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Understanding public preferences for learning about uncertain science: measurement and individual difference correlates

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Although uncertainty is inherent in science, public audiences vary in their openness to information about preliminary discoveries and the caveats and limitations of research. These preferences shape responses to science communication, and science communicators often adapt messaging based on assumed preferences. However, there has not been a validated instrument for examining these preferences. Here, we present an instrument to capture preferences for information about uncertainty in science, validated with a large U.S. adult sample. Factor analysis results show that preferring certain scientific information and preferring uncertain scientific information are orthogonal constructs requiring separate measures. The final Preference for Information about Uncertain Science (or "PIUS-11") scale comprises two dimensions: *preferring complete information* (*i.e., caveats, limitations, and hedging included)* and *being open to learning about preliminary science*. The final Preference for Certain Science Information (or "PCSI-9") scale comprises two dimensions: *preferring streamlined information* (*i.e., caveats, limitations, and hedging removed*) and *preferring to learn only about established science*. We present psychometric properties of each scale and report observed relationships between each set of preferences and an individual's scientific understanding, trust in science, need for cognitive closure, and sociodemographic factors.

KEYWORDS

science communication, health communication, information preferences, uncertain science, scientific uncertainty, uncertainty tolerance, science literacy, public understanding of science

Introduction

Scientific discoveries disseminated to the public are often related to health and medicine, and how public audiences receive this information can have bearing on individual and public health (National Academies of Sciences, Engineering, and Medicine, 2017). Nonexperts view the scientific process differently from experts (Bromme and Goldman, 2014; National Science Board, 2020), posing challenges for conveying the inherent complexities of scientific evidence to the public (Einsiedel and Thorn, 1999). Adding to these challenges, "the public" is not a single monolithic entity but is instead comprised of multiple publics with a diverse mix of backgrounds, dispositional characteristics, and preferences (Scheufele, 2018). Studies demonstrate mixed effects of communicating scientific caveats and limitations to public audiences (see reviews by van der Bles et al., 2019; Gustafson and Rice, 2020; Ratcliff et al., 2022), underscoring the likelihood that these reactions depend, at least in part, on individual differences.

A growing body of research finds support for the influence of audience characteristics on reactions to uncertain science communication. These characteristics include level of education (Jensen et al., 2017; Adams et al., 2023), dispositional uncertainty tolerance (Ratcliff et al., 2021), and beliefs about the nature of the scientific process (Rabinovich and Morton, 2012; Kimmerle et al., 2015; Ratcliff et al., 2023). While insightful, these characteristics only sometimes moderate the effects of communicating uncertainty,[1] suggesting that additional factors warrant investigation. Gustafson and Rice (2019, p. 699) recommend that "research should study more carefully how individual characteristics moderate these effects—especially characteristics that relate to attitudes toward, or preferences for, uncertainty." Emerging evidence suggests that public audiences do indeed have diverse preferences with regard to learning about uncertainty in scientific discoveries (Maier et al., 2016; Wegwarth et al., 2020; Post et al., 2021; Ratcliff and Wicke, 2023). Yet the relationship between these preferences and other individual characteristics is still unclear, and the literature lacks a comprehensive and validated tool for measuring such preferences.

Being able to directly capture preferences for (un)certain science information is an important step toward better public science communication. It paves the way for research that uncovers the factors shaping these preferences and, ultimately, for identifying ways to effectively disseminate uncertain scientific evidence to different publics, which remains a topmost goal in health, risk, and science communication (Jensen et al., 2013; National Academies of Sciences, Engineering, and Medicine, 2017; Sopory et al., 2019; Paek and Hove, 2020; Simonovic et al., 2023). To this end, we use the current project to develop and validate a comprehensive measure of information preferences related to uncertain science. We build on an existing measure (the 7-item Preference for Information about Uncertain Science, or "PIUS-7," scale; Ratcliff and Wicke, 2023), which captures the extent to which people want to hear about preliminary scientific discoveries and the specific caveats and limitations of research. Initial tests of that scale in two health contexts—genetic depression risk and COVID-19 vaccines—demonstrated that people's preferences and expectations regarding science communication help to explain their reactions to (un)certainty messages. Specifically, we found that communicating uncertainties in COVID-19 vaccine research had a negative effect on perceived source credibility *only* for people with low PIUS scores (Ratcliff et al., 2023). Similarly, we found that communicating uncertainties in research on genetic depression risk enhanced perceived source credibility for those with high PIUS scores (Ratcliff and Wicke, 2023). Although these tests of the initial PIUS scale were insightful, critical next steps are to (1) explore additional facets of preference not captured by that measure, (2) examine the psychometric properties of the measure, and (3) identify which individual characteristics are associated with these preferences. In the current project, we develop and test a large battery of items capturing preferences for both certainty and uncertainty communication. We test the factor structure, reliability, and validity of an expanded instrument and examine individual difference correlates in order to better understand which factors influence or relate to (un)certainty information preferences.

Characterizing (un)certain science information preferences

Scientific uncertainty takes many forms and comes from many different sources (Han et al., 2011; van der Bles et al., 2019; Ratcliff, 2021). Preliminary or initial scientific discoveries are inherently uncertain (Dumas-Mallet et al., 2018). Yet nearly all scientific claims—even well-established ones—are characterized by some degree of uncertainty, owing to methodological limitations, uncertainty associated with probabilistic models, or the sheer complexity of some phenomena (Han et al., 2011; Gustafson and Rice, 2020). Journalists and other science communicators choose whether to present preliminary science or to only report established findings with a strong evidence base and scientific consensus (Friedman et al., 1999). They also choose whether to convey complete information about uncertainties, or to instead *streamline* research reports—that is, to "remove caveats, limitations, and hedging so science appears simple and more certain" (Jensen et al., 2013, p. 1).

Science communicators' choices about whether to communicate uncertainty or to streamline science, and whether or not to share preliminary evidence, are often based on beliefs about audience preferences (Friedman et al., 1999; Guenther and Ruhrmann, 2016; Maier et al., 2016). Most often, these beliefs result in the systematic removal of uncertainty from science (Jensen et al., 2013; Dumas-Mallet et al., 2018; Ratcliff, 2021). Yet there have been few empirical attempts to actually understand public expectations and preferences for (un)certain science information. Are general audiences really so averse to communication of scientific uncertainty? Importantly, *desiring communication of uncertainty* does not indicate a preference for being in a state of uncertainty, but for learning about the uncertainty of others (e.g., scientific experts). A *preference for communication of certainty*, in contrast, captures a desire for streamlined and definitive summaries of complex and potentially uncertain science.

Why would some individuals choose to receive complete information about scientific findings, while others want a streamlined (even if inaccurate) account? Factors driving a preference for learning about research caveats and limitations include associating these with transparent (i.e., complete, honest, and accurate) information (Maier et al., 2016) and wanting full information about the research in order to make one's own judgement (Post et al., 2021). An interest in learning about preliminary science can arise from an acceptance of uncertainty as a normal part of science, with an awareness that conclusions may change in the future (Frewer et al., 2002; Maier et al., 2016). It can also stem from associating preliminary science with scientific progress and cause for optimism (Biesecker et al., 2014; Maier et al., 2016) or from viewing it as sometimes the best available evidence (Frewer et al., 2002). In contrast, a preference for streamlined science information can be shaped by a belief that one doesn't have the knowledge to make sense of uncertainty (Maier et al., 2016)

1 For example, uncertainty tolerance had no moderating effect in Simonovic and Taber (2022) and education was not a significant moderator in Ratcliff et al. (2023).

and a desire to instead rely on experts' interpretations (Einsiedel and Thorn, 1999). It can also be shaped by a belief that uncertain language is unnecessarily complex and confusing (Greiner Safi et al., 2023). Another common factor underlying preference for both established science and streamlined claims is a belief that information about certain science is more reliable and useful, while communicating uncertainty signals that the research is unreliable, unfinished, or poor quality (Frewer et al., 2002; Biesecker et al., 2014; Maier et al., 2016; Post et al., 2021).

A notable gap in the literature, however, is evidence about what shapes these appraisals and their associated preferences. Below, we outline three individual factors—a person's view of how science works, level of trust in science, and ability to manage ambiguity in general—that may underpin preferences for certain or uncertain science information. Additionally, we explore potential relationships between preferences and sociodemographic factors.

Understanding of science

Appraisal of uncertainty can be shaped by one's familiarity or experience with the issue (Mishel, 1988). Therefore, a person's scientific understanding is likely to play a central role in the formation of preferences for (un)certain science information. According to Miller (1983), scientific literacy is comprised of three dimensions: comprehension of specific scientific concepts (i.e., factual knowledge), understanding of the scientific process (i.e., understanding the process of conducting a scientific study), and awareness of contemporary scientific issues. The first two dimensions are likely to correlate with whether a person views uncertainty as a normal part of science; that is, whether they have "sophisticated epistemic beliefs" and view science as an ongoing process of discovery or have "simple epistemic beliefs" and view scientific knowledge as stable, concrete, and absolute (Kimmerle et al., 2015; Retzbach et al., 2016). Research has found that people with greater understanding of the concept of a scientific study react more favorably when scientific information is framed as uncertain rather than certain (Ratcliff et al., 2021), as do those with sophisticated epistemic beliefs (Ratcliff et al., 2023) and those who view science as "a debate between alternative positions" rather than as "a quest for absolute truths" (Rabinovich and Morton, 2012, p. 993). Further, Post et al. (2021) observed a connection between believing science is certain and preferring journalists to report definitive information during the COVID-19 pandemic. Given this, we investigate whether preferring information about uncertain science is related to greater scientific understanding; specifically, greater factual scientific knowledge, understanding of the concept of a scientific study, and sophisticated beliefs about the nature of scientific knowledge.

