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How the public evaluates media representations of uncertain science: An integrated explanatory framework

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Abstract

Understanding how to portray uncertain science to the public is a pressing goal for science communication. This study compared US public audience reactions to a news article depicting a novel discovery in neurogenomics as certain or uncertain, with statements of (un)certainty attributed to either affiliated or unaffiliated scientists. The uncertainty disclosure had no main effect on perceived news article credibility, scientist trustworthiness, objectivity of the scientists' depiction, or willingness to participate in genomic research. However, news credibility and scientist objectivity ratings were higher for uncertainty disclosure attributed to the affiliated scientists. Participants with greater preference for information about uncertainty found the scientists more trustworthy, their depictions more balanced, and the news article more credible when the research was described as uncertain, and these effects were stronger for affiliated scientist attribution. Findings underscore the important roles of disclosure source and audience characteristics in public reactions to media representations of scientific uncertainty.

Keywords

genomics, news credibility, science communication, science news, scientific uncertainty, transparency, trust in scientists

Understanding how public audiences evaluate news portrayals of uncertain science is a pressing research goal (Peters and Dunwoody, 2016; Ratcliff et al., 2022). Journalists are primary translators of scientific research for the public (Schwartz and Woloshin, 2004) and, in turn, public perceptions of science coverage can influence their beliefs and attitudes about scientific issues (Dixon and Clarke, 2013; Han et al., 2018) and even science in general (Ophir and Jamieson, 2021).

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Although news portrayals of uncertain science vary (Guenther et al., 2019; Maier et al., 2016; Ratcliff, 2021), scholars express concern that "the public is increasingly poorly informed about the uncertainty inherent in initial biomedical findings" (Dumas-Mallet et al., 2018: 124). News stories, particularly about emerging biomedical science, often depict scientific discoveries and their implications as more certain and significant than the evidence warrants (Dumas-Mallet et al., 2018; Marcon et al., 2018). Yet, some argue that this pattern of streamlining and hyping science for news audiences, as opposed to offering realistic depictions of discoveries, may be unnecessary and even harmful (Caulfield, 2018; Jensen et al., 2013; for a discussion, see Master and Resnik, 2013).

Discussions about whether to convey scientific uncertainty to the public often center on its impact on trust in scientific experts (Figdor, 2017; Hendriks and Jucks, 2020; Intemann, 2020; Master and Resnik, 2013) and, to a lesser extent, trust in other science communicators, such as science journalists (Figdor, 2017; Jensen, 2008). Engendering public trust is a primary goal for science communication, as society's willingness to support scientific discovery and adhere to evidence-based guidance (e.g. with regard to health and environmental behaviors) is thought to depend upon its trust in scientific experts and information (Intemann, 2020; Master and Resnik, 2013).

To date, however, evidence on the effects of disclosing uncertainty in public science messaging is mixed. Reviews of the empirical literature find that conveying scientific uncertainty can produce positive, negative, or neutral effects on public trust and related attitudes (Gustafson and Rice, 2020; Ratcliff et al., 2022). Notably, there has been minimal theory to guide extant research (Ratcliff et al., 2022). Without a solid understanding of how public audiences process the communication of uncertainty, it is difficult to interpret mixed evidence and develop effective strategies for communicating uncertain science.

To help address this gap, we sought to replicate and build on prior research with a focus on conditional factors that may explain varied public evaluations of scientific uncertainty disclosure. We modified a news story about an initial discovery in neurogenomics and used this to test a framework that incorporates message features, audience characteristics, and processing mechanisms to explain the effects of portraying uncertain science in the media.

1. Communicating Uncertain Science to the Public

Although scientific claims are inherently tentative, assumptions about how the public handles uncertainty often result in streamlined and overly certain accounts of scientific discoveries (Dumas-Mallet et al., 2018; Guenther et al., 2019; Marcon et al., 2018). Public audiences are thought to have a "bounded" understanding of science compared to that of experts, but it is unclear how this might affect reactions to scientific uncertainty disclosure. Competing hypotheses and evidence point to two possibilities. One view is that nonexperts are uncomfortable with, uninterested in, or confused by scientific uncertainty and thus respond negatively to its disclosure, with diminished faith in scientists or the scientific process (Frewer et al., 2003; Johnson and Slovic, 1998; Maier et al., 2016). Another view is that nonexperts understand that uncertainty is inherent to science and appreciate being informed of it even if they do not fully understand its implications (Hendriks et al., 2016a; Retzbach et al., 2016). According to the latter view, public audiences interpret hedged depictions of scientific discoveries as more accurate and see the disclosure as a heuristic marker of objectivity and transparency signaling trustworthiness (Jensen, 2008).

These competing views about public preferences influence how the news media portray uncertain science (Friedman et al., 1999; Guenther and Ruhrmann, 2016). Journalists serve a central role in translating science for the public (Schwartz and Woloshin, 2004) and the ways news stories depict science can influence public beliefs about scientists and scientific issues (Gustafson and Rice, 2020; Ophir and Jamieson, 2021). Yet, an ongoing tension exists between calls for more

