



Communicating uncertainty to the public during the COVID-19 pandemic: A scoping review of the literature

Chelsea L. Ratcliff, Rebekah Wicke & Blue Harvill

To cite this article: Chelsea L. Ratcliff, Rebekah Wicke & Blue Harvill (2022): Communicating uncertainty to the public during the COVID-19 pandemic: A scoping review of the literature, Annals of the International Communication Association, DOI: [10.1080/23808985.2022.2085136](https://doi.org/10.1080/23808985.2022.2085136)

To link to this article: <https://doi.org/10.1080/23808985.2022.2085136>



Published online: 08 Jun 2022.



Submit your article to this journal [↗](#)



View related articles [↗](#)



View Crossmark data [↗](#)

RESEARCH ARTICLE



Communicating uncertainty to the public during the COVID-19 pandemic: A scoping review of the literature

Chelsea L. Ratcliff , Rebekah Wicke  and Blue Harvill

Department of Communication Studies, University of Georgia, Athens, GA, USA

ABSTRACT

Pandemics are characterized by extreme uncertainty and effective communication is critical to help the public manage this uncertainty. We summarized scholarship on public communication related to uncertainty during the COVID-19 pandemic, synthesizing insights published from January 2020–February 2022. We reviewed key findings and arguments from 39 empirical papers and 21 nonempirical papers with a particular focus on the theories and concepts that underpinned them. While this work shed light on elements of effective communication, conceptual and operational treatments of uncertainty varied considerably, and less than half of papers used a theory to analyze or discuss uncertainty-related communication. In all, this review highlights opportunities to strengthen our field's theoretical and practical contributions to public communication in uncertain situations.

KEYWORDS

Public communication;
media; uncertainty;
uncertain science;
transparency; COVID-19;
theory

The coronavirus disease 2019 (COVID-19) pandemic has been marked by tremendous uncertainty, and understanding the roles of public communication in addressing this uncertainty has been a pressing question for our discipline (Dunwoody, 2020; Finset et al., 2020; Guttman & Lev, 2021; Paek & Hove, 2020; Pearce, 2020; Sauer et al., 2021). As de Vreese (2021) pointed out in his ICA Presidential Address, COVID-19 has not merely been a public health issue. Thus, it is not surprising that public communication during this pandemic—especially communication about uncertainty—has involved health communication, science communication, political communication, risk and crisis communication, journalism, and many other subdomains of the discipline (Caulfield et al., 2021; Gollust et al., 2020; Hanson et al., 2021; Hyland-Wood et al., 2021; Lilleker & Stoeckle, 2021).

This public communication has occurred largely through mass media platforms, which have buttressed public COVID-19 communication around the globe. Journalists have been key translators of emerging science for the public (Dunwoody, 2020; Rajkhowa, 2020). News and social media have been relied upon to convey official public health guidelines and government policies (Fernandes, 2021; Tsao et al., 2021). Social media platforms have also created spaces for dynamic debate about COVID-19 among scientific and medical experts, politicians, journalists, and citizens (Prettner et al., 2021; Trevisan et al., 2021; van Dijck & Alinejad, 2022).

One way in which communication theory and evidence prove critical during a pandemic is in guiding the development of effective public messaging. As Sauer et al. (2021, p. 65) argued, 'To reduce fear and uncertainty ... COVID-19 communication should be rapid and accurate, while building credibility and trust and showcasing empathy—all with a unified voice.' Other scholars have similarly prescribed the need for public COVID-19 communication that is fast, accurate, simple, clear, and transparent (Caulfield et al., 2021; Finset et al., 2020; Ho & Huang, 2021; Lasser et al., 2020; Sauer et al.,

2021). However, achieving these aims in a highly complex and uncertain environment—such as a global pandemic, which is characterized by rapidly evolving scientific information and changing circumstances—poses a colossal challenge for scientists, public health experts, government leaders, journalists, and other communicators tasked with conveying COVID-19 information to the public. How should these in many ways *competing* objectives be achieved in public messaging? What is the best way to communicate uncertainties to the public or to communicate in ways that help the public to manage uncertainty?

