cues. A slope-on-slopes analysis for each interaction predicted the slope for each cue with the moderator's value, with estimates indicating the change in cue effects with each increase in the response on the moderator scale (Table 5).

H5 had posited that cue effects would be stronger among people who are attentive to survey questions, interested in intrascience disputes, care about which side of the dispute is correct, and are highly involved in the dispute topic, but Table 3 results showed that only the latter had a statistically significant effect. Table 5 results show that topic involvement did not interact significantly with any cues, so H5 is rejected entirely. These four motivational factors had no moderating effects at all in this experiment.

The rest of Table 5 concerns the hypothesized capacity moderators. H6 had posited that cue effects would be weaker as mistrust of science, positivist beliefs, and subjective knowledge increased. If so, we should observe odds ratios less than 1.0 for mistrust and positivism (again, we omit subjective knowledge as being a nonsignificant covariate in Table 3): as the moderator rating increases, the cue should have less effect. This is what we observe for mistrust, although it is statistically significant for only four cues: majority vote, a small effect, replication, information quality, and experience. However, for

TABLE 4 Cue by topic interactions on choice of perceived "correct" position.

Marijuana (vs. dark matter)	Odds ratio	95% CI	Std. error	*p*
Majority vote	0.38***	0.27, 0.53	0.17	< 0.001
Replication	0.41***	0.28, 0.58	0.12	< 0.001
Information quality	0.37***	0.29, 0.49	0.14	< 0.001
Experience	0.60***	0.48, 0.76	0.12	< 0.001
Employer	0.64***	0.51, 0.80	0.11	< 0.001
Degree source	0.86	0.70, 1.06	0.11	0.151
Reference group	0.78***	0.71, 0.86	0.05	< 0.001
Sea level rise (vs. dark matter)				
Majority vote	0.55***	0.39, 0.79	0.18	0.001
Replication	0.69*	0.47, 1.00	0.19	0.049
Information quality	0.49***	0.35, 0.67	0.16	<0.001
Experience	0.83	0.64, 1.08	0.13	0.164
Employer	0.67***	0.52, 0.85	0.13	0.001
Degree source	0.75*	0.59, 0.96	0.13	0.022
Reference group	0.80***	0.72, 0.88	0.05	<0.001
Sea level rise (vs. marijuana)				
Majority vote	1.41*	1.03, 1.93	0.16	0.031
Replication	1.68**	1.21, 2.33	0.17	0.002
Information quality	1.27†	0.98, 1.65	0.14	0.076
Experience	1.34*	1.02, 1.77	0.14	0.033
Employer	1.02	0.81, 1.28	0.12	0.885
Degree source	0.85	0.67, 1.09	0.13	0.209
Reference group	1.00	0.84, 1.19	0.09	0.996

Note: Parentheses indicate reference topic.
Abbreviation: CI, confidence intervals.
†$p < 0.10$.
*$p < 0.05$.
**$p < 0.01$.
***$p < 0.001$.

believers in scientific positivism, the result was mixed: as positivism increased, the effect of experience and reference group decreased as expected, but the effects of majority vote and information quality cues increased, the reverse of expected. Because none of these associations was even a small effect, H6 is partly supported at best, primarily that cue effects are smaller among mistrusters. H7 is also only partly supported: reference group effects were indeed attenuated, while majority vote and information quality effects were indeed amplified, but experience's effects were attenuated rather than amplified, and positivism had no significant effects on replication, degree source, or employer cues.

H8 posited that knowledge of scientific facts or of scientific reasoning would amplify effects of replication and information quality. Table 5 shows that this is true for both moderators, but this is also true for the other top cues by main effects (Table 3), majority vote and experience, and none of these interactions met the small-effects criterion.

5 | DISCUSSION

5.1 | Findings

Largely consistent with H1–3 and with Johnson's (2019b) findings, we found that majority vote, replication, information quality, and experience were the strongest cues here in influencing lay judgments of which side in a dispute between groups of scientists held a likely more valid position. The convergence of the two studies' findings increases confidence that these relative effects are real. Further, the answer to RQ1 was that employer as a cue of private interests and reference group as a cue of salient shared values both had weak effects.

As for moderators, our general expectation that topic would be a factor in cue effects, even controlling for general (dispute interest) and specific motivations linked to topics—topical involvement, caring about which side is correct, subjective topical knowledge—was supported. Specifically, exposure to cues influences people's judgments for not just obscure topics like the nature of dark matter about which

TABLE 5 Cue by covariate interactions on choice of perceived "correct" position.