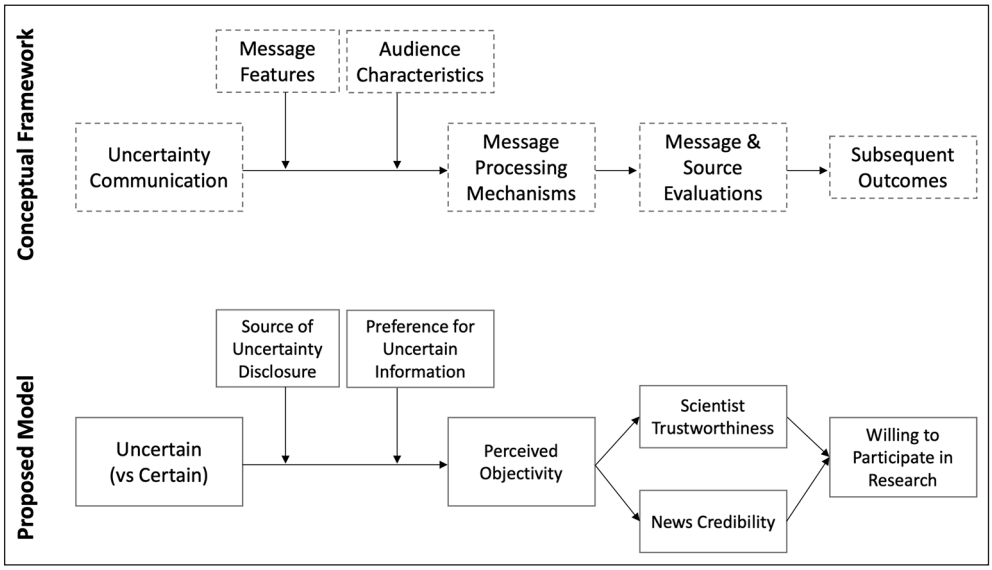

Figure 1. Conceptual framework (upper) and model of relationships examined in the current study (lower).

transparency and precision in science reporting (Caulfield, 2018; Figdor, 2017; Schwartz and Woloshin, 2004) and efforts to simplify and "marketize" science by making discoveries appear more newsworthy (Joyce, 2018; Marcon et al., 2018; Nelkin, 1994; Zhang, 2018). Each approach is argued to better promote favorable opinions of both science and news coverage. Greater attention to the factors that drive public audiences' evaluative processes is needed to settle this debate. In what follows, we integrate a set of theoretically plausible factors drawn from extant literature and depict relationships among them in a process-oriented framework (see Figure 1).

Perceived trustworthiness and the sources of uncertainty disclosure

When considering features of uncertainty communication that may influence public trust, one message feature that deserves particular attention is the *source* of uncertainty disclosure; for example, whether caveats surrounding scientific findings are conveyed by scientists affiliated or unaffiliated with the research (Ratcliff, 2021). Source attribution has received limited systematic examination in the uncertainty communication literature (Gustafson and Rice, 2020; Ratcliff et al., 2022). However, several studies comparing the source of uncertainty depictions found positive effects of communicating uncertainty *only* when it was attributed to the scientists responsible for the research. For example, Jensen (2008) found that both scientists and journalists were viewed as more trustworthy when high (vs low) uncertainty was disclosed, but only when the uncertainty was conveyed by affiliated scientists rather than outside scientists. Ratcliff et al. (2018) replicated this finding for trust in journalists, but not scientists. However, Hendriks et al. (2016a) did find that disclosure of study flaws by the affiliated scientist (compared to an outside scientist) boosted perceived integrity and benevolence of the scientist. Similarly, in a study of ethical implications conveyed in science blogs, Hendriks et al. (2016b) found that public audiences differently evaluated epistemic trustworthiness depending on who raised issues of ethics, in that affiliated scientists were evaluated as being more benevolent and having more integrity when they, rather than an unaffiliated scientist, conveyed such issues.

Taken together, these results suggest that the impact of uncertainty disclosure on perceptions of scientist and journalist trustworthiness is likely to depend on source of the disclosure. However, the underlying mechanisms have not been established. We now turn our attention to relevant theoretical perspectives that may explain this pattern of results.

Underlying evaluation processes

Due to often limited knowledge and understanding of scientific issues, members of the public must evaluate the sources of scientific information and determine, based on a variety of factors, whether to trust them. Scholars have theorized that a scientist's *epistemic trustworthiness* depends on an audience's evaluations of the scientist's integrity, expertise, and benevolence (Hendriks et al., 2015).[1] A trustworthy scientist, therefore, would have not only the necessary credentials and experience to speak with authority on a subject but also a commitment to honest practices and serving the good of the public. Disclosing research caveats, study flaws, or even uncertainties about one's own research could signal this commitment to honesty and indicate to the public that the scientist is not acting out of their own self-interest (i.e. sensationalizing their own work; Hendriks et al., 2015, 2016b). If unaffiliated scientists raise limitations or caveats about the research, however, it might make the affiliated scientists seem dishonest, self-serving, or less knowledgeable, thus undermining their epistemic trustworthiness.

As Hendriks et al. (2016b) articulated, the reasons for an effect of disclosure source on public perceptions of scientist trustworthiness might be further understood through the lens of inoculation theory. Scholars have argued that preemptively self-disclosing negative information can inoculate audiences against the impact of that information by enhancing perceptions of the source's trustworthiness, while also lessening the potential negative effects of such information being revealed by others (Easley et al., 1995; Krylova et al., 2018). Indeed, studies across various contexts (e.g. Easley et al., 1995; Hendriks et al., 2016b; Krylova et al., 2018) found that self-disclosing negative information lessens its damaging effects and even yields positive effects by way of more favorable evaluations of trust. Use of this strategy in the context of science news coverage has so far received limited empirical investigation.

Perceived objectivity of the sources

The aforementioned theoretical perspectives presume that disclosing negative information can bolster source trust because audiences believe the information is being conveyed in a realistic or unbiased way (Hendriks et al., 2016a). Trends in science reporting offer insight into why these assumptions might extend to the context of science journalism. For example, media reporting of science is prone to *hype*, or the inaccurate or exaggerated portrayal of information in which risks and uncertainties tend to be excluded or underreported (Caulfield, 2018; Dumas-Mallet et al., 2018; Marcon et al., 2018; Nelkin, 1994). Hype may influence trust in scientists and science journalists, if members of the public anticipate biased and sensationalized reporting (Master and Resnik, 2013). Given the suggested prevalence of hype (Intemann, 2020), the public may expect scientists to be biased in communications about their own work, and thus a disclosure of uncertainty may convey a willingness to present information objectively. However, this underlying processing mechanism is rarely explicitly tested (for an exception, see Steijaert et al., 2021).

