Original Research

Science Communication
1–27

DOI: 10.1177/10755470211038335
journals.sagepub.com/home/scx
SAGE

Communicating Scientific Uncertainty Across the Dissemination Trajectory: A Precision Medicine Case Study

Chelsea L. Ratcliff[1]

Abstract

This study provides an in-depth analysis of how scientific uncertainty was conveyed along the dissemination pathway for a novel discovery linking genomic markers to depression risk. In this article, knowledge limitations described in the original scientific paper were mostly omitted from press releases, and a majority of news coverage mirrored press release content. However, the affiliated scientists depicted uncertainty to different degrees, appearing to influence the tenor of each institution's press release and the news reports for which they were interviewed or quoted. News reports sometimes conveyed more caveats than the original scientific report. This case study presents detailed examples of uncertainty representations in the emerging domain of precision medicine, organized by a typology to guide future research.

Keywords

research output, dissemination, scientific uncertainty, hedging, science journalism, transparency, genomics, precision medicine, psychiatric genomics

[1]University of Georgia, Athens, USA

Corresponding Author:
Chelsea L. Ratcliff, Department of Communication Studies, University of Georgia, 617 Caldwell Hall, Athens, GA 30602, USA.
Email: chelsea.ratcliff@uga.edu

The news media are an important avenue for disseminating health science to the public. Yet some scholars express concern that uncertainty surrounding the state of scientific evidence is progressively removed along the chain of dissemination, such that by the time it reaches the news audience, findings appear much more certain and implications much more meaningful than the evidence warrants (Allan, 2011; Goldacre, 2014; Guenther et al., 2019; Maier et al., 2016; Sumner et al., 2014). These patterns of *streamlining* and *hyping*, although common in the dissemination of genomic science (Caulfield, 2018; Dumas-Mallet et al., 2018; Marcon et al., 2018; Nelkin, 1994), may have considerable social and ethical consequences in the emerging domain of precision medicine.

Precision medicine is a medical model aimed at providing precise prevention, diagnosis, and treatment of diseases based on individuals' genetic, environmental, and behavioral factors (Collins & Varmus, 2015). A key precision medicine objective is to provide "the right drug at the right dose to the right patient," with research into genomics at the forefront of this initiative (Collins & Varmus, 2015, p. 795). Although promising, precision medicine is in the early stages of discovery, and emerging and prospective findings are highly uncertain (Howard & Iwarsson, 2018; Ioannidis & Khoury, 2018; Kostick & Blumenthal-Barby, 2021; Parens et al., 2020). As precision medicine research ramps up around the world, prospective participants are being recruited from patient populations and the general public to support large-scale research programs. Thus, public audiences are not only potential end-users of genomic science but also prospective contributors as research volunteers.

Scholars argue that participation in precision medicine research has unique ethical, legal, and social implications (Ferryman & Pitcan, 2018; Sankar & Parker, 2017). Many individuals' first exposure to information about this research—including both scientific discoveries and opportunities to participate in research programs—is through media content, making transparent public communication about this research paramount (Ferryman & Pitcan, 2018; Marcon et al., 2018; Ratcliff et al., 2021; Sankar & Parker, 2017).

Given these implications, it is important to examine how novel precision medicine research is being conveyed to the public, including both the *content* and the *processes* of public communication. A better understanding of the nature of precision medicine media coverage—including the sources and the language features used to convey (or omit) uncertainty at each stage—can build on prior work in genomics communication, illuminating factors that may influence streamlined and hyped reporting in this novel domain. This understanding can then guide studies of how these communication patterns affect public audiences, including their impacts on health beliefs and behaviors, research participation, and trust in science communicators.

Contributing to this understanding, the current study used an interpretive qualitative approach to closely analyze the reporting of a novel scientific discovery in the area of precision medicine, tracing the treatment of scientific uncertainty from scientific articles to press releases and subsequent news coverage. Organized through a typology of uncertainty types and communicative strategies, this case study approach made it possible to see detailed examples of content in each stage, and, by tracing the content across a chain of dissemination, to also consider the processes by which this information was curated.

Communicating Uncertain Science to the Public

The Science Dissemination Process

Dissemination of scientific knowledge traditionally begins with a research report presented at an academic conference or published in a scientific journal, where scientists are expected to disclose and discuss any uncertainty surrounding their findings (Pollack, 2003). Although disclosure of uncertainty is seen as a common way that scientists maintain credibility (Hyland, 1996), the extent to which scientific reports contain discussion of caveats and limitations varies (Caulfield, 2018; Star, 1983).

University media offices then prepare press releases for newly published scientific articles in order to attract media attention for the research produced at their institutions, especially if the findings are novel or noteworthy. Scientific journals also produce press releases to attract media attention (de Semir et al., 1998; Stryker, 2002). To catch journalists' interest, institution press releases frequently streamline study findings and overstate their significance, and these streamlined accounts are then picked up by the news media and transmitted to the public (Haneef et al., 2017; Stryker, 2002).

Press releases and news articles are not the only conduits through which public audiences access new scientific research. For instance, scientists are increasingly sharing their own work with journalists and general audiences through outreach and social media (Peters et al., 2014). Furthermore, press releases are not the only means by which journalists learn about new science. Nonetheless, new scientific evidence still frequently travels from scientific publication to press release to news coverage. Scientific papers with press releases are significantly more likely to be covered (de Semir et al., 1998; Schwartz et al., 2012), and time-strapped journalists rely heavily on these sources (Fengler & Ruß-Mohl, 2008).