Trust in science

A person's trust in scientists and deference to science could influence their comfort with uncertain science information. In the absence of expertise, members of the public often rely on experts to inform their attitudes toward scientific issues (Hendriks et al., 2016). Potentially, being generally inclined to *trust scientists*—that is, to believe in their integrity and benevolence (Hendriks et al., 2016)—could predispose someone to interpret uncertainty and preliminary science in a favorable light. Conversely, people with low trust in scientists' integrity and goodwill might use motivated reasoning to interpret information about uncertainty as further evidence of untrustworthiness (Gustafson and Rice, 2020). *Deference to science* represents the extent to which an individual is likely to accept, rather than challenge, information from scientific entities and to view scientists as an authority on scientific-related matters (Binder et al., 2016). It also taps a belief that science need not be subject to the same level of regulation as other institutions, such as corporations and government entities (Brossard and Nisbet, 2007). It is possible that those with greater deference to scientific authority are more comfortable with information about uncertainty, perhaps because they believe that uncertain science is still the best information available, or they feel confident scientists will be able to resolve this uncertainty. An alternative possibility is that deference and trust lead individuals to believe science can provide definitive answers, or to prefer that scientists streamline their findings, choosing what information to present and how it should be interpreted. To date, studies have not found clear linkages between deference to science and reactions to messages about scientific uncertainty (e.g., Clarke et al., 2015; Binder et al., 2016; Dunwoody and Kohl, 2017). Thus, it remains in question whether trust in scientists and deference to science cause an openness to uncertain information and preliminary science, or whether these inspire a preference to receive certain scientific information.

Need for cognitive closure

Individuals are thought to have a general orientation toward uncertainty, which shapes their tolerance for ambiguity and other sources of uncertainty across a range of life contexts (Han et al., 2011; Hillen et al., 2017). As it pertains to information preferences, those less tolerant of uncertainty tend to have a high *need for cognitive closure*, defined as a desire for "an answer on a given topic, any answer, … compared to confusion and ambiguity" (Kruglanski, 1990, p. 337). Potentially, need for cognitive closure—or simply "need for closure"—influences a person's scientific information preferences: those with low need for closure may be much more open to learning about uncertain science and specific sources of uncertainty surrounding a discovery, while those with high need for closure may prefer to learn only about established science and may prefer certain or concrete (even if less accurate) information. An important question is whether scientific uncertainty information preferences are related to but *distinct from* a general need for closure.

Sociodemographic factors

Groups that differ in their response to (un)certain science communication may be distinguished by sociodemographic factors. Receptiveness to information about emerging or controversial science, such as new medical technologies or climate change, tends to be associated with factors such as race, political affiliation, political ideology, and religiosity (Drummond and Fischhoff, 2017; National Academies of Sciences, Engineering, and Medicine, 2017; Rutjens et al., 2022). However, aside from education level, which has been shown to moderate the effects of communicating scientific uncertainty (Jensen et al., 2017; Adams et al., 2023), relationships between sociodemographic variables and responses to uncertain communication are largely unexplored. Therefore, we investigate age, gender, education, race, ethnicity, religiosity, political affiliation, and political ideology as potential correlates of uncertainty preferences.

Research questions

Based on the conceptual and theoretical frameworks and evidence described above, we developed a measure of preferences for (un)certain science information with the goal of addressing the following research questions:

RQ1: What is the nature of (un)certain science information preferences, in terms of valid indicators and the factor structure of the construct(s)?

RQ2: Do preferences for (un)certain science information relate to scientific understanding (i.e., epistemic beliefs, factual science literacy, and understanding the concept of a scientific study), trust in science (i.e., trust in scientists and deference to science), or a need for cognitive closure?

RQ3: Do preferences for (un)certain science information relate to sociodemographic factors?

Item development

To develop a pool of items for testing, we built on the aforementioned PIUS-7 scale (Ratcliff and Wicke, 2023) with a focus on achieving broader coverage of the construct(s) and using language that resonates with nonexperts. In line with the original PIUS measure, we sought to capture preferences for both *complete information* (i.e., communication of research caveats, limitations, and unknowns) and *information about preliminary science* (i.e., wanting to learn about emerging science, not just established science). These dimensions share common attributes as both involve communicating about uncertain science. Yet, as previously discussed, they differ insofar as all scientific evidence is characterized by some degree of uncertainty, and therefore information about uncertainty can be communicated about most science (even relatively established evidence), whereas preliminary science is by nature highly uncertain. Moreover, the former preference emphasizes transparency about research details, while the latter emphasizes an interest in learning about novel discoveries even if they may be tentative.

A key limitation of the original PIUS scale was its focus on *uncertainty* preferences. Although it is possible that certainty-focused and uncertainty-focused preferences represent opposite sides of a spectrum—where low preference for uncertainty is the same as high preference for certainty—it is also possible that these are not mutually exclusive and instead represent distinct constructs. For example, although the original scale contained three items focused on preference for certainty, these were removed because they did not load inversely on the uncertainty preference factor (Ratcliff and Wicke, 2023). This suggests the possibility that preferences for certain and uncertain information can coexist and should therefore be captured with separate measures. Therefore, we created two distinct sets of items: one representing *uncertainty preferences* (with subsets for *complete information* and *preliminary science*) and the other representing *certainty preferences* (with subsets for *streamlined information* and *established science*). Within this conceptual framework of four possible preference dimensions, we developed a bank of items for further testing.

Because nonexperts view the scientific process differently from experts (Bromme and Goldman, 2014; National Science Board, 2020), we consulted qualitative studies (e.g., Maier et al., 2016; Greiner Safi et al., 2023) and existing scales (e.g., Frewer et al., 2002; Post et al., 2021) to get a sense of the language nonexperts use to describe preferences for learning about uncertainty. To enhance the informativeness of the scale, we sought to include a mix of straightforward item statements that simply capture information preferences, along with statements that capture specific reasons for these preferences, guided by the literature described in the previous section. Integrating these observations, we retained the seven uncertainty-focused items from the original PIUS scale without modification (items 1–7 in Box 1). We revised two certainty-focused items from the original scale[2] and developed an additional 20 items, rendering a battery of 29 items for testing. This initial item bank is presented in Box 1, with items labeled according to their intended conceptual dimensions.

Scale testing

Next, we conducted a survey study to test the factor structure and psychometric properties of the instrument, to remove irrelevant or uninformative items, and to examine individual difference correlates of the final measure(s).

Methods

Protocol

We conducted an online study using a sample obtained through Qualtrics Panels. Protocols were approved by the University of Georgia IRB (Project 00003819). In the absence of prior information to guide expectations about the levels of communality and number of factors present in a given battery of items, it is recommended that researchers obtain as large a sample as possible for factor analysis (MacCallum et al., 1999). Therefore, we set a target sample size of 2,000 participants in order to have subsamples of at least 1,000 for exploratory factor analysis (EFA) and confirmatory factor analysis (CFA).

Given the observed relationship between education level and scientific understanding (Miller, 1983), we set quotas to achieve a sample with a diverse range of education levels. In light of limited evidence linking scientific understanding to other demographic factors, as previously discussed, we did not set quotas for other demographic characteristics. Consistent with prior research (Jensen et al., 2017), we dichotomized level of education into two groups:

2 The original items from Ratcliff and Wicke (2023) used the word "guess," which may have the potential for unintended negative interpretation (e.g., signaling carelessness or a complete lack of evidence). Therefore, we revised these items by replacing "guess" with the phrases "educated judgements" and "experts' best interpretation" (items 22 and 24 in Box 1).

BOX 1 Initial item bank.

Uncertain information preferences
Preference for complete information (C) and preliminary science (P)
1. **I like it when scientists describe the limitations of their studies, in addition to the benefits.** (C) 2. **I like it when the caveats of a scientific study are fully explained.** (C) 3. I like to learn about new scientific discoveries, even if they're too preliminary to be acted upon. (P) 4. **Science journalists should describe the uncertainties or unknowns when reporting about a scientific discovery.** (C) 5. **I like to know about the limitations and caveats surrounding new research findings.** (C) 6. I like to learn about new scientific discoveries, even if they don't yet translate to solutions in the real world. (P) 7. **When learning about a new scientific discovery, I want to know how well the evidence supports a particular claim.** (C) 8. I like learning about new scientific discoveries, even if there's still some uncertainty surrounding the results. (P) 9. **I want to know all the details of how research was conducted so I can make my own judgements about it.** (C) 10. **If a study doesn't produce definitive conclusions, the researchers should say so.** (C) 11. Researchers should provide a full picture of their methods and results so I can feel confident in their claims. (C) 12. **I like to learn about preliminary research if it's the best answer we currently have.** (P) 13. Scientists don't need to be 100% sure about the conclusions of their research before they discuss it with the public. (P) 14. **Learning about new scientific discoveries gives me hope about future progress.** (P) 15. **Learning about preliminary scientific results makes me feel like I'm involved in the process of research.** (P) 16. **I like to know about preliminary or early evidence even if it's likely to change in the future.** (P)
Certain information preferences
Preference for streamlined information (S) and established science (E)
17. I don't need to know all the details about a scientific study—just the key takeaways. (S) 18. **I prefer it when experts present clear and definitive scientific conclusions, even if it means omitting parts of the research that are uncertain or incomplete.** (S) 19. **When scientists present their findings as uncertain or preliminary, I feel like it invalidates anything they claim to have found.** (E) 20. When scientists present findings as uncertain or preliminary, it makes me nervous about how things will change in the future. (E) 21. Science communicators should present research in a concrete, simplified way so I can understand it. (S) 22. **Scientists should decide what conclusions to present because they are trained to make more educated judgements than I am.** (S) 23. **I would rather scientists offer definitive answers than describe the uncertainties or unknowns that remain on an issue.** (S) 24. **Even when research isn't 100% certain, I prefer to hear concrete takeaways based on the experts' best interpretation of the evidence.** (S) 25. **A scientific claim shouldn't be presented to the public until the scientific community reaches an agreement about it.** (E) 26. **Scientists should only share findings that are certain and proven beyond a doubt.** (E) 27. **I would rather have scientists be completely certain before sharing information instead of describing "possibilities".** (E) 28. **Researchers should be completely sure about a conclusion before sharing it with the world.** (E) 29. Science communicators should present clear, definitive answers, even if it means they have to simplify things. (S)