Honesty and balance are also tenets of *news credibility* (Yale et al., 2015). Therefore, an unbiased disclosure on the part of scientists could enhance perceptions of news credibility, as observed by Jensen (2008) and Ratcliff et al. (2018). One possible reason is that trust in the affiliated scientist transfers to the journalist who chose to feature a trustworthy (or unbiased) expert source. Another possibility is that audience members assume a journalist selectively includes or excludes quotes from affiliated scientists. Featuring uncertainty disclosure from an outside scientist could be

perceived as an attempt to heighten uncertainty for sensation value, that is, using a "false balance" or "dueling" frame (Dixon and Clarke, 2013; Jensen, 2008; Stocking, 1999).

In light of these theoretical perspectives, we attempt to replicate earlier findings that positive effects of uncertainty disclosure are contingent on the disclosure being attributed to the scientists responsible for the research (H1). We then use RQ1 (and RQ3, articulated later) to investigate whether perceived objectivity of the scientists' depiction of their research could explain this effect.

H1: Depicting the scientific discovery as uncertain (as opposed to certain) will generate higher ratings of (a) scientist trustworthiness and (b) news credibility—but *only* when the disclosure is attributed to the affiliated scientists.

RQ1: Will depicting the scientific discovery as uncertain (as opposed to certain) generate higher perceived objectivity, when the disclosure is attributed to the affiliated scientists?

Impact on public engagement with research

Although conveying scientific uncertainty has been found to influence public attitudes toward science and science communicators, its impact on downstream behavioral outcomes is less often examined (see Gustafson and Rice, 2020). One potentially worthwhile behavior to investigate—especially in the context of novel discoveries that do not yet translate to actionable choices or behaviors—is engagement with scientific research. Recently, scholars have begun to investigate whether scientific uncertainty can influence public willingness to become citizen scientists (Retzbach et al., 2016) or to share health data for research (Ma and Kannampallil, 2021; Ratcliff et al., 2021). The latter is of particular importance in genomics and precision medicine, where new discoveries are often connected to large, ongoing research programs that rely heavily on public participation (Ratcliff, 2021). Although transparency about the scientific benefit of the research is paramount (Ma and Kannampallil, 2021), scientists may believe downplaying uncertainty will generate more public interest in volunteering (Joyce, 2018; Ratcliff, 2021). Research so far has found no impact of uncertainty on public intentions to engage with science (Ratcliff et al., 2021; Retzbach et al., 2016), but the number of studies is limited and these did not compare sources of uncertainty disclosure. We therefore use the current study to investigate the following:

RQ2: Does uncertainty disclosure (as opposed to conveying certainty), source of disclosure, or a disclosure × source interaction directly influence willingness to participate in research?

Potentially, because prospective participants evaluate the motives and ethics of research organizations when deciding whether to volunteer for biomedical research (Ma and Kannampallil, 2021), perceptions of transparent and unbiased communication will *indirectly* influence willingness to participate. Therefore, as depicted in Figure 1, we examine the following:

RQ3: Do perceived objectivity and (a) scientist trustworthiness or (b) news credibility serially mediate the relationship between message features (uncertainty disclosure, source, or disclosure × source) and willingness to participate?

Preference for information about scientific uncertainty

Science communication scholars recently highlighted the importance of recognizing public audiences as diverse (Scheufele, 2018) and identifying audience characteristics that can explain varied

responses to the communication of scientific uncertainty (Gustafson and Rice, 2020). According to Uncertainty Management Theory (UMT; Brashers, 2001), a person's response to uncertainty is likely to be situational because individuals have different goals for different aspects of their life. For instance, a person may be generally tolerant of uncertainty but prefer to only learn about new scientific discoveries that are concrete and actionable (Maier et al., 2016). While studies of trait-level uncertainty tolerance as a moderator of reactions to scientific uncertainty disclosure yielded mixed results (Han et al., 2018; Ratcliff et al., 2021), a measure specific to the context of science communication could render deeper insight.

Previous studies have examined preferences for *how* scientific uncertainty is communicated (e.g. Johnson and Slovic, 1998); yet, few studies have examined preferences for *whether* uncertainty is communicated. What is missing from the literature is a science-specific measure, ideally one that captures not only comfort with uncertainty but also comfort with *disclosure* of it. To explore this, we developed a scale to test the following:

RQ4: Does preference for information about uncertain science (PIUS) moderate the relationship between communication of uncertainty and (a) scientist trustworthiness, (b) news credibility, (c) perceived objectivity, or (d) willingness to participate in research?

Integrated conceptual framework

Communication scholars are often interested in combining message effects models and process models to investigate audience responses to message features (i.e. inputs and outputs) by taking into account the influences of individual characteristics and cognitive and affective processes along the information processing pathways (Jarecki et al., 2020). To date, studies of the effects of scientific uncertainty communication have rarely been based on integrated or process-oriented theoretical frameworks with explicit, testable assumptions (Ratcliff et al., 2022). Therefore, we embedded the hypotheses and research questions articulated above within the structure of a general message effects framework to propose an integrated, testable model for the current study (depicted in Figure 1). As we describe in the "Discussion," this model is meant to represent one theoretically plausible model of how public audiences evaluate communication of uncertain science. Indeed, many other variables will also be worthwhile to examine within this general conceptual framework.

2. Materials and methods

Participants

We recruited US adults to participate in this online experiment using Qualtrics Panel Services. The final sample consisted of 502 participants who passed quality checks based on *a priori* criteria. A majority of participants were non-Hispanic white (65%) and had at least some college education (78%). About half were female (52%) and had a household income above US$50,000 (48%). Median age was 56 (range 18–86) years. Full participant characteristics and quality check criteria are reported in the Supplemental material.