Conveying Scientific Uncertainty in the Precision Medicine Context

Science is often characterized by ambiguities, complexities, and controversies (Pollack, 2003), and science communicators—including scientists, public relations officers, and journalists—must choose whether and how to convey various elements of uncertainty. These include "uncertainty related to evidence, such as insufficient data, contradictory data, different interpretations of data, uncertainty about causality, predictive uncertainty about models or extrapolations, and uncertainty about the quality of information" (Friedman et al., 1999, p. 35).

These uncertainties can be portrayed in myriad ways and with varying levels of explicitness. For instance, the sources and implications of a knowledge limitation can be described in detail, or knowledge claims can simply be *hedged* without explanation through the use of qualifiers such as "suggest" and "may" or by describing findings as "preliminary" or "uncertain" (Stocking, 1999, p. 35). Alternately, sometimes hedges, caveats, and contextualizing information are omitted from scientific reports altogether. Communicators may *streamline* depictions of the research (i.e., omitting or limiting description of scientific uncertainty; Jensen, 2008) or use *hype* (i.e., exaggerated language) to portray the research or its implications (i.e., portraying a discovery as more significant, meaningful, or useful than is warranted, especially in light of sources of uncertainty; Caulfield, 2004).

Despite optimism about its potential, precision medicine research is characterized by numerous forms of uncertainty that limit the current meaningfulness and utility of scientific findings (Howard & Iwarsson, 2018; Ioannidis & Khoury, 2018; Marcon et al., 2018). For example, genome-wide association studies (GWAS) can pinpoint associations between genetic variants and disease occurrence but not provide causal evidence or rule out confounds. Using GWAS to generate polygenic risk scores may also be of limited utility to patients and their providers (Kostick & Blumenthal-Barby, 2021; Parens et al., 2020). The utility of such data for pharmacogenomics, or using gene-targeted drugs to treat disease, which is at the forefront of precision medicine, is also uncertain (Appelbaum & Benston, 2017). Despite this, public communication about human genetics research is often characterized by hype and overpromise, both from journalists and from scientists promoting their own work (Caulfield, 2005; Caulfield & Condit, 2012; Nelkin, 1994). Precision medicine may be even more susceptible to such hype, as scientific institutions strive to not only generate support for ambitious research programs but also recruit widely from public audiences to assemble research participant pools.

Communicators' Motivations for Conveying Uncertainty

Conflicting assumptions about the source of streamlining and hype in the dissemination chain abound. Some scholars assume that scientists describe their science accurately, but press officers and journalists remove uncertainty and make exaggerated claims (Post & Maier, 2016; see Stocking, 1999). Others contend that streamlining and hype start with scientists themselves (Caulfield, 2004; Caulfield & Condit, 2012; Nelkin, 1994; Star, 1983) but may be further magnified by journalists (Nelkin, 1994). A third hypothesis is that journalists construct uncertainty to a greater extent than is warranted for the sake of sensationalism (Dixon & Clarke, 2013; see Stocking, 1999).

These patterns are thought to be influenced by the communicator's goals and institutional norms and pressures (Guenther & Ruhrmann, 2016; Post & Maier, 2016; Star, 1983). For scientists, omission may be more likely when the goal is to preserve authority, garner prestige, or "have their work deemed worthy of public funding" (Zehr, 1999, p. 9). Disclosure may be more likely when a scientist's goal is to maintain credibility among scientists (Hyland, 1996), to demonstrate knowledge gaps in order to secure funding for further research (Star, 1983), or to accurately inform the public about the state of the science (Maier et al., 2016). They might also convey only the types of uncertainty they deem relevant to their audiences (Frewer et al., 2003; Maier et al., 2016). For journalists, audience expectations, perceived norms about how other journalists are covering the science, and their own perception of the uncertainty in a scientific field drive motivations to convey or omit uncertainty in their reporting of science (Guenther & Ruhrmann, 2016). In addition, journalists frequently face institutional pressures to produce newsworthy content under tight deadlines (Fengler & Ruß-Mohl, 2008).

These motivations and routines likely influence not only *whether* scientific uncertainty is depicted but also *which* types of uncertainty and *how*. In turn, each of these factors can impact public audiences differently (Gustafson & Rice, 2020; Jensen, 2008). Potentially, dissemination processes and audience effects differ in the context of precision medicine, making these important to examine.

Characterizing Features of Uncertainty Communication

Because scientific uncertainty can take myriad forms, it is important to clarify the type of uncertainty under study (Gustafson & Rice, 2020). In the current study, I focused on uncertainty arising from limitations of both research methodology (e.g., methods of data collection and analysis) and the nature of the scientific phenomenon (e.g., complex processes that are difficult to fully

examine or understand). To distinguish between the two, I term the former *study uncertainty* and the latter *epistemic uncertainty*. A third source of uncertainty to consider arises from divergent empirical evidence, which could be the result of either *study or epistemic uncertainty*; following Gustafson and Rice (2020), I refer to this as *consensus uncertainty*.

In addition to these *sources* of uncertainty, I also focused on communicative strategies used to frame or describe the uncertainty. Examined communication features included *normalizing frames* (e.g., messages conveying that the issue is complex and some uncertainty is to be expected; Han et al., 2018), *deficient frames* (e.g., suggesting that a knowledge gap can be filled with further studies; Gustafson & Rice, 2020), *source of the disclosure* (e.g., affiliated scientist, outside expert, or journalist; Jensen, 2008), *hedging devices* (e.g., use of tentative language such as "may," "could," or "suggest" when making knowledge claims; Nanayakkara & Hullman, 2020), and *level of specificity* (e.g., hedges used alone vs. in conjunction with an explanation of the tentative knowledge claim or the source or degree of uncertainty). Uncertainty is sometimes not mentioned when communicators convey the results of scientific research, either in the form of simplification and omission of caveats (i.e., *streamlining*; Jensen, 2008) or exaggerating potential value or benefits of discoveries despite limitations and uncertainties (i.e., *hyping*; Caulfield, 2018; Intemann, 2020). These types of uncertainty and communicative strategies are further described in the typology in Table 1.