Items included in the final instrument are bolded. Items 1–7 are copied and items 22 and 24 are adapted from the original scale (Ratcliff and Wicke, 2023).

less education (a high school education or less) and *more education* (completed some college or more). We set quotas so that roughly half of participants would belong to each group. Characteristics of the final sample are reported in Supplementary material 1.

Data screening

Four criteria were used to eliminate responses from participants who were not answering thoughtfully. Cases were removed if participants (a) completed the full survey in under half the median time (i.e., 309 s), (b) completed the 29-item preference instrument in under half the median time (i.e., 54 s), (c) failed the attention check questions, or (d) did not complete the survey. Out of 2,738 cases collected, the final sample contained 2,008 participants.

Measures

Participants first answered the battery of 29 scale items (Box 1). We retained the response set from the original scale (i.e., strongly disagree to strongly agree on a 5-point Likert scale) because it appeared to capture sufficient variance in earlier tests (Ratcliff and Wicke, 2023; Ratcliff et al., 2023). The scale prompt was: "For this set of questions, we're interested in your own preferences, as opposed to what you think the general public wants to know. In general, how much do you agree or disagree with the following statements?" Given the length of the statements and large number of items, we encouraged participants to "Please answer carefully and take your time."

The measures used to investigate RQ2 and RQ3 are shown in Table 1.

Results

Bivariate correlations between all study variables are presented in Supplementary material 2. Descriptives for all 29 items are reported in Table 2.

Factor analysis

We conducted EFA using one half of the sample ($N = 1{,}004$) and CFA using the other half of the sample ($N = 1{,}004$). To retain the education quotas within each subsample, we sorted the full sample into two groups (high school education or less vs. some college or more). Within each education level group, we randomly sorted the data and then assigned half the cases to the EFA subsample and half to the CFA subsample.

Bartlett's test of sphericity and the Kaiser–Meyer–Olkin (KMO) measure of sampling adequacy are indicators of whether the data violate statistical assumptions. Data are considered to have acceptable properties if Bartlett's test is statistically significant and the KMO value is above 0.80 (Howard, 2016). We checked Bartlett's test of sphericity and KMO for each subsample. The data did not violate statistical assumptions, and KMO values were similar between the two subsamples, suggesting each had a similar amount of common variance (Lorenzo-Seva, 2022). Statistics for the EFA subsample were $X^2(406) = 14{,}746.59$, $p < 0.001$, KMO $= 0.92$, and for the CFA subsample, $X^2(406) = 14{,}759.38$, $p < 0.001$, KMO $= 0.94$. Therefore, we proceeded with factor analysis using these subsamples.

EFA and item selection

EFA was conducted using SPSS v29. We used the principal axis factoring (PAF) factor analytic method, which provides adequate

TABLE 1 Measures.

Variable	Question wording	Response options	M (SD), α
Trust in scientists (National Science Board, 2020)	How much confidence do you have in scientists to act in the best interests of the public?	1 = none at all 2 = a little 3 = a fair amount 4 = a lot 5 = a great deal	3.63 (1.07) —
Deference to science* (Brossard and Nisbet, 2007)	*Please rate how much you agree or disagree with the following statements* 1. Scientists know best what is good for the public 2. It is important for scientists to get research done even if they displease people by doing it 3. Scientists should do what they think is best, even if they have to persuade people that it is right 4. Scientists should make the decisions about the type of scientific research done	1 = strongly disagree 2 = somewhat disagree 3 = neither agree nor disagree 4 = somewhat agree 5 = strongly agree	3.60 (0.78) $\alpha = 0.74$
Factual scientific literacy* (National Science Board, 2020)	*True or False?* 1. The center of the Earth is very hot (T) 2. The continents have been moving their location for millions of years and will continue to move (T) 3. All radioactivity is man-made (F) 4. Electrons are smaller than atoms (T) 5. Lasers work by focusing sound waves (F) 6. It is the father's gene that decides whether the baby is a boy or a girl (T) 7. Antibiotics kill viruses as well as bacteria (F)	0 = inaccurate or don't know 1 = accurate Score range: 0–7	4.00 (1.69) —
Understand scientific study* (National Science Board, 2020)	When you read news stories, you see certain sets of words and terms. For example, some articles refer to the results of a scientific study. When you read the term "scientific study," do you have a little understanding, general sense, or clear understanding of what it means?	1 = little understanding 5 = clear understanding (participants were given a scale without midpoint labels)**	3.70 (0.96) —
Sophisticated medical epistemic beliefs*† (Kienhues and Bromme, 2012)	*To what extent do you agree with the following statements with regard to knowledge in medical science?* 1. Scientific theories in medicine, that we currently assume to be right, can be proved wrong in the future 2. Even medical knowledge has to be revised over and over 3. It is natural for the viewpoints in medical research to change over time 4. Theories in medicine can be proved wrong anytime 5. Even though medical research deals intensively with the origin of different diseases, it does not find one clearly correct explanation	1 = strongly disagree 2 = somewhat disagree 3 = neither agree nor disagree 4 = somewhat agree 5 = strongly agree	3.96 (0.65) $\alpha = 0.78$
Simple medical epistemic beliefs*† (Kienhues and Bromme, 2012)	*To what extent do you agree with the following statements with regard to knowledge in medical science?* 1. Research in medical science has shown that there is one clear answer to most problems 2. If scientists address themselves to the investigation of a question, they can find the correct answer to almost all questions 3. If different scientists evaluate data from study participants, they almost always come to the same conclusion 4. One can almost always be confident that research published in scientific journals is correct 5. Someday medical researchers will be able to clear up all medical questions	1 = strongly disagree 2 = somewhat disagree 3 = neither agree nor disagree 4 = somewhat agree 5 = strongly agree	3.13 (0.91) $\alpha = 0.84$
Need for closure* (Roets and Van Hiel, 2011)	Please indicate how much you agree or disagree with each statement below 1. I don't like situations that are uncertain 2. I dislike questions which could be answered in many different ways 3. I find that a well-ordered life with regular hours suits my temperament 4. I feel uncomfortable when I don't understand the reason why an event occurred in my life 5. I feel irritated when one person disagrees with what everyone else in a group believes 6. I don't like to go into a situation without knowing what I can expect from it 7. When I have made a decision, I feel relieved 8. When I am confronted with a problem, I'm dying to reach a solution very quickly 9. I would quickly become impatient and irritated if I would not find a solution to a problem immediately 10. I don't like to be with people who are capable of unexpected actions 11. I dislike it when a person's statement could mean many different things 12. I find that establishing a consistent routine enables me to enjoy life more 13. I enjoy having a clear and structured mode of life 14. I do not usually consult many different opinions before forming my own view 15. I dislike unpredictable situations	1 = does not describe me 2 = describes me slightly well 3 = describes me moderately well 4 = describes me very well 5 = describes me extremely well	3.14 (0.78) $\alpha = 0.89$

N = 2008.
*Indicates that 30–35 cases were missing from the dataset for these variables.
**Indicates the response options were adapted from the original in order to create a continuous, 5-point scale.
"—"Indicates there is no Cronbach's alpha to report for the single-item measure.
†We treat simple epistemic beliefs and sophisticated epistemic beliefs as separate variables, rather than creating a combined scale by reversing items measuring simple epistemic beliefs to represent sophisticated beliefs or vice versa. We take this approach because the combined scale was not reliable (α = 0.70) and because the sophisticated and simple epistemic beliefs variables exhibited a small positive correlation, as we describe in the Discussion section.

TABLE 2 Descriptive statistics for initial item bank.