Study design

Participants were randomly assigned to read one of four versions of a news article in a 2 (certain or uncertain discovery) $\times$ 2 (affiliated or unaffiliated scientist attribution) between-participants factorial design. Participants provided sociodemographic information and were then asked to

carefully read the news article. Next, they responded to attention check questions and evaluated several aspects of the article. On survey completion, participants were informed they had read a modified news article and given the option to read the original version. The study was approved by the University of Utah IRB.

Uncertainty operationalization and experimental stimulus

Although there is always some uncertainty in science, genomic discoveries are often portrayed to the public without mention of caveats and limitations, instead "skewing toward hyperbole and promises of near-future benefits" (Caulfield, 2018: 560–561; for reviews, see Dumas-Mallet et al., 2018; Marcon et al., 2018). Therefore, while past research has typically compared disclosure of high and low uncertainty (Jensen, 2008; Ratcliff et al., 2018; Steijaert et al., 2021), in this study, we compare depictions of uncertainty and certainty.

The communication of scientific uncertainty can take many forms, and varied operationalizations could be another cause of mixed findings in extant research. In a recent review, Gustafson and Rice (2020) found that different uncertainty "frames" yielded different audience responses, underscoring the importance of clarifying the forms of scientific uncertainty under study. In our study, we presented participants with a news article that conveyed or omitted multiple elements of scientific uncertainty, guided by a case study that identified these as common in precision medicine/genomics research (Ratcliff, 2021). Specifically, the news article conveyed (un)certainty about the generalizability, validity, and reliability of the scientific findings, and (un)certainty about the utility of the discovery for treatment and prevention. In the uncertainty conditions, these elements of uncertainty were attributed to study methods and to the complex nature of the health issue. These elements could be considered to represent "technical" or "study" uncertainty, "deficient" uncertainty, and "scientific" or "epistemic" uncertainty in existing typologies (Gustafson and Rice, 2020; Ratcliff, 2021).

To create ecologically valid experimental messages, we used language from actual press coverage of a genomic discovery (Ratcliff, 2021). The discovery pertained to newly identified genetic markers for depression risk. We selected a *Newsweek* article as the base for the stimulus because it was from a recognizable outlet and had substantive reporting. This article contained depictions from the affiliated scientists about their study. We retained these depictions from the affiliated scientists, and we added additional interpretive statements of certainty or uncertainty about the study's findings and implications, conveyed by either the affiliated scientists or by an outside scientist. The unaffiliated scientist was invented for this study, but the certainty and uncertainty statements were derived from claims made by the scientists or by journalists in real media coverage (Ratcliff, 2021). The experimental messages are presented in the Supplemental material.

Measures

Demographics. Participants were asked to report their age, gender, race, ethnicity, level of formal education, and household income.

Perceived uncertainty. To serve as a manipulation check, participants reported whether the scientific findings described in the article seemed *certain, known for sure, established, without any doubt, settled*, and *able to be firmly relied on* (1 = *strongly disagree*, 7 = *strongly agree*). Items were worded in terms of certainty, as this was a more natural way for participants to consider the questions. We then reversed the scale to represent uncertainty ($M = 3.87$, $SD = 1.48$; $\alpha = .96$).

News credibility. Using 10 items that represent the balance and honesty dimensions of news credibility (Abdulla et al., 2004; Yale et al., 2015), in line with similar research (Ratcliff et al., 2018), we asked participants if they found the news reporting to be honest (i.e. *honest, believable*, and *trustworthy*) and balanced (i.e. *complete, objective, balanced, biased (reverse-coded), fair, accurate*, and *told the whole story*; 1=*strongly disagree*, 5=*strongly agree; M*=3.67, *SD*=0.77; α=.94).[2]

Scientist trustworthiness. Participants evaluated the scientists responsible for the research using a four-item scale: three items representing the trustworthiness dimension of expert source credibility from McCroskey and Teven (1999; *trustworthy, honest*, and *ethical*) plus an item from the news credibility scale that has been used to assess scientist trustworthiness in similar research (*told the whole story*; Steijaert et al., 2021). Anchors were 1=*strongly disagree*, 5=*strongly agree* (*M*=3.83, *SD*=0.77; α=.90).

Scientists' objectivity. Using four items adapted from the aforementioned news credibility scale, we asked participants to rate whether the scientists' representation of their research was *accurately represented, realistic, fair*, and *open-minded* (1=*not at all*, 7=*very much; M*=5.31, *SD*=1.36, α=.95).

Willingness to participate in research. We developed a five-item measure to assess how likely participants would be to volunteer for a genomic study like the one described in the article. They answered for each aspect of research participation: *complete a survey about yourself; share your medical records with the scientists; provide your DNA through a saliva sample; share results of genetic tests*; and *share information about your family health history* (1=*not at all likely*, 7=*very likely; M*=4.50, *SD*=1.28, α=.93).

PIUS. We developed a scale to assess participants' information preferences regarding uncertain science. We created an initial set of items by consulting science journalists, and the extant literature on scientists' and journalists' beliefs about how nonexpert audiences manage information about uncertain science (Frewer et al., 2003; Friedman et al., 1999; Guenther and Ruhrmann, 2016; Maier et al., 2016). The items are depicted in Box 1. Participants were asked to indicate their level of agreement with each statement. The measure was completed post test to avoid contaminating participants' processing of the stimuli.

Box 1. PIUS Scale Items.

1. I like it when scientists describe the limitations of their studies, in addition to the benefits.
2. I like it when the caveats of a scientific study are fully explained.
3. I like to learn about new scientific discoveries, even if they're too preliminary to be acted upon.
4. Scientists should be 100% sure about the conclusions of their research before they discuss it with the public. (R)
5. Science journalists should describe the uncertainties or unknowns when reporting about a scientific discovery.
6. I like to know about the limitations and caveats surrounding new research findings.
7. If scientists can't say for certain what their study shows, I'm fine with them presenting their best guess—they're the experts. (R)
8. I like to learn about new scientific discoveries, even if they don't yet translate to solutions in the real world.
9. When learning about a new scientific discovery, I want to know how well the evidence supports a particular claim.
10. I would rather scientists made an educated guess than present research findings as "uncertain." (R)

Notes. Reverse-worded items (indicated by R) were not included in the final scale.