As communication scholars work to address the questions outlined above, an important consideration is whether our discipline's theories and concepts related to uncertainty have been sufficient to guide communication research and practice in the COVID-19 context. Twenty years ago, Bradac (2001) highlighted a lack of sufficient and clear theorizing to guide investigations of uncertainty as it relates to communication processes, criticizing theories such as Problematic Integration Theory (Babrow, 1992) and Uncertainty Management Theory (Brashers, 2001) for being vague and not truly testable or disprovable. Has much changed in 20 years, or do flaws and gaps in our field's uncertainty theorizing remain? Further, do our conceptual and operational treatments of 'uncertainty' create a coherent and useful body of scholarship, or do we use the term to mean vastly different things?

As a step toward answering these questions, we conducted a scoping review of the literature on public communication and uncertainty in the context of COVID-19. We examined empirical papers that assessed communication processes related to uncertainty, as well as nonempirical papers describing these processes. To clarify our concepts of interest, we defined *communication* as 'the transfer of information between individuals or groups' and *uncertainty* as 'the condition in which reasonable knowledge regarding risks, benefits, or the future is not available.' We aimed to summarize key challenges and solutions that have been identified pertaining to communicating uncertainty in the COVID-19 context, as well as to characterize features of this scholarship. Concurrently, we sought to address whether current communication theories and concepts of uncertainty are sufficient to enable scholars to examine public reactions to uncertainty and guide public communication during COVID-19 and beyond.

Uncertainty, communication, and COVID-19

Without a doubt, *uncertainty*—referring to a lack of knowledge about a current or future situation or outcome (Babrow et al., 1998)—is a central aspect of a pandemic, and thus pandemic communication. The COVID-19 pandemic has been characterized by ongoing uncertainty about the emerging science (Capurro et al., 2021), uncertainty about official guidelines (Zhang et al., 2021), uncertainty about impacts on the economy (Dietrich et al., 2022) and the environment (Coll, 2020), and uncertainty about health, social, and financial impacts on individuals, families, and communities (Dietrich et al., 2022; Huang & Yang, 2020). How these sources of uncertainty are handled in public communication may have significant and wide-ranging implications for public trust in science, public officials, and the media (Balog-Way & McComas, 2020; Caulfield et al., 2021; Finset et al., 2020), as well as public adherence to behaviors that slow the spread of the virus (Huang & Liu, 2021; Kelp et al., 2021). Further, it may influence people's ability to navigate information uncertainty amidst the COVID-19 *infodemic*, characterized by a high volume of information and rapid spread of conflicting and misleading information (Escandón et al., 2021; Vraga & Jacobsen, 2020; World Health Organization, 2021; Zhou et al., 2021).

The COVID-19 pandemic is unique in its nearly universal impact, as well as the ways in which different parts of the world and different populations and communities have been affected in vastly different ways (Kim et al., 2020). A broad cast of public communicators—including public health experts, scientists, government leaders, news reporters, and healthcare workers—has been tasked with helping public audiences to navigate COVID-19 uncertainty, using the internet and traditional and social media to do so (Dunwoody, 2020; Gesser-Edelsburg, 2021; Malecki et al., 2021; Tsao et al., 2021; Vraga & Jacobsen, 2020).

Together, the above factors make uncertainty-related communication unique, and uniquely challenging, in the COVID-19 context. Communication scholars worldwide have responded by producing a rich body of research to understand and address these challenges. Here we review insights from the first two years of the pandemic, focusing on literature examining uncertainty communication processes involving public audiences. Public COVID-19 communication and information seeking have largely occurred in mass media settings (e.g. print newspapers, online news, public health and government websites, broadcast media, and social media), making this a salient topic for the special issue's theme.

Below we outline our research objectives and the rationale for each of the research questions that guided our review. Codebook categories are italicized.

Characteristics of the literature

First, we sought to understand what types of empirical and nonempirical scholarship have been conducted to examine communication related to COVID-19 uncertainty. Taking note of these characteristics can help to contextualize trends in the literature and identify gaps where more research is needed.