The Current Study

The current case study examined the chain of dissemination of a recent discovery in the context of precision medicine, focusing on the communication of study limitations, caveats, and other forms of uncertainty about the implications of the research. The goal was to determine which forms of uncertainty were presented and how as well as whether treatment of uncertainty differs between stages of dissemination. The abovementioned theoretical and conceptual frameworks guided the following research questions:

Research Question 1 (RQ1): What are the elements of scientific uncertainty in the selected case?
Research Question 2 (RQ2): How are these elements of uncertainty conveyed in the scientific paper, press releases, and news articles?
Research Question 3 (RQ3): Do the observed patterns reveal possible insights about the process of dissemination in this case?

Table 1. Typology for Characterizing the Communication of Scientific Uncertainty.

Source of uncertainty	Definition
Study uncertainty	Uncertainty arising from limitations of a study's methodology; for example, choice of sample, data collection method, analytic tools, etc., which can limit inferences about accuracy, generalizability, reliability, validity, and causality (Pollack, 2003).
Epistemic uncertainty	Uncertainty arising from the uncertain nature of science more generally (e.g., limits of scientific knowledge and what can be discovered about a phenomenon, especially complex systems; Pollack, 2003; Ratcliff et al., 2021).
Consensus uncertainty	Interpretation of evidence lacks consensus due to conflicting evidence or conflicting expert testimony (Binder et al., 2016; Gustafson & Rice, 2020; Jensen, 2008).
Communication features to describe uncertainty	**Definition**
Normalized frame	Conveys that the issue is complex, and some uncertainty is to be expected (Han et al., 2018; Ratcliff et al., 2021).
Deficient frame	Conveys that the uncertainty arises from a lack of knowledge; could be framed as knowable with more research or unknowable due to the nature of the phenomenon (Gustafson & Rice, 2020).
Hedges	Claims are made using tentative language (e.g., "can," "could," "may," "might," "possibly," "suggest"; Hyland, 1996; Nanayakkara & Hullman, 2020).
Level of specificity	Level of description of the uncertainty. At low end: use of hedges only; at high end: explanation of source of the uncertainty, or quantification of the uncertainty or of related risk (Hyland, 1996; Jensen, 2008; Niederdeppe et al., 2014).
Message source	Who communicates the uncertainty, such as scientists responsible for the research, outside or unaffiliated experts, press officers, journalists, etc. (Jensen, 2008; Ratcliff et al., 2018).
Omission of uncertainty	"Streamlining" refers to omitting or limiting the description of scientific uncertainty (Jensen, 2008). "Hype" or "hyping" refers to using exaggerated language to portray the research or its implications; for example, portraying a discovery as more significant, meaningful, or useful than is warranted, especially in light of sources of uncertainty (Caulfield, 2004; Caulfield & Condit, 2012; Intemann, 2020).

Method

This qualitative case study combined descriptive and interpretive approaches to address the abovementioned open-ended and exploratory research questions (Elliott & Timulak, 2005). I used this approach as the goal was to closely examine the specific communicative acts in a particular case, rather than to categorize instances in order to generate counts or produce generalizable takeaways. Because the observations that follow from this approach are inherently subjective, I included examples from the texts to support my classifications and interpretations so that readers can see the text upon which descriptive and interpretive claims were based. Drawing on prior theoretical and empirical work, I developed a typology (Table 1) to serve as a framework to guide the analysis in answering RQ1 and RQ2. I used the theoretical frameworks described earlier to guide the answering of RQ3.

Selection of Case for Analysis

The Altmetric database was used to identify a scientific article as the case for this study.[1] The search terms "precision medicine" and "genomics" were used. A priori criteria for selection of the scientific study were that it be (a) in the domain of precision medicine, (b) on a topic of broad relevance to the public, (c) published within the previous 2 years in a peer-reviewed academic journal, (d) ranked in the top 5% for online attention on Altmetric, and (e) have online media attention spanning press release and news outlets. From the pool of studies that met these criteria, one scientific paper was randomly selected for analysis.

The selected case exemplified precision medicine in its use of genome-wide association testing to generate complex or multifactorial disease risk profiles and identify gene-based targets for treatment. The scientific article, press releases, and linked mentions in news outlets were included in the analysis.

Altmetric identified mentions of the scientific article in 3 press releases and 103 online news stories across 86 news platforms, including press release news wires. The press releases were generated by three of the lead researchers' home universities. Few of the news stories offered original reporting; instead, most reused the content from the university press releases or republished syndicated material (e.g., from newswires). After screening out duplicative content, the final pool of news stories consisted of original reporting from 10 media outlets. The content was analyzed for depictions of scientific uncertainty and other knowledge limitations, or lack thereof, in accordance with the typology. Given the small final sample for each content type, it was

infeasible to calculate intercoder reliability using a subset of units. This lends subjectivity to the analysis and should be kept in mind when interpreting results.

Results

The Scientific Article

This GWAS combined datasets from seven cohorts to search for genetic markers of depression risk, comparing the DNA of those with and without major depressive disorder (MDD; Wray et al., 2018). The study led to the association of 44 genetic loci (i.e., locations of particular genes or genetic markers on chromosomes) with major depression. The study report was published in *Nature Genetics*, a scientific journal that publishes high-impact genetics and genomics research.

The scientists described knowledge limitations in three areas, arising either from limits of the study methodology (i.e., *scientific uncertainty*) or the complex nature of the phenomenon being studied (i.e., *epistemic uncertainty*). These knowledge limitations pertained to *reliability and validity, generalizability, and causal mechanisms*. These limitations and the scientists' treatment of them are described subsequently.