Item #	Min	Max	Mean	SD	Skewness	Kurtosis
1	1	5	**3.96**	0.98	−1.10	1.34
2	1	5	**4.05**	0.97	−1.22	1.65
3	1	5	3.76	1.04	−0.77	0.27
4	1	5	**4.01**	0.97	−1.14	1.39
5	1	5	**3.94**	1.00	−1.08	1.15
6	1	5	3.73	1.06	−0.73	0.16
7	1	5	**4.05**	0.96	−1.22	1.63
8	1	5	3.75	1.04	−0.79	0.35
9	1	5	**3.90**	1.03	−0.92	0.55
10	1	5	**4.13**	1.00	−1.29	1.52
11	1	5	4.03	0.88	−1.04	1.49
12	1	5	**3.78**	0.92	−0.64	0.36
13	1	5	3.11	1.21	−0.20	−0.91
14	1	5	**3.99**	0.90	−0.85	0.86
15	1	5	**3.48**	1.07	−0.34	−0.47
16	1	5	**3.70**	0.97	−0.68	0.34
17	1	5	2.88	1.16	−0.01	−1.00
18	1	5	**3.17**	1.25	−0.11	−1.06
19	1	5	**2.99**	1.18	0.03	−0.85
20	1	5	3.11	1.14	−0.11	−0.75
21	1	5	3.86	1.03	−0.88	0.49
22	1	5	**3.39**	1.18	−0.44	−0.60
23	1	5	**3.23**	1.18	−0.23	−0.83
24	1	5	**3.66**	1.04	−0.77	0.22
25	1	5	**3.30**	1.17	−0.28	−0.72
26	1	5	**3.28**	1.23	−0.22	−0.93
27	1	5	**3.34**	1.14	−0.20	−0.83
28	1	5	**3.43**	1.17	−0.32	−0.76
29	1	5	3.81	1.00	−0.80	0.39

Descriptive statistics are provided for the full sample (N = 2,008). The means for items retained in the final scales are bolded. Skewness SE = 0.06, Kurtosis SE = 0.11.

BOX 2 Final factor subscales based on EFA.

Preferring communication of uncertainty (i.e., "complete")

- I like it when scientists describe the limitations of their studies, in addition to the benefits.* (Item 1)
- I like it when the caveats of a scientific study are fully explained.* (Item 2)
- Science journalists should describe the uncertainties or unknowns when reporting about a scientific discovery.* (Item 4)
- I like to know about the limitations and caveats surrounding new research findings.* (Item 5)
- When learning about a new scientific discovery, I want to know how well the evidence supports a particular claim.* (Item 7)
- I want to know all the details of how research was conducted so I can make my own judgements about it. (Item 9)
- If a study doesn't produce definitive conclusions, the researchers should say so. (Item 10)

Preferring to learn about preliminary science (i.e., "preliminary")

- I like to learn about preliminary research if it's the best answer we currently have. (Item 12)
- Learning about new scientific discoveries gives me hope about future progress. (Item 14)
- Learning about preliminary scientific results makes me feel like I'm involved in the process of research. (Item 15)
- I like to know about preliminary or early evidence even if it's likely to change in the future. (Item 16)

Preferring communication of certainty (i.e., "streamlined")

- I don't need to know all the details about a scientific study—just the key takeaways.† (Item 17)
- I prefer it when experts present clear and definitive scientific conclusions, even if it means omitting parts of the research that are uncertain or incomplete. (Item 18)
- Scientists should decide what conclusions to present because they are trained to make more educated judgements than I am.** (Item 22)
- I would rather scientists offer definitive answers than describe the uncertainties or unknowns that remain on an issue. (Item 23)
- Even when research isn't 100% certain, I prefer to hear concrete takeaways based on the experts' best interpretation of the evidence.** (Item 24)

Preferring to learn about established science (i.e., "established")

- When scientists present their findings as uncertain or preliminary, I feel like it invalidates anything they claim to have found. (Item 19)
- A scientific claim shouldn't be presented to the public until the scientific community reaches an agreement about it. (Item 25)
- Scientists should only share findings that are certain and proven beyond a doubt. (Item 26)
- I would rather have scientists be completely certain before sharing information instead of describing "possibilities". (Item 27)
- Researchers should be completely sure about a conclusion before sharing it with the world. (Item 28)

*Denotes item is from the original Ratcliff and Wicke (2023) scale (unchanged).
**Denotes item is revised from original scale.
†Item removed at later stage based on CFA and IRT results.

results in most situations compared to other factor analytic methods and is robust to data non-normality (Howard, 2016). We used oblique (direct oblimin) rotation to allow factors to correlate, as we assumed processes underlying the factors would be correlated. Factor retention decisions were based on the Kaiser criterion (i.e., eigenvalues greater than 1) and a visual examination of the scree plot. Retention of items was guided by the "40-30-20" rule (Howard, 2016); that is, a cutoff factor loading of 0.40 should be used, and the item should not load onto multiple factors >0.30 unless the loading on the primary factor is at least 0.20 higher.

In the initial solution, five factors were extracted. Factor loadings are presented in Supplementary material 3. Three items did not meet retention criteria as they did not load onto any factor ≥0.40 (items 13, 21, and 29). The mean score for item 13 was relatively low compared to related items. This statement may have represented something akin to "guessing" for participants and thus been viewed as more universally undesirable. In contrast, the mean scores for items 21 and 29 were relatively high. These items captured an expectation that scientists should present information in a "simplified" way, and it is possible this was not perceived to be about oversimplification or streamlining but merely simplicity, which is a generally desirable attribute of science communication. Therefore, we removed these items and ran the EFA again.

In this solution, only four factors remained. However, additional items did not meet retention criteria due to problematic

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TABLE 3 Factor loadings in the final EFA solution.

Item	Factor 1 (complete)	Factor 2 (established)	Factor 3 (preliminary)	Factor 4 (streamlined)
1	**0.688**	−0.076	0.095	0.063
2	**0.763**	−0.074	0.003	0.119
3				
4	**0.795**	0.028	−0.046	−0.006
5	**0.777**	−0.033	0.101	−0.035
6				
7	**0.786**	0.030	0.011	−0.043
8				
9	**0.632**	0.145	0.119	−0.097
10	**0.753**	0.064	−0.087	−0.054
11				
12	0.155	−0.076	**0.659**	0.032
13				
14	0.255	−0.057	**0.504**	0.074
15	−0.080	0.165	**0.744**	−0.066
16	0.041	−0.093	**0.746**	0.074
17†	−0.051	−0.021	−0.104	**0.472**
18	−0.039	0.148	0.169	**0.473**
19	−0.010	**0.447**	0.006	0.229
20				
21				
22	0.068	0.144	0.186	**0.516**
23	−0.030	0.221	0.031	**0.628**
24	0.186	0.016	0.192	**0.481**
25	0.125	**0.568**	−0.081	0.232
26	0.030	**0.768**	−0.069	0.128
27	−0.019	**0.801**	0.029	−0.031
28	0.028	**0.832**	0.066	−0.094
29				
M (SD)	3.95 (0.84)	3.22 (0.88)	3.69 (0.77)	3.32 (0.88)
% Var.	32.16	17.64	6.88	5.52
Cumulative % var. explained				62.20%

N = 1,004. Loadings meeting factor inclusion criteria are bolded. Items that did not meet the criteria were excluded from the scale in the confirmatory study.
Inclusion criteria: Primary loadings of ≥0.40 and the item should not load onto multiple factors >0.30 unless loading onto the primary factor is at least 0.20 higher.
†Item 17 was removed from scale at later stage.

cross-loadings: items 3, 6, 8, and 11 had near-equivalent loadings on factors 1 and 3. Notably, items 3, 6, and 8 all contained the phrase "I like to learn about new scientific discoveries"—which could apply to people who prefer information about uncertainty *and* preliminary science—while the latter portion of each statement was focused specifically on preliminary science, explaining the potential conceptual overlap. Additionally, item 20 had near-equivalent loadings on factors 2 and 4. This item captured negative reactions to "presenting findings as uncertain or preliminary," which could explain the overlap (however, item 19 included similar phrasing and did not exhibit problematic cross-loading).[3] One item (item 17) exhibited very low communality (0.17) relative to the other items but otherwise met retention criteria, so we retained it at this stage.

3 In light of the results observed here, it may be helpful to reword these statements to focus on either the "uncertain" or the "preliminary" aspect when using these items in the future.

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TABLE 4 Factor correlation matrix in the final EFA solution.

	1	2	3	4
Factor 1 (complete)	1.00	–	–	–
Factor 2 (established)	0.17	1.00	–	–
Factor 3 (preliminary)	0.58	0.20	1.00	–
Factor 4 (streamlined)	0.12	0.51	0.21	1.00

N = 1,004. Matrix for the 21-item instrument (see Table 3 for included items).

After removing items 3, 6, 8, 11, and 20, a four-factor solution was extracted with all remaining items meeting criteria for retention. As shown in Box 2, these factors were conceptually aligned with the four dimensions of preference we previously articulated: preferring communication of uncertainty (factor 1, henceforth "Complete"), preferring to learn about preliminary science (factor 3, henceforth "Preliminary"), preferring communication of certainty (factor 4, henceforth "Streamlined"), and preferring to learn about established science (factor 2, henceforth "Established"). Factors were represented by 4–7 items.

As shown in Table 3, factor loadings were within acceptable ranges: Complete (0.69–0.80), Established (0.45–0.83), Preliminary (0.50–0.75), and Streamlined (0.47–0.63). Eigenvalues are reported in Supplementary material 4. The final four-factor instrument explained 62.20% of variance cumulatively, with the Complete and Established factors explaining the bulk of the variance.

As expected, the Complete and Preliminary factors were highly correlated ($r = 0.58$), and the Streamlined and Established factors were highly correlated ($r = 0.51$). However, there was no evidence of an inverse relationship between certainty-focused and uncertainty-focused preferences. Certainty preference items did not exhibit negative loadings on the factors representing uncertainty preferences (Table 3). Moreover, the factor correlation matrix for the final solution revealed small *positive* correlations between the uncertainty- and certainty-focused factors ($r = 0.12$–0.21; see Table 4). Conceptually, this suggests that certainty-focused and uncertainty-focused preferences are not opposite sides of a spectrum but instead represent discrete dimensions of information preferences.