Given the global nature of the pandemic, it is important to consider for which *countries* COVID-19 uncertainty communication has been examined; that is, which geographic regions are focused on in nonempirical papers and which are represented in study samples (i.e. study participants or media content). Following extant typologies for characterizing public uncertainty communication (Gustafson & Rice, 2020; Peters & Dunwoody, 2016; Ratcliff, 2021), we also consider the public *communication settings* (e.g. news media, public health websites, social media, etc.), *message or information sources* (e.g. public health officials, scientists, journalists, politicians, etc.), and *COVID-19 topics*, for both empirical and nonempirical papers. We address type of uncertainty as a separate research question.

For empirical papers, we also sought to characterize features of the authors' methodological approaches, including *study type*, *sample size*, *sample type* (i.e. student or general population for studies with human participants; unit of analysis for content analyses), and whether the paper reported results of *multiple studies* or *preregistered studies* (i.e. preregistration of hypotheses, methods, and/or analyses). These features help to contextualize research results, as well as serve as indicators of robustness and representativeness, which may be especially important for evaluating COVID-19 research quality (Quinn et al., 2021). Lastly, given the continually evolving COVID-19 environment, the *timing* of empirical observations could significantly influence the nature of uncertainty communication and audience responses. With these factors in mind, we address the following research question:

RQ1. What are the characteristics of this empirical and nonempirical literature?

Treatment of the concept of uncertainty

Uncertainty, broadly, is a state of not (fully) knowing—for example, about a current or future situation or outcome—caused by having complex, ambiguous, incomprehensible, incomplete, or contradictory information (Babrow et al., 1998). Uncertainty can be a self-perception (e.g. perceiving that one does not have sufficient information), or it can describe the state of knowledge more generally (e.g. within an organization or a scientific discipline; Brashers, 2001). The former is sometimes termed 'internal,' 'personal,' or 'subjective' uncertainty and the latter 'external' or 'situational' uncertainty (Bradac, 2001; Peters & Dunwoody, 2016). Since this review focuses on assessments of public communication, we categorize uncertainty along similar dimensions: as communicated or experienced.

We define *communicated* uncertainty as uncertainty that is present within the message (related to external uncertainty) and *experienced* uncertainty as a subjective perception or feeling of uncertainty

held by the message recipient or information seeker (related to internal uncertainty). In general, experienced uncertainty is usually treated as a cognitive state, referring to a perceived lack of knowledge or a *knowledge gap*, but it is sometimes treated as a negative *emotional state* akin to anxiety (Bradac, 2001; Griffin et al., 1999). In the COVID-19 context, uncertainty may refer to unknowns caused by incomplete information, conflicting information, or unvalidated information, all of which may be communicated to or experienced by public audiences. It is also possible the term ‘uncertainty’ will be used to characterize an affective state experienced by individuals during the pandemic.

Although we present a simple classification scheme above, we recognize that scholars may conceptualize, operationalize, and label uncertainty in vastly different ways. It may also be the case that researchers are not explicit about the type of uncertainty being examined. Therefore, in posing the following research question, we intend to classify according to the above definitions, when possible, but to also provide a detailed description of how uncertainty is treated.

RQ2. How has uncertainty been conceptualized and operationalized in this literature?

Use of theoretical frameworks

Given the social scientific focus of this review, we adopt the definition of *theories* as explanations of causal processes, which can include explanations of mechanisms and boundary conditions—the *how* and *under what circumstances*—of these processes (DeAndrea & Holbert, 2017; Popper, 1959; Slater & Gleason, 2012). Theoretical frameworks are important tools for social scientific inquiry, guiding scholars in producing interpretable and replicable discoveries (Popper, 1959). Using well developed theoretical frameworks to guide research foci and the generation of hypotheses can help scientists to make sense of and assimilate discoveries across disciplines, ensuring we don’t end up with ‘a potpourri of disconnected empirical findings’ (Muthukrishna & Henrich, 2019, p. 221). In addition to applying theory in empirical communication research, scholars can engage social scientific theories in nonempirical communication scholarship to offer explanations for observations or to underpin critiques and recommendations. Being able to understand causal processes is important for building reliable knowledge about communication phenomena (DeAndrea & Holbert, 2017; Slater & Gleason, 2012).