Uncertain Reliability and Validity. The seven datasets combined for the GWAS—drawn from biobanks including UK Biobank, Generation Scotland, deCODE, and 23andMe—were described as using varying methods of classifying depression. Some cases had records of clinical diagnosis of MDD, while others had self-reported clinical diagnosis (e.g., the 23andMe data, which comprised half the sample), and some cases had self-reported symptoms but not necessarily clinical diagnosis (e.g., the UK Biobank data).[2] The scientists indicated that records of clinical diagnosis would be considered the most valid and reliable. They also acknowledged that many symptoms of depression are common to other psychiatric disorders and could be misclassified as MDD. Thus, there is a possibility of misdiagnosed depression for both clinical and self-diagnosis, and the scientists noted questions of reliability and diagnostic accuracy as potential limitations of this data collection approach.

Uncertain Generalizability. Data in the study were collected from participants in the United States and three European countries (United Kingdom, Iceland, and Denmark). The scientists reported that all sample cohorts were of European ancestry and noted a lack of existing trans-ancestry comparisons for

major depression. They reported the results of one comparison between this study's sample and a study using a Chinese sample, concluding that the loci identified in the Chinese sample are uncommon in Europeans and were not significant in their analysis. This indicates that the results of this study may not generalize to individuals with non-European ancestry; however, the scientists did not explicitly discuss this as limiting the generalizability of their findings, and they described the study as proof that "all humans" carry genetic markers for depression.[3]

Uncertain Causal Mechanisms. The scientists stated that the observed link between MDD and the identified genetic markers did not necessarily prove causality, cautiously referring to findings as "causal, or correlated with causal." They acknowledged, "Due to limitations inherent to observational studies, understanding whether a phenotypic correlation is potentially causal or if it results from reverse causation or confounding is difficult" (p. 673). The scientists searched for additional evidence of a causal relationship, such as regressing the predictive model on new samples to assess whether it accurately predicted MDD, and they found that it did. They disclosed an important caveat, however, that one of the two comparison samples contained data that partially overlapped with the current study sample.

The scientists also described correlations between the identified gene variants and other risk factors, continuing to frame these associations with hedged language. For instance, they noted an association between the identified loci and self-reported sleep quality that "*suggests* a close and *potentially* profound mechanistic relation" (emphasis added). In addition, they reported correlations between MDD and body mass index (BMI) and years of education, describing these as "either causal risk factors or correlated with causal risk factors for major depression." Yet they also acknowledged the likelihood of an additional mechanistic component underlying these links among depression, education, and BMI. Finally, the scientists noted an identified link between MDD and schizophrenia that suggested the likelihood of a shared biological basis but noted the caveat that misdiagnosis was possible and could have contaminated the analyses.

Summary of Communication Features. The scientists depicted knowledge limitations as arising from the study methodology (study uncertainty) and the complex nature of depression (epistemic uncertainty). They discussed limitations pertaining to reliability, validity, and causality. Although their analysis generated findings that differed from a prior study with a Chinese sample, this was not framed as consensus uncertainty nor discussed as evidence of uncertain generalizability from the European ancestry sample.

The scientists generally depicted uncertainty using a deficient frame and asserted that knowledge gaps could be filled with more research. For example, regarding the reliability and validity of the data, they defended their approach of merging different types of datasets, stating that they "invite and welcome empirical studies to further support or refute this hypothesis" (p. 675). With regard to links between depression and other risk factors such as BMI and education, they stated that more research is needed, suggesting the results "provide hypotheses for future research to understand these potentially directional relationships" (p. 674). Overall, they described the study as a building block for future research leading to more precise diagnosis and therapeutic treatment of depression, noting this "could form a cornerstone of precision medicine in psychiatry" (p. 677).

In terms of study implications, the scientists' report was generally free of hype and streamlining, except in the area of generalizability. They framed the results as helping to "refine and define the fundamental basis of major depression" but acknowledged that depression had "modest" genetic heritability and that depression "is a complex malady with both genetic and environmental determinants" (p. 677). Furthermore, they noted that "MDD is probably influenced by many genetic loci each with small effects, as are most common diseases including psychiatric disorders" (p. 669), thereby acknowledging that the loci identified in the study likely play only a small role in one's depression risk.

Press Release Coverage

Three press releases were generated by the lead researchers' home institutions. These were from the University of Queensland (henceforth UQ; Scientists A and B), University of North Carolina Chapel Hill (henceforth UNC; Scientist C), and King's College London (henceforth KCL; Scientists D and E).

Uncertain Reliability and Validity. Uncertainty related to reliability or validity of study findings was not discussed in any of the press releases. The KCL release mentioned that multiple datasets were combined, but none of the releases described the nature of data collection (i.e., combining different cohort datasets and including self-report diagnoses) as a potential knowledge limitation or source of uncertainty.

Uncertain Generalizability. Mirroring language used in the scientific paper, all three press releases described the study findings as applying to "all humans"

and none mentioned the European ancestry sample or divergent findings from a Chinese sample.

Uncertain Causal Mechanisms. The press releases contained language of correlation rather than causation, describing genetic markers as "linked" or "associated" with depression risk. All three press releases included a quote from lead scientists acknowledging nongenetic causes of depression. In the KCL release, a quote from Scientist D explained: "We need further research to uncover more of the genetic underpinnings, and to understand how genetics and environmental stressors work together to increase the risk of depression." In the UQ release, a quote from Scientist A also acknowledged other causes, saying, "We know that many life experiences also contribute to the risk of depression, but identifying the genetic factors opens new doors for research into the biological drivers."