Cues X involvement	Odds ratio	95% CI
Majority vote	0.96	0.89, 1.04
Replication	1.00	0.92, 1.07
Information quality	1.02	0.92, 1.04
Experience	1.00	0.94, 1.05
Employer	0.99	0.92, 1.07
Degree source	1.00	0.94, 1.05
Reference group	1.03	0.99, 1.08
Cues X mistrust		
Majority vote	0.58***	0.53, 0.65
Replication	0.71***	0.63, 0.79
Information quality	0.77***	0.71, 0.84
Experience	0.91*	0.84, 0.98
Employer	0.96	0.91, 1.02
Degree source	1.04	0.98, 1.11
Reference group	0.99	0.85, 1.15
Cues X scientific positivism		
Majority vote	1.39***	1.15, 1.68
Replication	1.10	0.91, 1.29
Information quality	1.21*	1.03, 1.42
Experience	0.88*	0.77, 1.00
Employer	0.99	0.86, 1.13
Degree source	1.11	0.99, 1.22
Reference group	0.92**	0.86, 0.97
Cues X science facts		
Majority vote	1.20**	1.07, 1.35
Replication	1.44***	1.29, 1.60
Information quality	1.10*	1.00, 1.21
Experience	1.14***	1.06, 1.22
Employer	0.98	0.90, 1.06
Degree source	1.01	0.93, 1.08
Reference group	1.02	0.96, 1.08
Cues X scientific reasoning		
Majority vote	1.27***	1.19, 1.35
Replication	1.33***	1.24, 1.42
Information quality	1.25***	1.17, 1.31
Experience	1.10**	1.04, 1.16
Employer	0.98	0.93, 1.04
Degree source	0.98	0.94, 1.03
Reference group	0.99	0.94, 1.03

Abbreviation: CI, confidence intervals.
*$p < 0.05$;
**$p < 0.01$;
***$p < 0.001$.

people are less likely to care or hold a prior opinion, but we saw—consistent with H4—that cue effects were larger for dark matter than for either sea level rise from climate change, and particularly for marijuana benefits and risks, for which people felt they knew more and were more involved in the topic. The motivation-oriented moderators we explored—attention, involvement, caring, dispute interest—had no substantive effect on cue effects, contrary to H5, while among capacity moderators, mistrust of science had strong effects (H6), knowledge of scientific facts and of scientific reasoning had significant effects on the most powerful cues, and not just on replication and information quality cues, but not on others (H8), and belief in scientific positivism had mixed effects (H6, H8).

5.2 | Research implications

This presents several intriguing paths to follow in future research on cues to the relative performance of disputing groups of scientists. First, there is relative consistency in scientific majorities, research quality (e.g., replication, information quality), and experience exhibiting the strongest effects across multiple topics and two separate U.S. samples (with a more discriminating experimental design in the current study) on people's choice of which dispute position is more credible. For their five common cues, the Kendall's tau-b rank-order correlation coefficient between Johnson's (2019b) results and those here was 0.60, a respectable association ($\tau = 0.33$ when replication ranked first here after covariates were included). Taking a quite different criterion—not whether the cue is descriptively effective in altering which side in the dispute is more likely correct, but the cues' perceived reliability for discerning the relative performance of disputing groups of scientists (Johnson, 2019a)—the latter measure correlated well with the cue-effects ranking by Johnson (2019b) at $\tau = 0.71$, but much lower here ($\tau = 0.24$), contradicting Johnson's (2019b) speculation that perceived reliability ratings could reflect actual cue effects. In other words, people may not be good judges of which cues affect their response, at least on this which-side-correct question, acknowledging that perceived cue reliability was not rated in the same studies in which these cues were manipulated.

However, these results still beg for explanation. One might argue that these cues are the equivalent of strong arguments in the persuasion literature (e.g., Petty et al., 1981). If there is scientific consensus, and the underlying evidence has been independently gathered and analyzed by experts who have learned over time how to do this competently (Goldman, 2001), logically one could conclude that the resulting dispute position is more likely correct. Similarly, experience as a cue to trustworthiness in daily life—for example, contrast one's expectations of a newly minted doctor versus of a doctor with several years of medical experience—might seem a strong cue. Yet, our experimental evidence does not allow us to determine whether this is how our respondents reasoned. The extensive education of both our and Johnson's (2019b) samples—both had over half of their respondents reporting college degrees or better—may be the simplest explanation of the relatively strong effects of the research quality cues of replication and information quality. We cannot rule out social desirability pressures—for example, "I think these are cues that real scientists use, so I'll follow them too"—but given that scientific knowledge (of facts and of scientific reasoning) amplified not only these cues' effects, but those of majority vote and experience, such pressure seems less likely. Post-manipulation debriefings of individual respondents, in a format that allows for near-real-time feedback to researchers on how specific cues affected their judgments, would be one way to understand these strong influences.