Despite the importance of theory, it is unclear whether we have sufficient theories (or make sufficient use of existing theories) to address uncertainty communication. In a systematic review of the literature on uncertainty communication during public health emergencies, Sopory et al. (2019, p. 81) concluded that ‘the research literature remains generally atheoretical’ and that ‘theories of communication research that directly speak to uncertainty have not been used to investigate this phenomenon in the context of public health emergency events.’ In another review of literature on communicating crisis uncertainty, Liu et al. (2016, p. 479) summarized: ‘Despite the well-recognized role of uncertainty in crisis communication, research has not theorized exactly how communicators should best ‘manage’ uncertainty to help publics cope and respond appropriately.’

Scholars have similarly observed a lack of theorizing about how public audiences process messages about uncertain science. Recent work in science communication highlighted a need for formal theorizing about boundary conditions (e.g. message features, audience characteristics, and topics) and processing mechanisms (Ratcliff et al., 2021; Steijaert et al., 2021), in order to make sense of the vastly mixed evidence about public reactions to the communication of scientific uncertainty (Gustafson & Rice, 2020).

In light of persistent criticisms about lack of sufficient theory to guide communication research about uncertainty, both in general (Bradac, 2001) and in the areas of crisis and risk communication (Liu et al., 2016; Sopory et al., 2019) and science communication (Ratcliff et al., 2021; Steijaert et al., 2021), we examined *theory use* in this literature in order to identify strengths and weaknesses of extant theories for the COVID-19 context.

RQ3. How have theories been used to guide empirical investigations and nonempirical scholarship related to public communication and COVID-19 uncertainty?

Uncertainty communication trends and effects

At the root of the goal to understand uncertainty communication in the COVID-19 context are questions about how to communicate uncertainty without causing panic, distrust in experts, or lack of adherence to public guidelines (Finset et al., 2020). Related to this are questions about how citizens manage the uncertainty they perceive or experience during the pandemic, and how communication influences these experiences, including whether certain communication approaches can help to mitigate negative outcomes of experienced uncertainty (Finset et al., 2020; Sauer et al., 2021).

The most prominent arguments for and against communicating uncertainty center on its impact on public trust. There are, from one camp, calls for transparency about COVID-19 uncertainty as a way to preserve public trust in experts and in science (e.g. Caulfield et al., 2021; Finset et al., 2020; Saitz & Schwitzer, 2020). Indeed, there is some evidence from non-pandemic contexts to support this claim (Gustafson & Rice, 2020; Jensen, 2008; Steijaert et al., 2021). Yet some scholars worry that transparency can erode public trust in experts (e.g. Nguyen, 2021a; O'Neill, 2003). In the COVID-19 context, there is also concern that disclosing uncertainty can cause confusion, increase vulnerability to misinformation, decrease belief in authorities' competence to manage the situation, and lower compliance with public health guidelines (see Guttman & Lev, 2021).

To best answer whether and how uncertainty should be communicated in the context of a global pandemic, it is essential to assess current communication approaches and the impacts of such communication. What does the empirical literature suggest will be the effects of either communicated or experienced uncertainty on trust, information seeking, precautionary health behaviors, and other COVID-19 related outcomes? For example, does disclosing uncertainty actually increase or decrease trust in scientists and public health experts? Does communicated or experienced uncertainty have an impact on compliance with COVID-19 behavioral guidelines? What are the emotional impacts of uncertainty, and how do these relate to outcomes like information seeking or intentions to comply with recommended precautionary behaviors? Lastly, do empirical results align with recommendations and arguments in nonempirical work? To address this, we investigate the following open-ended question:

RQ4: What trends emerged in terms of empirical findings and nonempirical critiques or recommendations for communication?