We performed exploratory factor analysis (EFA) to assess the factor structure of the scale. The seven positively worded items exhibited a single-factor structure with acceptable loadings onto this factor, while reversed items did not load onto the primary factor nor form a separate cohesive factor. We report detailed EFA results in the Supplemental material. Taking these results into account, we used only the seven positively worded items for analyses. A higher score for the seven-item scale indicates greater PIUS (1 = *strongly disagree*, 5 = *strongly agree; M* = 4.06, *SD* = 0.61, α = .87).

Manipulation check

Participants who read the uncertain versions of the news article perceived significantly more uncertainty (M = 4.34) than those who read the certain versions (M = 3.37), $F(1, 500) = 59.78$, $p < .001$. This indicates that participants registered the manipulations as intended.

Analytic plan

All analyses were conducted using SPSS v22. We dummy-coded the Uncertainty factor (certain = 0, uncertain = 1) and the Source factor (affiliated scientists = 0, unaffiliated scientists = 1). We used two-way ANOVAs to test H1 and RQ1–RQ2; consistent with similar research (e.g. Jensen, 2008; Ratcliff et al., 2018), we conducted pairwise comparisons with Bonferroni correction to probe the interactions. For RQ3, we used Models 6 and 83 in the PROCESS macro (Hayes, 2018) to test serial mediation and moderated serial mediation, respectively. Model 6 was used to test each factor as a separate predictor and Model 83 was used to test the uncertainty × source interaction as predictor. We used PROCESS Model 2 to answer RQ4, entering Uncertainty as predictor and both Source (the second message factor) and PIUS (the individual difference variable) as moderators in each model. We used the Johnson-Neyman procedure to identify the regions of significance at different values of PIUS, with values labeled "low," "moderate," and "high" corresponding to the 16th, 50th, and 84th percentiles (Hayes, 2018). In line with Hayes' recommendation, we probed interactions with p values less than .10.

3. Results

Table 1 reports means and standard deviations by condition. Means and standard deviations by factor are presented in the Supplemental material, along with bivariate correlations between study variables.

Effects of message features

H1 predicted a positive effect of uncertainty disclosure on (a) scientist trustworthiness and (b) news credibility *contingent upon* disclosure being attributed to affiliated scientists. The overall uncertainty × source interaction was not statistically significant for scientist trustworthiness, $F(1, 498) = 0.22$, $p = .64$, but was close to significant for news article credibility, $F(1, 498) = 3.20$, $p = .07$. Pairwise comparison showed that within the uncertainty disclosure conditions, news credibility ratings were higher when disclosure was attributed to affiliated rather than unaffiliated scientists, $F(1, 498) = 4.63$, $p = .03$ (see Table 1). As expected, uncertainty disclosure had no main effect on scientist trustworthiness, $F(1, 498) = 0.04$, $p = .84$, $r = .01$, or news credibility, $F(1, 498) = 0.12$, $p = .73$, $r = .02$. Source also had no main effect on scientist trustworthiness, $F(1, 498) = 2.60$, $p = .11$, $r = .07$, or news credibility, $F(1, 498) = 1.48$, $p = .22$, $r = .06$.

Answering RQ1, the overall uncertainty × source interaction was not significant for objectivity, $F(1, 498) = 1.35$, $p = .25$. However, pairwise comparison showed that within uncertainty conditions,

Table 1. Means by Uncertainty Disclosure and Scientist Source.

Condition:	Certain affiliated ($N = 120$)	Certain unaffiliated ($N = 125$)	Uncertain affiliated ($N = 128$)	Uncertain unaffiliated ($N = 129$)
Scientist trustworthiness	3.86 (.78)	3.78 (.74)	3.91 (.80)	3.77 (.75)
News credibility	3.66 (.78)[ab]	3.70 (.72)[ab]	3.76 (.81)[a]	3.55 (.76)[b]
Scientist objectivity	5.47 (1.31)[a]	5.34 (1.31)[ab]	5.43 (1.33)[a]	5.02 (1.47)[b]
Willingness to participate	4.65 (1.22)	4.46 (1.25)	4.52 (1.32)	4.38 (1.33)

Notes. Summary of means (*SD*s in parentheses) by article condition. Means in the same row that do not share a common superscript letter are significantly different from each other at $p < .05$.

perceived objectivity was higher when the disclosure was attributed to the affiliated rather than unaffiliated scientists, $F(1, 498) = 5.88$, $p = .02$. There was no main effect of uncertainty disclosure on perceived objectivity, $F(1, 498) = 2.36$, $p = .13$, $r = .07$, but source had an unexpected main effect, $F(1, 498) = 4.96$, $p = .03$, $r = .10$. The scientists' depiction of their research was viewed as more objective when the additional interpretive statements of (un)certainty were attributed to the affiliated as opposed to unaffiliated scientists.

Answering RQ2, willingness to participate was not influenced by uncertainty disclosure, $F(1, 498) = 0.85$, $p = .36$, $r = .04$; source, $F(1, 498) = 2.12$, $p = .15$, $r = .06$; or an uncertainty × source interaction, $F(1, 498) = 0.06$, $p = .81$.