While the quote from Scientist A was also included in the UNC release, that press release repeatedly referred to "the genetic basis of depression" and featured a quote from an unaffiliated expert remarking that the study "confirms the genetic roots for depression"—thereby emphasizing a central, causal role of genetic mechanisms. Also, in the UNC release, Scientist C stated that "[f]iguring out the genetic basis of major depression has been really hard . . . and we now have a deeper look than ever before into the basis of this awful and impairing human malady." Thus, only two of the lead scientists' quotes in the UNC release (quotes taken from the other press releases) acknowledged the causal role of nongenetic factors, while quotes from the other lead and unaffiliated scientists appeared to suggest genetic factors represent the main or only cause of depression.

When reporting linkages found between MDD and other psychiatric disorders, BMI, and sleep quality, the language was appropriately cautious (i.e., referring to correlation) in the KCL and UNC releases; these were referred to as having a "shared genetic basis" or there being "links" or "overlap" between risk factors. The associations were not discussed in the UQ release.

Summary of Communication Features. Overall, the UNC press release used more hyped language to characterize the research compared to the other two press releases. In the UNC release, Lead Scientist C referred to the study as "a game-changer," while two unaffiliated medical experts described it as "incredibly important," a "pioneering study," and a "landmark study" that "represents a major step toward elucidating the biological underpinnings of depression." Such claims were absent from the UQ and KCL releases, which also did not contain quotes from outside sources.

Sources in the KCL and UNC press releases claimed the study "has mapped out" or "figured out" the genetic basis of major depression, implying a level of comprehensiveness and precision not warranted by the results. Per the original disclosure in the scientific paper, the study identified a small fraction of the total loci, and these likely play only a small role in a person's depression risk.

The implications of the discovery were characterized differently between the unattributed press release content and the scientists' quotes. For instance, the UQ release described the study findings as "providing new insights for prevention and treatment" and the UNC release claimed the "results can be used for improved therapies." In contrast, Lead Scientist B in the UQ release stated, "Our eventual aim is to develop improved treatments," and Lead Scientist C in the UNC release stated, "With more work, we should be able to develop tools important for treatment and even prevention of major depression." Lead scientist E in the KCL release also described the study's "potential to revitalise depression treatment by opening up avenues for the discovery of new and improved therapies." Lead Scientist A in the UQ release stated that the discovery "opens new doors for research into the biological drivers," while Lead Scientist D in the KCL release clarified that the study "shed a bright light on the genetic basis of depression, but it is only the first step."

The lead scientists did depict the utility of the findings using tentative language, framing depression as complex and multicausal, but they indicated that knowledge gaps about its causes could be filled with more research into biological mechanisms.

Two of the press releases (UQ and KCL) paired the knowledge deficiency frame with an appeal for research volunteers, perhaps with the hope that this call would be shared in media coverage of the study. Both releases contained a website link or contact information for prospective participants to sign up.

Online Media Coverage

This study received coverage from prominent online media outlets, including original reporting from news outlets (*The Guardian*, *U.S. News*, and *Newsweek*) and other media (the health magazine *Prevention* and digital media sites Gizmodo, Bustle, and Medical News Today) as well as republishing of syndicated content from newswires (Agence France-Presse [AFP; which creates syndicated content in English], Reuters, and EurekAlert!). *The Guardian* and *Newsweek* offered the most in-depth coverage of the research, while the *Prevention* story gave in-depth coverage of the broader topic and mentioned the study. The remainder of the online media content tracked by Altmetric were short news stories, most of which borrowed heavily from the

content in the press releases or *Guardian* and *Newsweek* articles. The *Guardian* story was the only one to include an original interview with a lead scientist (Scientist D from KCL), while other stories used scientist quotes from the press releases or used outside sources. Given that much of this content was similar, a summary of the main trends is highlighted.

Uncertain Reliability and Validity. A few stories, including those from Medical News Today, *The Guardian*, *Newsweek*, and AFP, mentioned that multiple datasets had been combined in the study. They did not make explicit that the data were from different types of sources, with the exception of a mention in the Medical News Today story that one dataset was from the company 23andMe. Only the *Guardian* journalist pointed out that these datasets included self-reported data and that this represents a knowledge limitation. He explained,

> Many of the participants involved in the research self-reported depression, which is far less reliable than a clinical diagnosis. This means that some of the gene variants the scientists link to depression could turn out not to be involved in the disorder.

The *Guardian* journalist clarified that "[i]t will take more research to confirm that the gene variants found in the study are really linked to depression." None of the other stories mentioned the inherent possibility of misdiagnosis or mistaken self-report, given the nature of the data collection methods.

Uncertain Generalizability. Only the Gizmodo, *Guardian*, and Bustle articles mentioned that the study datasets were drawn from the United Kingdom, United States, Iceland, and Denmark or that the sample primarily included participants of European descent. The Bustle article described this as an "important" caveat in terms of the generalizability of study findings. The Gizmodo article stated that the scientists found divergent results between the European descent sample and data from a Chinese population, explaining that "the lack of overlap in relevant variants between the two populations highlights the ongoing need for more diversity in genetic research." Also related to generalizability, the Gizmodo story hedged the scientists' original claim about the results applying to "all humans," stating that the study "suggests that all humans may carry" some of these variants, while "suggests" and "may" were absent from the scientists' claim in the original scientific abstract.