Second, the continuing (after Johnson, 2019b) weak performance of cues like reference group, employer, and degree source also warrants examination. This might simply indicate that these are ineffective cues, but even if that is the only reason we would need to ask why. By necessity in this case, the reference group manipulation could not invoke a group salient to the individual respondent who also might plausibly hold a position on the topic of dispute. For example, we were unable without risking priming effects or social desirability bias to probe the individual respondent's salient values or appropriate reference group for the dispute topic, and then provide a tailored reference-group cue. However, a different research design could do so, and such studies should be conducted before we conclude that this kind of cue—dealing with salient shared values, argued to be a critical factor in trust in at least one model (Earle & Siegrist, 2008)—will not influence relative-validity judgments. Given the general literature support for private interest as a critical moderator, and specifically for employer effects, the employer cue's general failure here (it did distinguish the dark matter topic from the other two topics, but not among them, and had no other moderation effects) is surprising. It may indicate that we need to make the employer more specific (as indicated in Table 1, we did not name the employers as in some other interest-cue research [also see Johnson & Dieckmann, 2021]), explore other cues to private interests, and/or acknowledge that the role of interest is highly context-specific. As for credentials like degree type and source, there is a long tradition of field studies—usually ones in which scientists are largely pitted against nonscientists, rather than against each other—in which credentials are found wanting as cues to trustworthiness (Jasanoff & Wynne, 1998; Wynne, 1989). That said, credentials are used even by scientists to some degree as cues (e.g., Collins & Evans, 2007, pp. 50–51, note 10), and laypeople without much interest in scientific disputes were slightly more likely to rate them as reliable cues to relative validity than did high dispute-interest respondents (Johnson, 2019a), so they may still deserve consideration in certain cases.

Third, moderator findings also merit following up. Motivational factors distinguished among topics even if they did not directly moderate effects of specific cues, and topic managed to significantly predict cue effects even controlling for motivational factors, raising the question of what other attributes of the topic might explain this residual effect. Collectively capacity moderators performed more effectively than motivational moderators, particularly mistrust of science. Knowledge of science facts and scientific reasoning had smaller effects, but all three had statistically significant effects only on the cues that had the strongest main effects, probably reflecting only enough variance in response to these cues for moderator effects to be visible. As in prior research on factors in lay explanations for intrascience disputes (Dieckmann & Johnson, 2019; Johnson & Dieckmann, 2018), belief in science positivism had mixed and somewhat inexplicable effects. For example, when positivism was high people placed more weight on the quality of the information and majority vote. A greater faith in science to produce a linear progression in the advancement of knowledge may cause people to favor the most cutting-edge and state-of-the-art techniques, while 75% consensus among scientists may signal to positivists that an objective truth has been found. On the other hand, it is unclear why the cues of scientist experience and reference group had less effect among high than low believers in scientific positivism.

Fourth, we must underline that only in the main effects (Table 3) were there even medium effect sizes (majority vote and replication, with information quality added once we controlled for covariates). Small effect sizes were observed for direct effects of information quality (without covariates) and experience on relative performance judgments, as well as for the strongest cues in distinguishing between topics. For other moderators, only mistrust exhibited a single small effect; all other associations had less-than-small effect sizes. We acknowledge that suggested thresholds for calculating "small" or "large" effects (e.g., Chen et al., 2010) are arbitrary if potentially helpful, and a "small" effect statistically may carry practical significance (e.g., in health promotion, a "small" intervention may aid millions of people). As our data concern attitudes and relative performance choices rather than outcomes observable without self-reports, the failure to observe even small effect sizes here for several cues and most moderators implies that most cue and moderator effects are trivial, pending confirming findings from future research.

Fifth, the study's limitations in the number and variety of cues tested, and of its sample (U.S. residents, as in Johnson, 2019b), will need to be complemented by studies using other cues, samples, and research designs to be able to generalize these findings. Given that our dependent variable was narrow—whether one or another side of the disputing scientists was more likely correct—and we focused primarily on ability cue effects, it also would be useful to assess the effect of a wider set of relative performance cues, including those more salient to integrity and benevolence (Mayer et al., 1995), on a wider set of dependent variables.

5.3 | Practical implications

There are also several implications to explore regarding practical applications of these findings, if with caveats we will cover at the end of this section.