Answering RQ3, the lack of a main effect of uncertainty disclosure on objectivity, as well as lack of an overall uncertainty × source effect on objectivity, meant serial mediation as depicted in Figure 1 was not supported for these message features. However, for source as a message factor by itself, the serial mediation pathways were significant (i.e. confidence intervals did not overlap zero). For scientist trustworthiness (Model A: source → perceived objectivity → scientist trust → research participation), the effect was −.09 (Boot SE = 0.04, 95% Boot CI: −.1713, −.0108). For news credibility (Model B: source → perceived objectivity → news credibility → research participation), the effect was −.05 (Boot SE = 0.03, 95% Boot CI: −.1169, −.0043). Statements attributed to unaffiliated (vs affiliated) scientists had a small indirect, negative effect on willingness to participate via lower perceived objectivity and lower scientist trustworthiness or news article credibility. We report path coefficients in the Supplemental material.

Effects of PIUS

Interaction plots are presented for significant interactions in Figure 2. PIUS moderated the effect of uncertainty disclosure on scientist trustworthiness (RQ4a; interaction coefficient = .27, $p = .01$). The disclosure produced greater trust when preference for disclosure was high ($M \geq 4.71$; 20% of sample). The positive effect was stronger in the affiliated scientist disclosure condition (coefficient = .24, $p = .03$) than the unaffiliated disclosure condition (coefficient = .20, $p = .08$). There was no effect of uncertainty disclosure on news credibility at any other level of information preference.

PIUS also moderated the effect of uncertainty disclosure on news credibility (RQ4b; interaction coefficient = .40, $p < .001$). The disclosure produced higher credibility when the preference for disclosure was high ($M \geq 4.71$), but only when the disclosure was attributed to the affiliated scientists (coefficient = .36, $p < .01$). Conversely, communicating uncertainty produced significantly lower news credibility ratings when preference was low ($M \leq 3.43$; 18% of sample), but only when

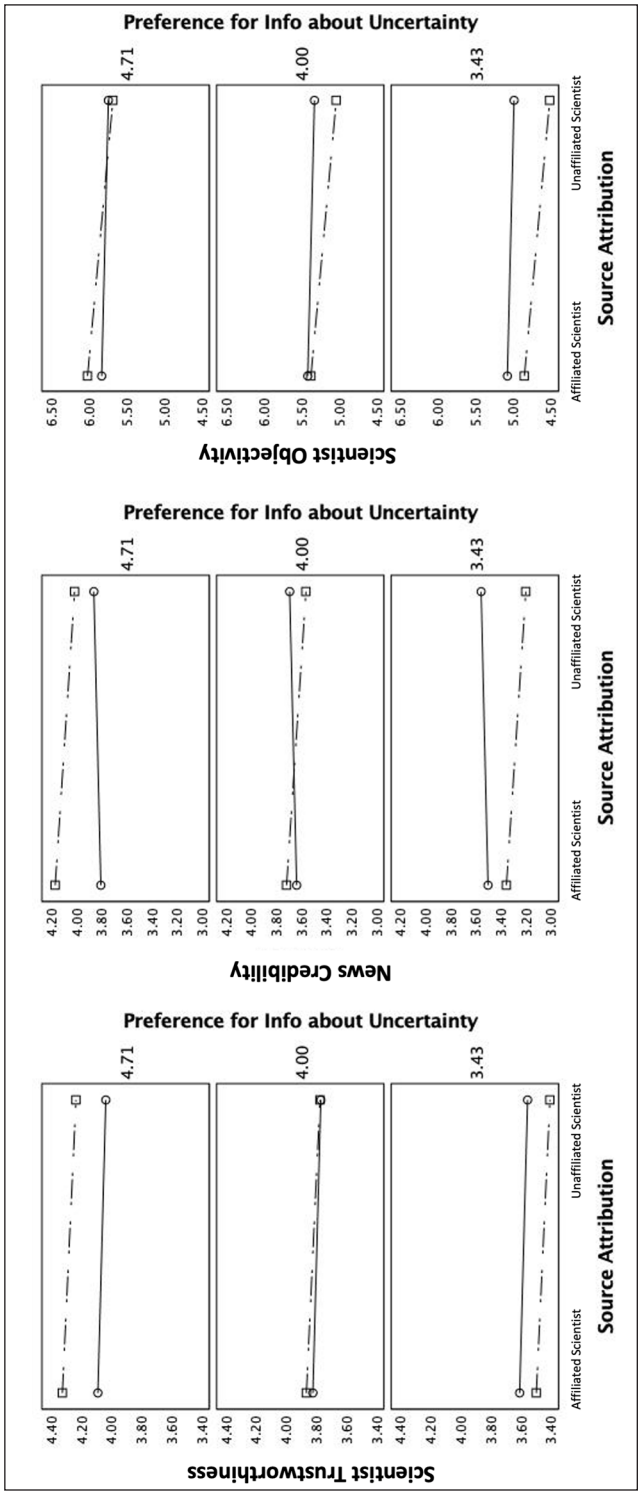

Figure 2. Uncertainty disclosure × source interaction at different levels of information preference.
The uncertainty disclosure × source interactions are shown for *scientist trustworthiness, news credibility*, and *objectivity of the scientists' depiction* at different (low, moderate, high) levels of PIUS. The solid line represents the Certainty message and the dotted line represents the Uncertainty message. These figures show that participants with high preference for uncertain information perceived greater scientist trustworthiness, news credibility, and scientist objectivity when uncertainty (vs certainty) was conveyed. These positive effects were stronger when disclosures were attributed to the affiliated scientists. Conversely, people with low preference responded negatively to uncertainty disclosure, primarily for the unaffiliated scientist attribution.

the uncertainty disclosure came from the outside scientists (coefficient = −.36, $p < .01$). There was no effect of communicating uncertainty on news credibility at any other level of information preference.

The interaction was not quite statistically significant for perceived scientist objectivity (RQ4c; interaction coefficient = .32, $p = .09$). Communicating uncertainty did produce lower perceived objectivity among those whose preference for disclosure was low ($M \leqslant 3.43$), but only when the uncertainty was communicated by outside scientists (coefficient = −.47, $p = .02$). There was no effect of the uncertainty disclosure on objectivity at any other level of information preference.