Construct reliability and validity

We examined additional indicators of construct reliability and validity using the EFA sample and the factor structure suggested by the final EFA (see Box 2 for items included at this stage). Providing evidence of construct reliability for each of the four factors, the retained items within each factor demonstrated good internal consistency (Complete: Cronbach's $\alpha = 0.91$, Preliminary: $\alpha = 0.81$, Streamlined: $\alpha = 0.76$, and Established: $\alpha = 0.85$). With one exception, reliability for each subscale was not improved by removing any item. But for the Streamlined factor, reliability was slightly improved without item 17 ($\alpha = 0.77$). Combined items from the Complete and Preliminary factors were internally consistent ($\alpha = 0.90$), as were combined items from the Streamlined and Established factors ($\alpha = 0.86$).

The average variance extracted (AVE) can be a useful statistic for assessing divergent and convergent validity. Given the significant correlations between the Complete and Preliminary factors, and between the Streamlined and Established factors, we examined discriminant validity for each pair of factors. Discriminant validity was assessed using a statistical formula proposed by Fornell and Larcker (1981). There is evidence of discriminant validity if the AVE for each construct is greater than the square of the correlation between the factors. In this case, the AVEs for the Complete factor (0.55) and the Preliminary factor (0.45) were greater than the square of the correlation between these factors ($R^2 = 0.34$; see factor correlations in Table 4). The AVEs for the Established factor (0.49) and the Streamlined factor (0.27 with item 17 or 0.28 without it) were greater than the square of the correlation between these factors ($R^2 = 0.26$). This indicates that the two factors within each pair represent distinct dimensions.

Strong evidence of convergent validity within a factor is indicated by an AVE of 0.50 or higher. As shown in the previous paragraph, AVE values were close to 0.50 for the Complete, Preliminary, and Established factors but much lower for the Streamlined factor. Yet Fornell and Larcker (1981) argue the 0.50 criterion is a conservative benchmark, and other indicators, such as composite reliability, are important to consider. Therefore, we used AVE to calculate composite reliability (or construct reliability), which is an alternative measure of internal consistency of scale items similar to Cronbach's alpha. Composite reliability was excellent for the Complete factor (0.90) and good for the Established (0.82) and Preliminary (0.76) factors but suboptimal for the Streamlined factor (0.64 with item 17, 0.60 without it).

Taken together, we interpret these results as initial evidence that each factor is a distinct dimension and that the subscales representing the Complete, Preliminary, and Established factors are valid and reliable indicators of their respective dimensions. The subscale representing the Streamlined factor appears acceptable at this exploratory stage but would benefit from further development (see Discussion).

CFA

To confirm the results of the EFA, we conducted CFA using the other half of the sample ($N = 1{,}004$). We tested the factor structure suggested by the EFA and included only the 21 retained items (see Box 2). Structural equal modeling (SEM) was performed in Mplus v8.6 using the maximum likelihood method of estimation. Following recommendations, we used three model fit statistics for analyses: root mean square error of approximation (RMSEA), confirmatory fit index (CFI), and standardized root mean squared residual (SRMR) (Hu and Bentler, 1999; Holbert and Grill, 2015). Conventional standards suggest that cutoffs for strong model fit are RMSEA of 0.06 or lower, CFI of 0.95 or higher, and SRMR of 0.09 or lower, whereas models with RMSEA above 0.09 or CFI below 0.90 are considered a poor fit and should not be evaluated (Holbert and Grill, 2015). The chi-square distribution test can be overly sensitive when a sample size is large, but it remains a useful index for model comparison, with lower values being a comparative indicator of better fit (Holbert and Grill, 2015). Therefore, we report and assess the chi-square distribution test for each model.

We initially tested a single-order, four-factor model, which treats each factor as a separate unidimensional construct. We

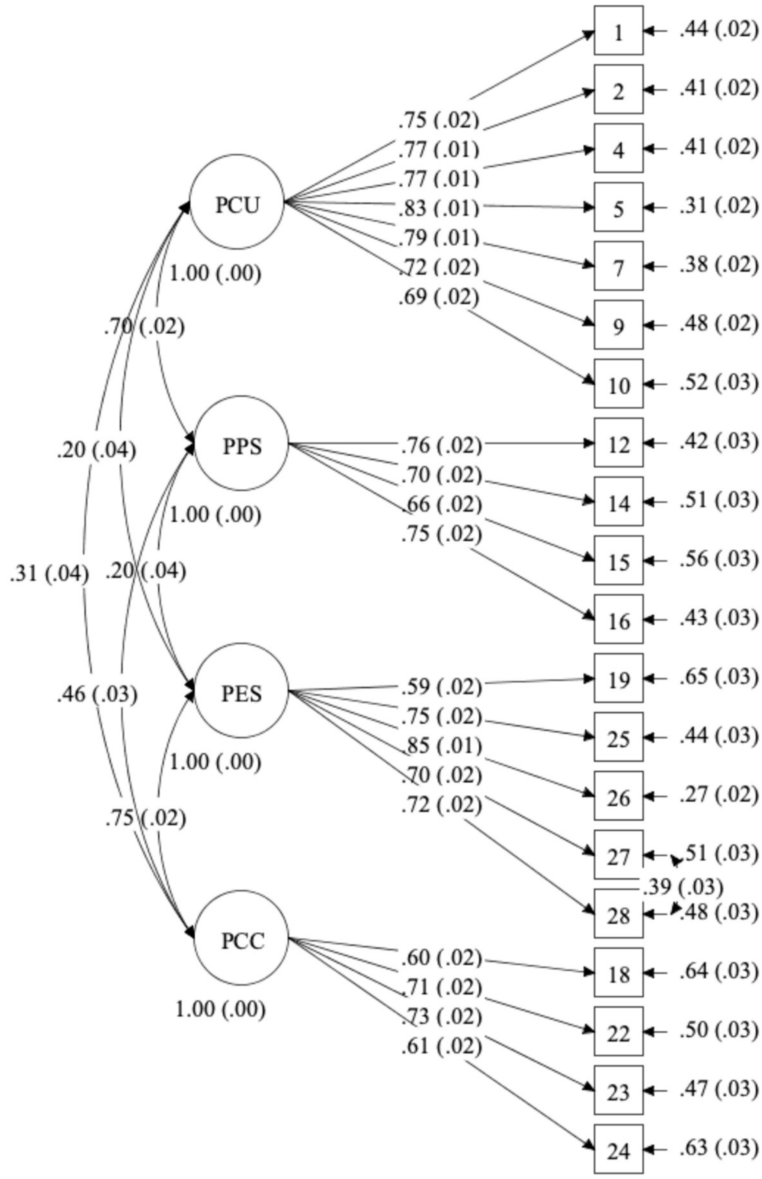

FIGURE 1
Single-order four-factor model. PCU, prefer communication of uncertainty (i.e., complete); PPS, prefer preliminary science; PES, prefer established science; PCC, prefer communication of certainty (i.e., streamlined).

specified the 21 items to load onto their respective factors (see Box 2) and specified correlations between the two uncertainty factors, and between the two certainty factors. The model fit the data relatively well: $X^2(183) = 874.22$, $p < 0.001$, RMSEA = 0.06 (90% CI: 0.057, 0.065), CFI = 0.93, SRMR = 0.06, X^2/df ratio = 4.78. Modification indices suggested fit would be improved if the error terms for items 27 and 28 were allowed to correlate. Additionally, item 17 exhibited a small loading (0.33) compared to all other items. This item had low communality in the EFA and, as previously noted, removing it slightly improved internal consistency for the Streamlined factor. Similar to other removed items, item 17 may capture a preference for simple (as opposed to streamlined) science communication. Therefore, we removed it from the model.

Removing item 17 and allowing error terms of items 27 and 28 to correlate improved model fit: $X^2(163) = 658.30$, $p < 0.001$, RMSEA = 0.06 (90% CI: 0.051, 0.059), CFI = 0.95, SRMR = 0.05. The X^2/df ratio was 4.04. This model yielded a good fit to the data, which we interpret as evidence confirming the factor structure suggested by the EFA. The model diagram is depicted in Figure 1.