The argument for making scientific consensus a major feature of persuasive messages about climate change and other politicized issues when scientists are in conflict with mostly nonscientists raises the question of whether the gateway belief model (e.g., van der Linden et al., 2015b, 2019) could be generalized to intrascience disputes, given that a majority vote of merely 75% (vs. 90% or 97% proportions used elsewhere) was persuasive here. Might similarly majority but less-than-consensus results be persuasive in practical applications for other topics? Questions will arise about whether and how scientific majorities arise for which aspects of a contentious issue, whether majorities are epistemically salient in mid-dispute, and how to demonstrate effectively to a public audience that a particular majority exists, but these questions do not alone make the suggestion implausible. Replication and information quality are among cues that scientists themselves use, and among factors recommended to citizens for educating themselves on how to evaluate individual scientific studies, or media reports on such studies (Alberts & McNutt, 2013; Collins & Weinel, 2011; Harvard School of Public Health, 2016; Sutherland, Spiegelhalter, & Burgman, 2013). While these guides are neither comprehensive nor devoted to explaining the relative strength of different cues, seeing whether replication and information quality might have large persuasive effects in practice seems warranted, even if their persuasiveness might be limited to people who are well-educated if not already knowledgeable about science. The persuasiveness of our last strong cue, experience, warrants further exploration, given that it does not appear in such guides, and while it is used by scientists sometimes in evaluating their peers' competence, its interpretations are obscure. For example, what aspects of experience are salient when? under what conditions is experience counter-productive, as in Planck's principle that new science triumphs only when its opponents die, which seems to be true for life sciences at least (Azoulay et al., 2019)? And do citizens recognize these variations in experience's value as a cue?

This last point brings us again to caveats about the efficacy of such cues for accurately determining which expert, or group of experts, is more likely to turn out to be correct. While the nonempirical literature about lay capability to judge expertise at the nonlocal level (e.g., Collins & Evans, 2007) did not apply in the current experiment, as people did not have to search for or interpret cues that we phrased colloquially rather than in expert jargon, those concerns do apply in real-world contexts. That some cues are stronger than others in influencing which side in an intrascientific dispute laypeople decide is more valid does not mean that these cues are objectively reliable, nor that cues presented in ordinary journalistic or scientific language, buried within legacy or social media information, will be as influential as they were in these explicit, simple, clear cue scenarios. For example, in practice, majorities may not be always formed from scientists' independent judgments of the evidence, but rather from groupthink (Goldman, 2001); even scientists from subfields outside the one in the discipline convulsed with controversy may not fathom the technical grounds for the dispute (e.g., Collins & Evans, 2007); and greater experience could imbue scientists with resistance to new evidence rather than greater insight and competence (e.g., Rappa & Debackere, 1993). Further, the frequency and format with which these cues might appear in laypeople's usual information sources about scientific disputes, and the information processing they do or do not engage in to grasp and interpret these cues, have not been assessed (Johnson, 2019b). We need ethnographic studies of how people deal with trustworthiness cues *in vivo*, including challenges or opportunities in daily lives that could attenuate or amplify cue effects observed here, to promulgate better help for people on how to find and use intrascience trustworthiness cues.

6 | CONCLUSIONS

Readily accessible scientific media and popular science have made the public increasingly aware of scientific disputes. For topics touching upon issues of daily life—for example, health and safety—people arguably *should* be interested in such disputes, and our results implied that those self-reporting low or no interest in scientific disputes were still affected by the largely ability cues provided in this experiment. Conversely, the sheer amount of information available forces people to regularly prioritize the relevance of individual scientific disputes. As such, cues to the relative performance of disputing scientists will play an increasing role in how laypersons cognitively construct a current and defensible perception of which side is correct. The question of which cues to the more credible position in a scientific dispute are more influential, and why, will be of continuing theoretical and practical interest, to risk communicators as well as to scholars of public understanding of science. We hope colleagues join us in further exploring this topic, as outlined in the Discussion.

More broadly, the development of risk science, the rise in scholarship on misinformation and disinformation, and the increasing effort devoted to discussing scientific findings and procedures with citizens at large all underline the payoff for risk communicators to attend to the issues raised by the topic of trustworthiness cues regarding intrascience disputes. These issues range from detailed phrasing of messages (e.g., "how does one convey the strengths and weaknesses of scientific majorities as cues to performance, and how to weigh them in making one's own decisions?") to major tactical questions (e.g., "How do people weigh ability, integrity and benevolence cues in judging trust in disputing scientists, and how should they?") to debates over how authoritative science and scientists should be in society. While the experimental insights gained here are far less sweeping, we hope that they have highlighted the value of probing these larger questions about the meaning and interpretation of disagreements among scientists over what science knows.

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