There was no moderation effect for willingness to participate in the research (RQ4d; interaction coefficient = −.13, $p = .45$).

4. Discussion

It is critical to understand how to effectively convey the caveats, limitations, and complexities of scientific evidence to the public (Figdor, 2017; Maier et al., 2016; Peters and Dunwoody, 2016; Ratcliff et al., 2022). Depicting scientific discoveries as tentative or uncertain produces mixed public reactions (Gustafson and Rice, 2020; Ratcliff et al., 2022), highlighting the need for more theory and experimental research to identify communication features and audience characteristics that drive these varied effects. Answering this call, we examined the impact of communicating scientific uncertainty (vs certainty) in a news story about a novel discovery in neurogenomics, focusing on testing mediating and moderating variables. We sought to replicate earlier work that tested the conditional impact of disclosure source and to build on prior work by testing an integrated, explanatory model of effects and developing a measure of science information preferences.

Public evaluation of scientist trustworthiness and news credibility

Replicating earlier research, this study found that depicting the scientific discovery as certain or uncertain had no main effect on perceived trustworthiness of the scientists or credibility of the news article. Instead, in line with Jensen (2008) and Ratcliff et al. (2018), there was an uncertainty disclosure × source interaction for news credibility, such that credibility ratings were higher when the discovery was presented as uncertain, but only when the disclosure of caveats and limitations came from the affiliated scientists. The affiliated scientist uncertainty disclosure generated the highest news credibility ratings, while the unaffiliated scientist uncertainty disclosure generated the lowest (Table 1).

Counter to expectation, no interaction effect emerged for scientist trustworthiness, which replicates the finding of Ratcliff et al. (2018), but differs from Jensen (2008) and Hendriks et al. (2016a, 2016b), where scientists were perceived as more trustworthy or as having more integrity when disclosures were made by affiliated versus outside scientists. In the current study, trust in the scientists was indeed highest for the uncertain-affiliated condition and lowest for the uncertain-unaffiliated condition (see Table 1), but the difference was not significant.

The reason for source-contingent effects of uncertainty disclosure was not explicitly tested in prior research (e.g. Jensen, 2008; Ratcliff et al., 2018). Therefore, we examined perceived objectivity of the scientists' depictions of their research as an explanatory mediator. Specifically, while all message versions contained a description from the lead scientists, the messages varied in whether additional interpretive statements of (un)certainty were conveyed by affiliated or unaffiliated scientists. There was no overall disclosure × source interaction, but, as anticipated, within uncertainty conditions, perceived objectivity was higher for the affiliated (vs unaffiliated) scientist disclosure (Table 1). Unlike the findings of Steijaert et al. (2021), uncertainty disclosure did not have a direct

impact on perceived objectivity. Source attribution did have an unpredicted main effect on perceived objectivity; however, the scientists' depiction of their research was perceived as more objective when additional interpretive statements about the discovery (whether portrayed as certain or uncertain) came from the affiliated scientists rather than outside scientists. We found support for a modified version of the full conceptual model (Figure 1) with source as predictor, where articles with interpretive statements attributed to the affiliated scientists generated higher perceived objectivity of the scientists' earlier depictions. This, in turn, led to higher news credibility or scientist trustworthiness and, ultimately, greater willingness to participate in genomic research.

Individual preference for learning about scientific uncertainty

Inspired by postulates of UMT (Brashers, 2001), we created a science-specific scale to capture audience information preferences as a moderator of the effects of uncertainty disclosure (see Box 1). Participants with high preference for uncertain information—those who expressed a desire to get all of the facts surrounding new discoveries—responded favorably to the uncertainty disclosure, perceiving greater scientist trustworthiness, news credibility, and scientist objectivity when uncertainty (vs certainty) was conveyed. These effects were stronger when disclosures were attributed to the affiliated rather than unaffiliated scientists. Conversely, people with low preference—those who expressed a desire to hear streamlined depictions of scientific discoveries—responded negatively to uncertainty disclosure, primarily for the unaffiliated scientist attribution. For the rest of participants, depicting the scientific discovery as certain or uncertain had no impact on the outcomes (see Figure 2). These findings indicate that preference for information about scientific uncertainty indeed varies among public audiences and is one likely reason for mixed results in the empirical literature (e.g. Gustafson and Rice, 2020; Ratcliff et al., 2022). These results also underscore the importance of thinking about science information audiences as consisting of "multiple publics" with diverse expectations (Scheufele, 2018).

Public willingness to participate in scientific research

With increasing efforts to engage the public in genomic research (Ma and Kannampallil, 2021), news audiences are sometimes targeted as prospective volunteers (Ratcliff, 2021; Ratcliff et al., 2021). Scientists giving media interviews or writing op-eds may assume that presenting discoveries as certain and significant will generate more public engagement in ongoing research programs (Joyce, 2018). Yet in this study, conveying uncertainty did not lessen public willingness to participate in the research, aligning with another recent finding (Ratcliff et al., 2021). There were, however, small indirect effects of source attribution—regardless of uncertainty disclosure—on willingness to participate, via perceived objectiveness and subsequent scientist trustworthiness or news credibility (see Figure 1).

Implications for theory

To date, empirical findings have painted a picture of two publics: one comfortable with hearing about scientific uncertainty, and one not (Gustafson and Rice, 2020). Cohesive, testable theories that could help to make sense of mixed effects have been lacking (Ratcliff et al., 2022). Creating theoretical frameworks —such as cognitive process models that synthesize relevant audience and message characteristics and information processing mechanisms (Jarecki et al., 2020) — is an important step toward understanding public responses to the communication of scientific uncertainty.