We also tested alternative models, all without item 17. Given correlations between the two uncertainty factors, and between the two certainty factors, we tested a single-order model with all items from the Complete and Preliminary factors loading onto a single latent construct, as well as a single-order model with all items from the Streamlined and Established factors loading onto a single latent construct. Fit statistics for the unidimensional uncertainty model were: $X^2(44) = 730.16$, $p < 0.001$, RMSEA = 0.13 (90% CI: 0.117,

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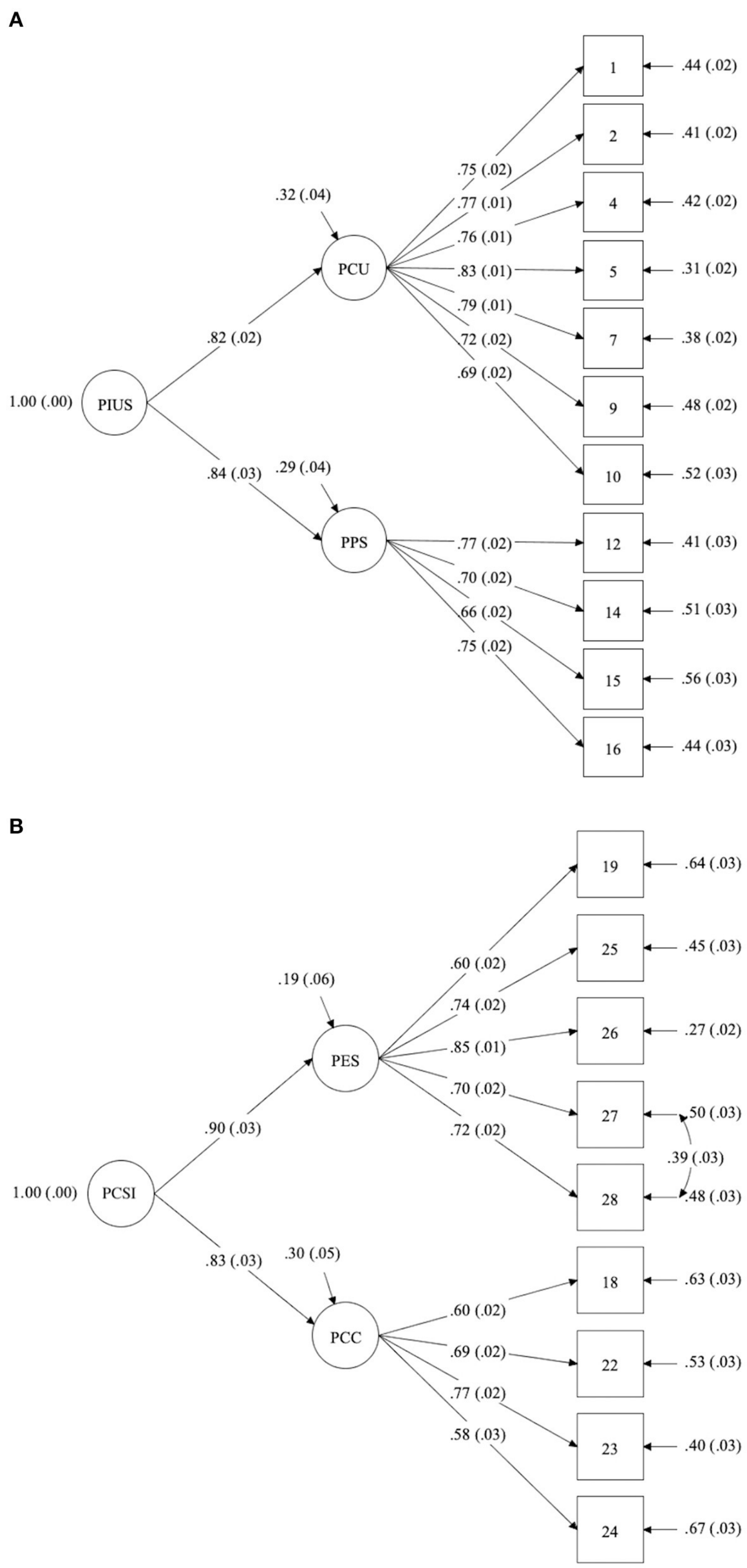

FIGURE 2
(A) Second-order factor structure of PIUS scale. **(B)** Second-order factor structure of PCSI scale. PCU, prefer communication of uncertainty (i.e., complete); PPS, prefer preliminary science; PES, prefer established science; PCC, prefer communication of certainty (i.e., streamlined).

TABLE 5 Descriptives for the final four subscales.

	Complete	Preliminary	Streamlined	Established
M (SD)	4.01 (0.80)	3.74 (0.77)	3.36 (0.88)	3.27 (0.93)
% Var.	31.68	8.48	5.15	18.82

N = 2,008. Descriptives are for the final four subscales (items are those shown in Box 2, excluding item 17). Scale range is 1–5.

0.133), CFI = 0.88, SRMR = 0.07, X^2/df ratio = 16.59. Fit statistics for the unidimensional certainty model were: $X^2(27) = 490.26$, $p < 0.001$, RMSEA = 0.13 (90% CI: 0.121, 0.141), CFI = 0.87, SRMR = 0.06, X^2/df ratio = 18.16. In both cases, model fit was comparatively worse than previous models.

A second-order model with all four factors loading onto a single latent variable was also a poor fit to the data, $X^2(166) = 1136.74$, $p < 0.001$, RMSEA = 0.08 (90% CI: 0.072, 0.081), CFI = 0.90, SRMR = 0.10, X^2/df ratio = 6.85. Given the low correlations between the certainty- and uncertainty-focused factors observed in the EFA, this outcome was not surprising.

However, two second-order models—one with the Complete and Preliminary factors loading onto a second-order latent variable, and one with the Streamlined and Established factors loading onto a second-order latent variable—demonstrated excellent fit. To allow for an identified two-factor model, the loading of both first-order factors on the second-order factor was fixed to 1. Model fit statistics for the uncertainty preference second-order model were $X^2(43) = 218.56$, $p < 0.001$, RMSEA = 0.06 (90% CI: 0.056, 0.072), CFI = 0.97, SRMR = 0.04, X^2/df ratio = 5.08. Fit statistics for the certainty preference second-order model (with correlated error terms for items 27 and 28) were $X^2(25) = 92.10$, $p < 0.001$, RMSEA = 0.05 (90% CI: 0.041, 0.063), CFI = 0.98, SRMR = 0.03, X^2/df ratio = 3.68. In all, these models were comparable to the final single-order, four-factor model in terms of fit, but these second-order models appeared to be a slightly stronger fit to the data. Model diagrams are depicted in Figures 2A, B.

Answering RQ1 by taking into account the results of CFA, EFA, and additional tests of construct reliability and validity, we find strong evidence for two second-order latent constructs, each represented by two discrete dimensions. To this end, we believe it makes the most sense to divide the final measure into two separate scales: 11 items capturing Preference for Information about Uncertain Science (henceforth PIUS-11, comprising the Complete and Preliminary subdimensions) and 9 items capturing Preference for Certain Science Information (henceforth PCSI-9, comprising the Streamlined and Established subdimensions). Descriptives for the final subscales, based on the full study sample, are presented in Table 5.

An important question is whether the subscales comprising PIUS, or comprising PCSI, can be combined and treated as unidimensional for analyses. The aforementioned results suggest that the Complete and Preliminary subscales can be analyzed as separate variables or combined, depending on the researcher's interests. The same can be said for the Streamlined and Established subscales. Alternatively, PIUS-11 or PCSI-9 could be modeled as a second-order latent construct with first-order factors allowed to correlate.

Supplemental item response theory (IRT) analysis

IRT is a family of latent variable measurement models that can provide useful insights for scale construction above and beyond what can be gleaned from factor analysis (Edwards, 2009). IRT can help researchers determine which items are a good fit and which provide more or less information—that is, which are uniquely informative (vs. redundant) and which appear to best capture the construct. Given this, we conducted a supplemental IRT analysis using the full sample of 2,008 cases. Using the Winsteps software package, we fitted a Rasch model (specifically, a partial credit model) to the data. Because this model assumes unidimensionality and the EFA and CFA results showed that the certainty and uncertainty items formed distinct dimensions of preference, we fitted two separate models: one for the uncertainty data (items 1–16) and one for the certainty data (items 17–29). Overall, results aligned with the factor analyses, providing evidence of good fit for all retained items and showing that removed items were, indeed, performing poorly. We provide these results in Supplementary material 5.

In summary, results of the IRT analysis corroborated the EFA and CFA results, leading us to keep the 11-item PIUS scale and 9-item PCSI scale as shown in Box 2.

Correlates of preferences

RQ2 and RQ3 explore audience characteristics that relate to and may influence science information preferences. To answer RQ2, we examined relationships between each of the four preference dimensions and *scientific understanding* (i.e., epistemic beliefs, factual science literacy, and understanding a scientific study), *trust in science* (i.e., trust in scientists and deference to science), and *need for cognitive closure*. To answer RQ3, we examine relationships between each of the four preference dimensions and sociodemographic factors (i.e., age, gender, education, race, ethnicity, religiosity, political party affiliation, and political ideology). Pearson's correlations are reported in Table 6 and a full correlation matrix is presented in Supplementary material 2. We summarize key patterns below. Given the large sample size, we focus our interpretation on correlations with $p < 0.001$.

Answering RQ2, *scientific understanding* aligned with preferences in expected and unexpected ways. Factual science literacy correlated positively with uncertainty preferences (Complete and Preliminary) and negatively with certainty preferences (Streamlined and Established). Along the same lines, having sophisticated epistemic beliefs was positively correlated with both types of uncertainty preferences, and having simple epistemic beliefs was positively correlated with both types of certainty preferences. Overall, these patterns are in expected directions. However, having simple epistemic beliefs was not inversely correlated with preferring uncertainty, and having sophisticated epistemic beliefs was not inversely correlated with preferring certainty, as one might expect. Self-reported understanding of a scientific study correlated positively with both uncertainty preferences (Complete and Preliminary) but also Streamlined, while it was unrelated to Established preference.

TABLE 6 Correlates of information preferences.