Uncertain Causal Mechanisms. Journalists often alternated between causal and correlational phrasing within a story, likely confusing readers about the

knowledge limitations arising from GWAS, which can only identify associations. News stories also varied in their presentation of the gene variants' overlap between depression and BMI. Instead of noting an ambiguous "link" between variants for obesity and depression, which may lead readers to infer causality, *The Guardian* article explicitly stated that "DNA that predisposes people to obesity also raises the risk of depression," rather than suggesting obesity causes depression or vice versa. Conversely, the *Prevention* story interpreted correlation as causation in the following claim: "The *Nature Genetics* study . . . found that having a high body mass index—an indicator of obesity—could up your risk of major depression." At other times, journalists used confusing wording, such as in this content from AFP: "Variations on 44 genes—30 of them identified for the first time—showed an unambiguous correlation." Although the writer avoided making a causal claim, it is not clear how this statement should be interpreted, and it contrasts with the statement from the *Guardian* journalist that confounds were possible, given the nature of the data.

Summary of Communication Features. Overall, the *Guardian* and Gizmodo stories conveyed the most forms of uncertainty and with high specificity—in some cases, more explicitly than the original scientific paper. The authors of these two stories added contextualizing information and the *Guardian* report included an interview with Lead Scientist D, who provided more explanation of study caveats than what was conveyed in the original scientific paper. This scientist hedged the study findings, explaining that those who have a lower number of the identified gene variants are "perhaps" less likely to experience depression. She also explained this risk with a higher degree of specificity than what was conveyed in her press release quotes. Rather than using the vague language of "greater risk," she quantified the risk, stating: "If people are ranked according to the number of genetic risk factors for depression they carry, those in the top 10% are two-and-a-half times more likely to experience depression than those in the bottom 10%."

Lead Scientist D further hedged the significance of the study findings in the *Guardian* story by stating: "We know that thousands of genes are involved in depression with each having a very modest effect on a person's risk." Furthermore, the *Guardian* journalist (possibly based on information from the KCL Lead Scientist D) added that the 44 identified variants "are only a small fraction of the total, because many more will have had too small an effect to be discovered in the latest study." Two unaffiliated scientists interviewed about the research for the *Prevention* article mentioned these caveats, as well. Thus, the discovery of these 44 genetic markers was characterized as being, in itself, somewhat limited in utility in these two articles, in contrast to

much of the other news coverage, press release content, and even the original scientific paper.

The *Newsweek* article contextualized the significance of the study findings in other ways, such as highlighting that more research is needed and that genes are only one of many causal factors. Three sources in the story called attention to nongenetic causes of depression. First, the press release quote from Lead Scientist D was included, stating that the study is "only the first step" and concluding, "An even larger study is now needed to uncover more of depression's genetic underpinnings, and to understand how environmental stresses increase the risk of depression." Two unaffiliated experts also highlighted the roles of social and economic factors and life experiences in depression, noting that genetic makeup only represents one "piece of the jigsaw." Thus, the affiliated and unaffiliated scientists were in agreement in their caution and contextualization of the findings.

The two outside sources in the *Prevention* story highlighted that the majority of depression risk comes from nongenetic factors and one of these sources described the likelihood of complex gene-environment interactions. Both the journalist and the outside sources noted that more research is needed. The journalist stated: "While the results are promising, many researchers argue it's likely too early to turn to genetic tests for answers. Many DNA sequence variations that could have an impact on depression have yet to be discovered." In terms of the implications of the discovery for treating depression, the journalist and outside sources concluded that it is promising "but science just isn't there yet." Lead scientists were not interviewed or quoted for the story. Although outside sources complexified the research in this story, their statements aligned with comments from Lead Scientists A and D elsewhere, as well as some caveats mentioned in the original scientific article, so this may not necessarily represent a consensus uncertainty frame. The Medical News Today writer similarly put the role of genetics into perspective, using the metaphor of "welcoming soil" (genetic factors) and "fertilizer" (life events) to explain the gene-environment relationship. In terms of implications, the *Guardian* article's headline and body text used the language of hope and tentativeness to describe study findings, rather than making bold claims about the study's impact. For example, the journalist said, "scientists now hope to understand more" and "scientists have raised hopes for more effective treatments." Hedging language was employed throughout the *Guardian* article, such as noting that the study "could . . . help in the search for drugs to treat the condition." The *Newsweek* story also described study implications with hedged language, noting that the newly discovered genes "could increase the risk of developing depression" in a study that looked into "potential" genetic risk factors and that "could pave the way for more

effective treatments." The other articles conveyed less uncertainty, but some did include caveat statements from the scientists, taken from the press releases, saying that more research is needed. Content from Reuters conveyed study findings in a tiered effect, with claims going from certain to increasingly hedged from headline to subhead to body text. Notably, only the Bustle story included the volunteer appeal and link for members of the public to sign up.

Discussion

This case study examined patterns of scientific uncertainty portrayal for a single scientific discovery across the dissemination trajectory, from scientific publication to press releases and news reports. The research was the result of a high-profile, international collaboration of over 200 scientists and produced a GWAS based on seven participant cohorts, aimed at identifying genetic markers for depression in order to develop gene-targeted therapeutics. This case represented a salient example of emerging precision medicine research, where scientific uncertainty is high (Howard & Iwarsson, 2018; Ioannidis & Khoury, 2018; Kostick & Blumenthal-Barby, 2021; Parens et al., 2020), the potential for streamlining and hype is high (Joyce, 2018; Marcon et al., 2018), and the way the research is portrayed to the public has unique social and ethical considerations (Ratcliff et al., 2021; Sankar & Parker, 2017).