Drawing elements together from prior studies of uncertainty disclosure (e.g. Hendriks et al., 2016a; Jensen, 2008; Ratcliff et al., 2018, 2021; Steijaert et al., 2021), we proposed an integrated

model to examine the conditional impacts of one message feature (source of uncertainty disclosure) and one audience characteristic (PIUS) through one mediator (perceived objectivity). We situated this model within a broader message effects framework (see Figure 1). Our findings add to a growing body of research that suggests source of disclosure and individual motivations are important to consider. We view the set of variables in this model not as exhaustive, but as some of many variables that can explain how public audiences evaluate media representations of scientific uncertainty.

Additional message features, such as scientific uncertainty type or "frame" (Gustafson and Rice, 2020) and amount or "dose" of uncertainty disclosure (Ratcliff, 2021), would make sense to systematically test as part of continued efforts to develop message effects theory in this area. There are many additional audience characteristics that also deserve further theorizing as moderators of uncertainty processing (see, e.g. Gustafson and Rice, 2020; Scheufele, 2018). Finally, behaviors have received much less empirical attention than public trust, beliefs, and attitudes toward science in this literature (see Gustafson and Rice, 2020). We examined willingness to participate in research as a downstream effect of uncertainty disclosure, yet there are many other outcomes that could be included in this model. Further attention to disclosure source is also warranted. It is possible that uncertainty disclosure from an unaffiliated expert is perceived by the public as consensus uncertainty, which tends to produce negative effects compared to other types of scientific uncertainty (Gustafson and Rice, 2020). Although Gustafson and Rice (2020) did not conceptualize uncertainty disclosure from an unaffiliated scientist (e.g. Jensen, 2008) as "consensus uncertainty," a possible connection is important to investigate going forward. Future research could also compare the effects of scientist versus journalist disclosure.

Implications for practice

Findings from this study suggest public audiences are not generally put off by disclosure of scientific uncertainty. However, results do indicate that public audiences are attentive to the source of information about uncertainty, and uncertainty disclosure is likely to be better received when coming from the scientists responsible for the research rather than unaffiliated scientists. Inviting unaffiliated experts to comment on new scientific discoveries is a hallmark of balanced science journalism, and affiliated scientists do not always convey their own research in an unbiased way. However, journalists can strive to include uncertainty disclosure from affiliated scientists in their stories whenever possible, and scientists can strive to be transparent about uncertainties in their own work. This, in turn, may help to avoid creating a heightened appearance of lack of consensus among scientists (Dixon and Clarke, 2013; Figdor, 2017; Stocking, 1999).

Limitations and future directions

Several limitations of this study should be considered, especially in light of some nonsignificant results and effects for which *p*-values hovered around .05. First, the relative subtlety of the experimental manipulations—although perhaps more ecologically valid—might have resulted in weaker effects than what would be observed with stronger manipulations of (un)certainty. Second, the sample skewed toward having higher educational attainment than the general US population, and education correlated with PIUS and willingness to participate in genomic research (see Supplemental material). Third, a larger sample might have provided better statistical power to detect small but meaningful differences in audience responses. Thus, replicating this study with a larger sample, a sample balanced across education levels, and a stronger experimental manipulation will help to confirm our results.

Another important step will be to test the proposed model across a range of different scenarios. Although our results in a genetic depression risk context largely replicated results of studies in

other contexts, such as cancer (e.g. Jensen, 2008; Ratcliff et al., 2018) and precision medicine (Ratcliff et al., 2021), it is possible that uncertainty about discoveries in these domains is of less practical and immediate relevance to public audiences than topics pertaining to, say, COVID-19 (Ratcliff et al., 2022). Future work should examine whether (and if so, why) public evaluation processes differ between scientific topics. Furthermore, although our stimuli focused on news portrayals of scientific uncertainty, social media is quickly becoming an important source of scientific information for the public (Höttecke and Allchin, 2020). We therefore hope future studies will test whether the patterns observed in this study generalize to other science communication channels and topics.

Finally, our scale of PIUS may also benefit from further development. While our intention was to capture information preferences, the items may also, to some extent, capture individuals' attitudes toward science more broadly, such as whether they believe uncertainty is an inherent part of scientific discovery. Future work could examine the relationship between PIUS and potentially related characteristics, such as deference to science, epistemic beliefs, need for cognition, and science literacy.

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Supplemental material

Supplemental material for this article is available online.

Notes

1. The three dimensions of *epistemic trustworthiness* (integrity, expertise, and benevolence; Hendriks et al., 2015) align with the three dimensions of *source credibility* articulated by McCroskey and others (trustworthiness, competence, and goodwill; McCroskey and Teven, 1999). This demonstrates that "trustworthiness" and "credibility" are sometimes treated as interchangeable concepts, while at other times, trustworthiness is considered a subdimension of credibility (Jensen, 2008; McCroskey and Teven, 1999). Our operationalization of trustworthiness takes the latter approach because this is more in line with our interest in whether uncertainty disclosure is perceived as a gesture of transparency or honesty in contrast to an intent to persuade or deceive by downplaying uncertainty.
2. It is important to acknowledge the asymmetry between conceptualizations of news credibility and source credibility. News credibility includes perceptions of *honesty* (i.e. trustworthiness) and *balance* (i.e. absence of bias), along with *currency* (Yale et al., 2015), while source credibility—often used to assess the credibility of scientists—captures *honesty* along with *competence* and *goodwill* (McCroskey and Teven, 1999). To create symmetry between these concepts in the current study, we focused on the *honesty* dimension of source credibility (i.e. scientist trustworthiness) and created an additional measure to

capture perceived *balance* (i.e. objectivity of the scientists' depiction). Prior research indicates that news credibility is ideally treated as a single-factor scale in analyses (Yale et al., 2015), whereas each dimension of source credibility is ideally treated as a discrete variable in analyses (McCroskey and Teven, 1999). Thus, we treat news credibility as a single multidimensional variable but scientist trustworthiness and scientist objectivity as separate variables. Keeping the latter two variables separate also enabled us to investigate our research question about whether perceived objectivity of the scientists' claims helped to explain evaluations of scientist trustworthiness and news credibility.

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