Variable	PIUS-11		PCSI-9	
	Complete	Preliminary	Streamlined	Established
Age	0.05*	**−0.14*** **	−0.02	−0.01
Gender	0.05*	0.05*	**0.08*** **	0.06**
Education	**0.18*** **	**0.16*** **	0.03	0.02
Race	−0.03	0.01	0.02	0.05*
Ethnicity	0.00	**0.08*** **	0.01	0.03
Religious	**0.16*** **	**0.13*** **	**0.11*** **	**0.14*** **
Political party	−0.02	**−0.12*** **	**−0.07*** **	0.02
Political ideology	−0.04	**−0.12*** **	0.02	**0.11*** **
Factual science literacy	**0.17*** **	**0.10*** **	**−0.16*** **	**−0.21*** **
Simple epistemic beliefs	0.06*	**0.29*** **	**0.42*** **	**0.37*** **
Sophisticated epistemic beliefs	**0.32*** **	**0.31*** **	0.07**	0.02
Understand scientific study	**0.22*** **	**0.30*** **	**0.10*** **	0.02
Trust in scientists	**0.19*** **	**0.35*** **	**0.24*** **	**0.08*** **
Deference to science	**0.23*** **	**0.40*** **	**0.32*** **	**0.13*** **
Need for closure	**0.09*** **	**0.18*** **	**0.31*** **	**0.38*** **

Coefficients are Pearson's r. N = 2,008; 30–35 cases were missing from the dataset for epistemic beliefs, scientific literacy, understand scientific study, deference, and need for closure.
Variable response options: Gender (1 = woman, 2 = man), Education (5 levels, see Supplementary material 2), Race (1 = white, 2 = nonwhite/mixed), Ethnicity (1 = not Hispanic, 2 = Hispanic), Political Party (1 = Democrat, 2 = Republican), Political Ideology: (1 = Liberal, 5 = Conservative).
Religious question asked: "Do you identify with or belong to an organized religion, faith or spiritual community?" Response options: 1 = no or decline to state (combined), 2 = yes.
Given the large sample size, we focus on interpretation of correlations with p-values <0.001 (bolded). Other correlations should be interpreted more tentatively.
*p < 0.05.
**p < 0.01.
***p < 0.001.

All four dimensions correlated positively with *deference to science* and *trust in scientists*. In other words, trust in experts and the scientific enterprise seems to associate with stronger preferences for, and openness to, scientific information of any kind (whether certain or uncertain). Similarly, all four dimensions correlated positively with having a higher need for cognitive closure, suggesting that need for closure, too, drives a greater desire for scientific information of any kind (whether certain or uncertain).

Answering RQ3, education correlated positively with both uncertainty preference dimensions (Complete and Preliminary)—resembling aforementioned results for scientific understanding—but bore no relationship to certainty preferences (Streamlined and Established). Being older, Republican, and politically conservative correlated with lower interest in preliminary science, while being Hispanic related to higher interest. Identifying as Republican also correlated with lower preference for streamlined communication. Interestingly, there was a small positive correlation between identifying as religious and all four preference dimensions. There were minimal relationships between preferences and a person's gender or race.

Synthesizing these results, we present an initial typology of each preference dimension and factors that shape these preferences (Box 3), based on the final set of items that represent each dimension and the individual difference variables that correlate with each dimension.

Discussion

As Scheufele (2018, p. 1123) argued, "Understanding different publics for science communication is more important than ever before." It is tempting to ascribe universal truths to the public—to say that public audiences expect uncertainty as a normal part of science communication, or that public audiences are unable to understand this inherent uncertainty and expect concrete communication of scientific conclusions. Yet our research presents evidence that public audiences expect both, to varying degrees and depending on a range of individual characteristics. This builds on prior observations, in which nonexperts expressed a range of expectations and preferences for certain or uncertain scientific information (e.g., Frewer et al., 2002; Maier et al., 2016; Post et al., 2021; Ratcliff and Wicke, 2023), underscoring that instead of asking whether the public wants information about scientific uncertainty, it is more useful to ask "who prefers communication of uncertainty, who does not, and why?"

To begin answering these questions, the current project put forward a set of measures for capturing individual preferences for certain and uncertain science information. Previous measures have consisted of only a few items (Post et al., 2021) or were specific to one scientific issue, such as food risks (Frewer et al., 2002), cancer (Carcioppolo et al., 2016), or medical decision making (Han et al., 2009). Building on these measures, our purpose was to examine the validity and utility of a more comprehensive, general

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BOX 3 Science information preferences: dimensions and underlying motivations.

Preference for information about uncertain science	
Dimension: Complete	**Dimension: Preliminary**
Definition: Reflects a desire for information about uncertain aspects of scientific research • Prefers a fuller account of scientific evidence from scientists and journalists, including research caveats, limitations, and complexities of study methods and results • Combines a desire for complete and accurate information with an expectation of science as inherently uncertain • Motivated by a desire to be able to assess information for oneself and come to one's own informed judgment about scientific conclusions • Comfort with scientific uncertainty seems related to higher formal education and scientific literacy combined with less need for cognitive closure (this dimension exhibited the smallest correlation with need for closure)	*Definition:* Reflects an interest in learning about preliminary science • Does not represent preferring preliminary science *over* established science, but rather an openness to learning about preliminary science • Views emerging science with curiosity and optimism (e.g., as a sign of progress) • Likely combines scientific understanding or interest in science with high trust in science and scientists • May be associated with a belief that scientific knowledge is iterative *or* a belief that scientific knowledge is stable (in which case, preliminary evidence may be viewed as reliable and true), given its high correlation with both epistemic belief types • May also be influenced by a desire for novelty

Preference for certain science information	
Dimension: Streamlined	**Dimension: Established**
Definition: Reflects a desire for definitive and streamlined information about scientific conclusions • Prefers simplified and definitive information, even if it means information (including uncertainty) is omitted • Would rather defer to scientific experts than assess information for oneself • Likely driven by high deference to science and trust in scientists, combined with lower scientific literacy or a belief that science can arrive at absolute truths • May be partly motivated by need for closure	*Definition:* Reflects a preference for hearing only about established science • Combines a desire for informed judgement with a view of preliminary and uncertain science as unreliable or likely to change in the future • Expects consensus among scientists • Driven by a belief that science can arrive at absolute truths, combined with a high need for closure • May be related to lower scientific understanding

measure. We sought to explore whether individuals have general information preferences when it comes to scientific uncertainty, just as a person can have a general disposition toward uncertainty (Hillen et al., 2017) even though their reactions to uncertainty may also vary to some degree depending on the context (Brashers, 2001). Further, we sought to determine whether preference for certain science information is distinguishable from dispositional intolerance of uncertainty; more specifically, a need for cognitive closure (Kruglanski, 1990).

Results of this study provide evidence of construct validity for measures of four distinct dimensions of information preferences. Two of these dimensions (*preferring complete information* and *openness to preliminary science*) mapped onto a latent construct representing a preference for receiving information about uncertain science, and these together formed the final PIUS 11-item scale. The other two dimensions (*preferring streamlined information* and *desiring only established science*) mapped onto a latent construct representing a preference for receiving certain science information, and these together formed the final PCSI 9-item scale. As we discuss below, results of this study go far in illuminating the nature of preferences for certain and uncertain science information, explicating each as a multifaceted construct that is likely influenced by a range of individual factors.

The nature of (un)certainty information preferences

As previously noted, desiring communication of uncertainty does not indicate a preference for being in a state of uncertainty, but for learning about scientific uncertainty (or the uncertainty of others). In contrast, a preference for communication of certainty captures a desire for streamlined and definitive information. Overall, our results show that some individuals prefer streamlined science information while others want the "full picture," corroborating results of other studies (e.g., qualitative research by Maier et al., 2016). As reported in Table 5, participants were slightly more inclined to prefer communication of uncertainty and preliminary science than certainty and established science.

Somewhat surprisingly, our study found that preferences for certain and uncertain information formed orthogonal constructs, rather than representing opposite sides of a spectrum. The preference dimensions comprising PIUS and PCSI were not inversely correlated, but rather slightly positively correlated (see Table 4). This suggests that individuals may simultaneously hold conflicting desires for communication of certainty and uncertainty about scientific evidence. We observed a similar pattern in individuals' epistemic beliefs: whereas simple and sophisticated epistemic beliefs are thought to capture opposite expectations of science (i.e., as stable or evolving), these exhibited a small positive correlation ($r = 0.09$, $p < 0.001$; see Supplementary material 2). This further illustrates the possibility that some individuals hold seemingly contradictory expectations of science, which could drive conflicting expectations of science communication—a possibility that warrants further investigation.

In the meantime, we take these results as an indication that preferences for certain and uncertain science information should be assessed using separate measures, rather than reversing certainty-focused items to represent uncertainty preferences or vice versa. Patterns that emerged in the relationships between preferences and individual differences further support this perspective, as we describe below.

Correlates of (un)certainty information preferences

Information preferences were clearly related to scientific understanding. Having sophisticated epistemic beliefs, higher factual science literacy, and a stronger understanding of the concept of a scientific study all correlated positively with preferring uncertainty (that is, wanting to receive complete information and to learn about preliminary science). In a similar vein, higher factual science literacy was negatively associated with preferring streamlined communication and information about established science, while having simple epistemic beliefs was positively associated with these preferences. Yet self-reported understanding of the concept of a scientific study also correlated with preferring streamlined communication. One possible interpretation is that subjective understanding really captures interest in science, while objective understanding (insofar as this is represented by the factual science literacy measure) better reflects a person's scientific understanding. More scientifically literate individuals may have a better ability to make sense of uncertainty (thus being more open to it) and an expectation of it as being inherent to science (thus preferring it to be communicated). Individuals who are interested in science—regardless of their beliefs about its nature as stable or evolving—may respond favorably to *any* type of science communication. In other words, having strong information preferences (that is, high scores on any of the four dimensions) might be driven by an interest in science.