By using a qualitative case study approach, this analysis presented an in-depth look at how scientific uncertainties surrounding a novel precision medicine discovery were characterized at each stage of dissemination. Its depth complements the breadth of other analyses by showing examples of the ways in which scientific uncertainty is described (or omitted) in real messages and how this messaging evolves along the chain of dissemination. Both RQ1 and RQ2 were guided by prior empirical and conceptual work, which was used to develop a typology to structure the analysis. The goal for RQ1 was to first identify the elements and sources of scientific uncertainty in the selected case. Answering RQ1, these elements were related to validity and reliability (arising from study uncertainty), generalizability (arising from study uncertainty and consensus uncertainty), and causality (arising from study uncertainty and epistemic uncertainty). Next, the goal for RQ2 was to examine how the abovementioned elements were portrayed at each stage of dissemination. Finally, the goal for RQ3 was to examine whether observed patterns would reveal possible insights about the process of dissemination, in this case, comparing observations against extant theory about communicators' motivations and routines for translating science to the public. Observed patterns and directions for further research are discussed subsequently.

Communicative Strategies and Types of Uncertainty Portrayed

A diverse range of uncertainty types was portrayed, mostly arising from *study* uncertainty rather than *epistemic* or *consensus* uncertainty (see Table 1). The depicted types of uncertainty pertained to the study results' generalizability, validity and reliability, and evidence of causality. Despite the deeper uncertainties that characterize emerging genomic discoveries and their implications for precision medicine (Howard & Iwarsson, 2018; Ioannidis & Khoury, 2018), it was usually intimated that the scientists either had discovered or with more data would be able to discover all that is to be learned about the genetic basis of depression risk and gene-targeting treatments. The lead scientists frequently used a deficient frame in the scientific paper and press release quotes, likely to justify ongoing research and attract volunteers for their research programs.

Despite the research being conducted with a European ancestry population and failing to replicate results from a Chinese sample, the scientists interpreted their findings as applying to "all humans" in both the scientific paper and media quotes. Study sample details and potentially limited generalizability were not mentioned in the press releases and were rarely mentioned in media coverage, with the exception of two journalists' comments on this caveat. However, polygenic risk scores based on research with European populations may not apply equally to non-Europeans, and implications for pharmacogenomics may not apply equally across populations; for example, African Americans are thought to have greater genetic variation compared to other populations (Carlson et al., 2013; Wojcik et al., 2019). Only the Gizmodo and Bustle journalists discussed this caveat in their reporting, which is somewhat surprising since the study received worldwide media attention. Furthermore, only the *Guardian* journalist depicted the uncertainty related to reliability and validity of the data, given data collection methods.

Scholars have expressed concern that science journalists sometimes include dissenting fringe opinions to create the appearance of dueling scientists (Binder et al., 2016; Dixon & Clarke, 2013; Jensen, 2008). Perhaps reassuringly, that trend did not emerge in this case. When outside sources were used, they typically either conveyed uncertainty similar to what the lead scientists had conveyed elsewhere or hyped the study's implications.

Press Releases' Roles in the Dissemination Process

Press releases figured prominently in the chain of dissemination in this case, in line with findings from systematic reviews (de Semir et al., 1998; Stryker, 2002). With the exception of the *Prevention* story, all media coverage quoted

content from at least one of the press releases. This suggests that the press releases played a key role not only in how the research was depicted in the media but also in the study receiving news coverage in the first place.

A central observation in this case study was that the level of uncertainty conveyed in the news articles often reflected which press release was used or which scientist was interviewed or quoted. Tracing this lineage was possible because quotes or information in the news article was identical to content from the press releases. As previously described, each press release featured quotes from the researchers affiliated with that respective institution. In those press releases, each of the lead scientists communicated different degrees of certainty about the implications of the study and interpreted the results with varying amounts of caution and contextualization. For example, the scientific claims made in the press release from KCL were significantly more hedged as were claims in the news articles that featured comments from the KCL scientists (e.g., *The Guardian* story). This finding aligns with another case study observation in which the frame of the press release influenced subsequent media coverage (Zhang, 2018). Yet it is less clear what influences the extent of uncertainty discussed in a press release. While streamlining and hype may be expected in press release material given their promotional nature, these varied across press releases in this case. Whether a scientist's approach to communicating uncertainty influences the tenor of press releases or vice versa would be interesting to examine, potentially through interviews with university press officers and scientists.

Journalists drew heavily, and sometimes fully, on press release content. This finding is not surprising given the time pressures faced by many science journalists (Fengler & Ruß-Mohl, 2008), but it underscores scientists' responsibility to convey their science accurately in this medium, since they may not have the chance to provide further contextualizing information in a media interview. Holding press release writers responsible for accuracy, for instance by including their bylines, might also bring greater accountability (Goldacre, 2014). That the press releases appeared to double as research recruitment tools further stresses a need for accuracy.

Patterns in Journalists' Reporting

Roughly half of the news stories in this case included some depiction of uncertainty, but none discussed all three types pertinent to the research. These depictions of caveats and limitations came primarily from Lead Scientist D, outside expert sources, or the journalist's own commentary.

Only one news story (*The Guardian*) included an original interview with lead scientists (those from KCL). It is unclear whether the other scientists

were harder to reach for comments, or whether other journalists simply chose to use press release quotes or outside scientist sources because they were more readily available. Past work suggests that genetic scientists may also be selective about which media outlets they communicate with, and their choices can be driven by time constraints and the quality of the media outlet (Geller et al., 2005). Yet findings in this case indicate that incorporating more commentary from lead scientists would have likely generated more accurate news media portrayals of the research. Some research has shown that science dissemination can begin to resemble a game of "telephone," where caveats and limitations get progressively lost at each stage of retransmission (Goldacre, 2014; Sumner et al., 2014). This was not necessarily observed in the current case study. Some elements of uncertainty were not communicated by the scientists to begin with. Other elements were omitted from press releases whose depictions were often mirrored by subsequent news coverage. Three news stories added or described in greater depth several elements of uncertainty that were not conveyed in the press releases or scientific papers. One possible explanation is that these journalists were more seasoned science writers.[4] Experts have suggested that trained science journalists are less easily "fooled by the quick press releases and fast-breaking stories" than other reporters because of their familiarity with the subject (Boffey et al., 1999, p. 83). This example corroborates findings from a recent content analysis, which found that—although scientific findings were predominantly portrayed as certain in online media—this occurred less often in sections dedicated to science (Guenther et al., 2019).

Implications, Limitations, and Future Research

The purpose of this case study was not to make predictions or generalizations but to study communicative strategies and processes in depth in a particular case, interpreting these through the lenses of extant theoretical and empirical frameworks. These findings can then be triangulated with other examples or used to guide systematic analyses of a larger scale. For example, case studies of news coverage can be used to generate research questions for experimental studies or categories for content analyses by identifying important variables and content features to consider.

The types, depth, and message sources of uncertainty disclosure varied considerably across the content in this case. Given that such communication variables can differently influence audience responses (Gustafson & Rice, 2020; Jensen, 2008; Ratcliff et al., 2018), it was important to attend to these in the current analysis (Stocking, 1999). An a priori classification scheme was developed for this study to highlight a range of relevant variables

addressed in prior literature and to facilitate qualitative analysis of content. Potentially, this typology can serve as a basis for larger content analyses that test and expand these categories and their definitions (Slater, 2013). Furthermore, the typology can facilitate the design and interpretation of message experiments that strategically vary these communication features, helping to organize the discordant empirical literature on the effects of communication of scientific uncertainty (Gustafson & Rice, 2020).

This case study had several limitations. First, while Altmetric is a useful tool for examining the dissemination of science across platforms, its database is limited to online media coverage. Second, although the number of media mentions was high in this case, coverage was frequently duplicative and redundant. Together, these factors limited the content available for analysis. Furthermore, as this was an interpretive, qualitative analysis focused on a single case of scientific research output, it is not yet possible to make general observations about the dissemination of precision medicine research. Instead, findings from this study could be used to develop experiments that test assumptions about audience preferences and reactions to different types of portrayals. For example, do streamlining and hype in the depiction of precision medicine research help or hurt communicator credibility, public attitudes toward this branch of science, or willingness to volunteer for research? Does the source of the uncertainty disclosure—lead scientist, outside scientist, or journalist—differently influence how public audiences perceive the research or the communicators?

This study treated dissemination as a stage process in which information about the scientific discovery traveled from scientific article to press release to news coverage. Although support for this process was observed in the current study, this is not the only path through which new scientific discoveries are disseminated to the public. Indeed, journalists can bypass press releases and scientists can share their research directly with the public via social media and blogs (Peters et al., 2014). Whether precision medicine research is portrayed to the public with less streamlining and hype when media content is not based on a press release, and whether scientists use their own media platforms to discuss complexities in their research when not given the chance to do so through press release and news interviews, would be useful to examine in future research in light of the findings in this case.

Conclusion

A diverse range of uncertainty types was portrayed using different frames and varying levels of detail. Study uncertainty was much more frequently depicted than epistemic or consensus uncertainty, with a focus on uncertain

generalizability, validity and reliability, and causal claims. Although some uncertainty was conveyed at each phase of dissemination, streamlining and hype varied depending on the press release or lead scientist source, which had a downstream effect on media coverage. These findings, combined with the presentation of an initial typology for categorizing variables in scientific uncertainty communication, can help to guide content analyses and experimental research in this area.

Acknowledgements

The author is grateful to Jakob D. Jensen, Kevin Coe, James Tabery, Rebekah Wicke, Editor Susanna H. Priest, and three anonymous reviewers for constructive feedback that helped shape this final manuscript.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

ORCID iD

Chelsea L. Ratcliff https://orcid.org/0000-0002-8066-1233

Notes

1. Altmetric follows conversations about specific research outputs across phases and platforms of dissemination, tracking press coverage of scientific articles across more than 2,000 global online media sources. The Altmetric page for this case can be accessed at https://app.dimensions.ai/details/publication/pub.1103659983. For more information about Altmetric tracking criteria, see https://www.altmetric.com/aboutour-data/our-sources/news/.
2. Use of self-reported data, as well as data amalgamated from multiple sources, has raised questions about data quality in precision medicine research (Hollister & Bonham, 2018).
3. It is not yet clear whether results from genome-wide association studies (GWAS) from European Ancestry populations will generalize to populations of diverse ancestry (Carlson et al., 2013; Wojcik et al., 2019).
4. It is worth considering the differing economic nature of these media outlets. For instance, unlike most media outlets, *The Guardian* is owned by a trust designed to protect its financial and editorial independence, and its profits are reinvested in journalism. Conversely, outlets such as *Newsweek, Prevention, U.S. News*,

and *Gizmodo* are owned by large media companies or media proprietors, and these derive profits primarily from advertising revenue, thereby indicating that attracting a high volume of readers is likely the primary goal. Syndicated content, meanwhile, is created to sell to media outlets and thus also likely to prioritize mass appeal. While these factors may explain the careful reporting from *The Guardian*, as it is less susceptible to market influences that create time and resource constraints and pressure to publish hyped stories (Fengler & Ruß-Mohl, 2008), the *Prevention* and Gizmodo articles were also noteworthy in their original reporting and journalists' careful contextualization of the scientific issue. Thus, market pressures and media outlet type may partially but not fully explain the occurrence of streamlining and hype in science reporting.

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Author Biography

Chelsea L. Ratcliff (PhD, University of Utah) is an assistant professor in the Department of Communication Studies at the University of Georgia. Her research focuses on unintended effects in health and science communication, especially effects pertaining to the disclosure or omission of scientific uncertainty. Prior to academia, she worked as a health journalist and a marketing/public relations writer.