Deference to science and trust in scientists were also positively correlated with all four preference dimensions, suggesting that faith in science and scientists may predispose someone to respond favorably to any type of science communication. As another possibility, faith in science may lead some individuals to be more tolerant of uncertainty but lead others to expect absolute truths and want scientists to distill complex science information into concrete and actionable insights. Fascinatingly, deference to science and trust in scientists were strongly correlated with having simple epistemic beliefs ($r = 0.54$ and 0.42, respectively; see Supplementary material 2).

All four preference dimensions also correlated positively with having a higher need for cognitive closure, suggesting that need for closure, too, drives a desire for information of any kind. Alternatively, it could be that need for closure drives some people to want *certain* information and others to want *uncertain* information. Need for cognitive closure is defined as a desire for "an answer on a given topic, any answer, ... compared to confusion and ambiguity" (Kruglanski, 1990, p. 337). Perhaps for some high-need for closure individuals, having "all the information" (even information about uncertainty) reduces ambiguity about the state of the evidence. Other high-need for closure individuals may prefer simple and definitive scientific conclusions (even if prematurely) as a means of reducing ambiguity. Other factors, such as those related to scientific understanding, may influence whether a need for closure drives someone to want certainty or uncertainty communicated. Although need for closure captures one form of ambiguity aversion (Webster and Kruglanski, 1994), other measures of uncertainty (in)tolerance may prove useful to examine in further unpacking this relationship, as they may exhibit different relationships with PIUS and PCSI.

For exploratory purposes, we also examined relationships between preferences and sociodemographic variables. Preferences were largely unrelated to demographic factors such as age, race, ethnicity, and gender. However, education was positively correlated with preferring Complete and Preliminary Science information. This aligns with findings from prior research, in which individuals with a high school education or less reacted unfavorably to communication of scientific uncertainty while those with more than a high school education did not (Jensen et al., 2017; Adams et al., 2023). This may simply reflect a link between education and scientific understanding, which was also observed in our data (see correlations in Supplementary material 2). Interestingly, however, education was not related to *certainty* preferences.

Republicans had less interest in preliminary science, yet also expressed lower preference for streamlined information. Potentially, this is explained by a lower deference to science among Republicans than Democrats (Blank and Shaw, 2015), which can be seen in our data (see Supplementary material 2). Interestingly, there was a small positive correlation between identifying as religious and all four dimensions. Our measure assessed belonging to an "organized religion, faith or spiritual community" (see Table 6), making this finding surprising, since Rutjens et al. (2022) found spirituality to be a strong predictor of science skepticism. It could prove insightful to further examine relationships among science skepticism, political ideology/party affiliation, religiosity/spirituality, and preferences for certain or uncertain scientific information.

Synthesizing these observations, the results suggest two things: first, that preferences for (un)certain scientific information are distinct constructs from need for closure, scientific understanding, trust in science, and education (given small to medium correlations), and second, that each dimension of preference is shaped by a unique combination of these (and perhaps other) factors. In all, this highlights the complexity of individual uncertainty management strategies. More work to understand the complex interplay of motivations underlying each type of preference, perhaps through qualitative interviews, could help to further contextualize these results. In the interim, we present an initial typology in Box 3.

Practical and theoretical implications

The key to effective science communication is knowing your audience (van der Bles et al., 2019). Understanding (un)certain science information preferences, as well as the individual characteristics that correlate with these preferences, can help health and science communicators design messages that resonate with different audience groups.

Although our results show that information preferences vary, it is generally advisable to communicate uncertainty when it exists, because transparency earns public trust (Jensen et al., 2013; Blastland et al., 2020). Communicating unwarranted certainty can backfire and harm the credibility of institutions, as we saw during the COVID-19 pandemic (Caulfield et al., 2020; Ratcliff et al., 2022). Yet it may be possible to develop uncertainty messages that are received favorably by those who prefer certainty. The PCSI and PIUS scales presented here can be useful for investigating this possibility. One promising avenue will be to examine whether certain types of "normalizing" frames—which depict uncertainty (Han et al., 2021; Simonovic and Taber, 2022), conflicting or evolving evidence (Nagler et al., 2023), and even "failure" (Ophir and Jamieson, 2021) as a normal and healthy part of science—lead to more favorable reception of uncertainty by those who prefer certain science information. Ideally, such frames could highlight the value in knowing about scientific uncertainty from a citizen's perspective, or equip nonscientists with ways to manage or make sense of scientific uncertainty.

The PCSI and PIUS measures could also facilitate the development of much needed predictive theories of uncertainty communication effects. Despite ongoing calls for theory about the effects of communicated uncertainty (e.g., Hurley et al., 2011; Paek and Hove, 2020), we still lack theory to explain how people respond to information about scientific uncertainty in mass mediated contexts (Sopory et al., 2019; Ratcliff et al., 2022; Simonovic et al., 2023). Potentially, the PIUS and PCSI scales can help researchers to gain a better understanding of what types of communication approaches work effectively for individuals with different preference types, and why.

Limitations and future directions for scale development

Although the PIUS-11 and PCSI-9 scales exhibited good psychometric properties overall, there are several potential areas for improvement of the instruments. First, long statements may be a limitation of some scale items. In order to create items that captured the complex concepts of interest with as much precision as possible, many of the item statements used compound sentences. Using similar language and parallel stems, where possible, may have helped to reduce cognitive load. But it could be useful to test shorter versions of the statements, ideally developed in consultation with a science or health literacy expert.

Second, the final subscales for Preliminary and Streamlined preferences contained just four items, and these each explained only a small amount of variance. Although having between 4-7 items is considered ideal for a scale (Lozano et al., 2008), MacCallum et al. (1999) note that 6-7 is generally better than 3–4, and this may be especially true for complex constructs such as those in question here. Adding additional items to the four-item subscales may further improve reliability and strengthen validity. Results of the EFA and CFA suggested that the factor representing Streamlined preferences, in particular, may be underdetermined. Many of the items intended to capture Preliminary and Streamlined preferences were excluded due to problematic cross-loadings (e.g., items 3, 6, and 8, intended to capture Preliminary preferences) or statements that were likely worded too vaguely, such that they specified more universally desirable or undesirable attributes than we had intended (e.g., items 17, 21, 29, intended to capture Streamlined preferences). These could be revised and reintroduced into the scale for further testing. Additionally, items 19 and 20 may have tapped both the Streamlined and Established dimensions. These items could be revised to represent aversion to portrayal of science as either "uncertain" *or* "preliminary" and included in the respective subscale.

Whereas the PIUS and PCSI scales can be useful for getting a general sense of a person's information preferences, we also recognize that preferences for (un)certain information will naturally depend, to some extent, on the specific context. Prior research suggests that people's information preferences regarding uncertain science are also influenced by their prior issue beliefs (Gustafson and Rice, 2020; Kelp et al., 2022). Preferences for (un)certain information may also be influenced by the severity of the issue and its relevance to the individual (see discussion in Ratcliff et al., 2023). Just as scales exist to examine individual preferences for information about uncertainty in the contexts of medical decision-making (Han et al., 2009), cancer (Carcioppolo et al., 2016), and food safety (Frewer et al., 2002), the PIUS and PCSI scales could be adapted to investigate information preferences for a specific scientific domain (e.g., COVID-19 or climate science) or to compare preferences between domains (e.g., high vs. low stakes issues or controversial vs. non-controversial issues). Future research could also include open-ended questions to ask participants whether specific cases or contexts, such as medical science, came to mind when they completed the measures. It may also be insightful to examine relationships between PIUS and PCSI and health-specific scales such as medical ambiguity aversion (Han et al., 2009).

Research has shown that public audiences tend to be least tolerant of information about conflicting evidence (i.e., "consensus uncertainty"; Gustafson and Rice, 2020; Nagler et al., 2020; Iles et al., 2022). With the exception of item 25, our proposed scales do not directly capture preferences related to information about consensus uncertainty. Identifying whether preferences differ for different types of conflicting scientific information (Iles et al., 2022) compared to other types of scientific uncertainty (e.g., technical, deficient, or epistemic uncertainty; Gustafson and Rice, 2020; Ratcliff, 2021) is an important next step. Researchers could develop additional items (perhaps as part of the Established subscale of PCSI) or create a separate scale altogether.

Lastly, the simultaneous existence of conflicting preferences—as demonstrated in the orthogonality of the PIUS and PCSI constructs and the contradictory correlates of preferences—suggests untapped complexity. Individuals' uncertainty management strategies are often layered and nuanced (Brashers, 2001), and preferences expressed in abstraction are unlikely to fully capture this complexity. We believe the proposed PIUS and PCSI scales represent a promising start toward understanding diverse preferences for (un)certain scientific information among public audiences, yet there is much more complexity to tease out moving forward.

Data availability statement

The dataset presented in the study is publicly available. This data can be found at: https://osf.io/5rynm/?view_only=3bd1d1d1c81447e8be2295e467903524.

Ethics statement

The study involving humans was approved by University of Georgia Institutional Review Board. The study was conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study.

Author contributions

CR, BH, and RW conceptualized and designed the study and wrote the manuscript. CR supervised the data collection and performed the data analyses. All authors contributed to the article and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Publisher's note

Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fcomm.2023.1245786/full#supplementary-material

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