Method

Inclusion Criteria and Definition of Terms

Empirical and nonempirical articles were included if they focused on an examination of uncertainty in the context of public or mass mediated COVID-19 communication, either describing communication of uncertainty or examining uncertainty as a predictor or outcome of a communication process (e.g. reactions to uncertainty communication, seeking information to manage uncertainty, etc.). In line with the Medical Subject Headings controlled vocabulary provided by the National Library of Medicine, we defined *uncertainty* as 'the condition in which reasonable knowledge regarding risks, benefits, or the future is not available' (National Library of Medicine, n.d.[a]) and *communication* as 'the transfer of information between individuals or groups.' (National Library of Medicine, n.d.[b]). We included only papers that specifically addressed uncertainty, as opposed to discovering it as an incidental finding (e.g. as a *post hoc* theme emerging in qualitative research) or merely mentioning it (e.g. by contextualizing findings 'in these uncertain times'). We included nonempirical papers to capture narrative reviews, commentaries, and

rhetoical analyses of uncertainty communication. However, some coded categories were irrelevant to nonempirical papers.

Literature Search

We searched for papers published in academic journals and written in English. To locate relevant papers, we performed a search of the entire Web of ScienceTM Core Collection, an electronic database that provides broad coverage across disciplines. We used the advanced topic search function with the Boolean search phrase '(communicat* OR messag* OR media) AND (uncertain* OR ambigu* OR conflict*) AND (COVID* OR coronavirus OR pandemic OR sars-cov-2)'. Our search phrase was developed in line with our operational definitions described above and to capture additional commonly used terms for communication in the public domain (i.e. media and messages or messaging) and for uncertainty in COVID-19 contexts (i.e. conflicting information and ambiguity or ambiguous). We limited our search to papers published between January 1, 2020 (roughly the onset of the COVID-19 public health crisis; Centers for Disease Control and Prevention [CDC], 2021) and February 16, 2022. This search identified 1,451 papers.

The research team scanned paper titles and abstracts in the Web of ScienceTM interface. We retrieved 117 papers for further screening based on our inclusion criteria. After screening full papers, we retained 57 papers. Additionally, we scanned reference lists for papers missed in the search and 3 additional papers were identified, screened, and ultimately included. This generated a final set of 60 papers. The PRISMA diagram presents full details (Figure 1).

Data Extraction Protocol

Prior to data extraction, all three authors collaboratively developed a coding form based on our research questions and relevant analytic frameworks (Chavez-Yenter et al., 2021; Peters & Dunwoody, 2016; Ratcliff, 2021). To further establish the validity of the coding scheme, we sought input from two communication scholars with expertise in pandemic uncertainty communication.

To examine theory use, we applied a framework presented in a scoping review by Chavez-Yenter et al. (2021). Specifically, we assessed whether a paper referenced a theory, conceptual model, or theoretical framework (henceforth referred to as 'theory') in line with our definition in the previous section. A theory had to be explicitly referenced and named for us to include it. We did not assess implicit use of theory due to the difficulty in reliably coding inexplicit theory use (see DeAndrea & Holbert, 2017; Slater & Gleason, 2012). Reference to theory without naming a specific theory (e.g. 'theoretical frameworks,' 'crisis and risk communication theory,' 'framing theory') was also not counted. However, if authors explicitly presented their own novel theory in the paper but did not name it, we counted this as a specific theory. To be relevant for our purposes, the theory had to be related to the authors' examination of uncertainty.

Following the framework developed by Chavez-Yenter et al. (2021), we also assessed how the theory was used: (1) to guide hypotheses/research questions, (2) to guide measure/theme selection, (3) to explain or speculate about reasons for findings/observations, (4) to discuss implications for the theory based on study findings, or (5) only mentioned in the paper's introduction. For nonempirical papers, we considered only the third category (i.e. to explain or speculate about reasons for the authors' observations) to be relevant.

After retrieving the literature, all three members of the research team tested the coding form with a random subset of 10 papers and refined the coding definitions and instructions. Following protocol used in prior work (Chavez-Yenter et al., 2021), the total pool of papers ($N = 60$) was then coded by a single coder (BH, RW) and 20% of papers ($N = 12$) were coded by a second coder (CR, RW). Given the low number of papers, complexity of some categories, and exploratory nature of the project, we calculated percent agreement and deemed a threshold of 80% to be satisfactory (Saldaña, 2013). Inter-coder agreement was above 80% for all categories except two. Agreement was 100% for *country*,

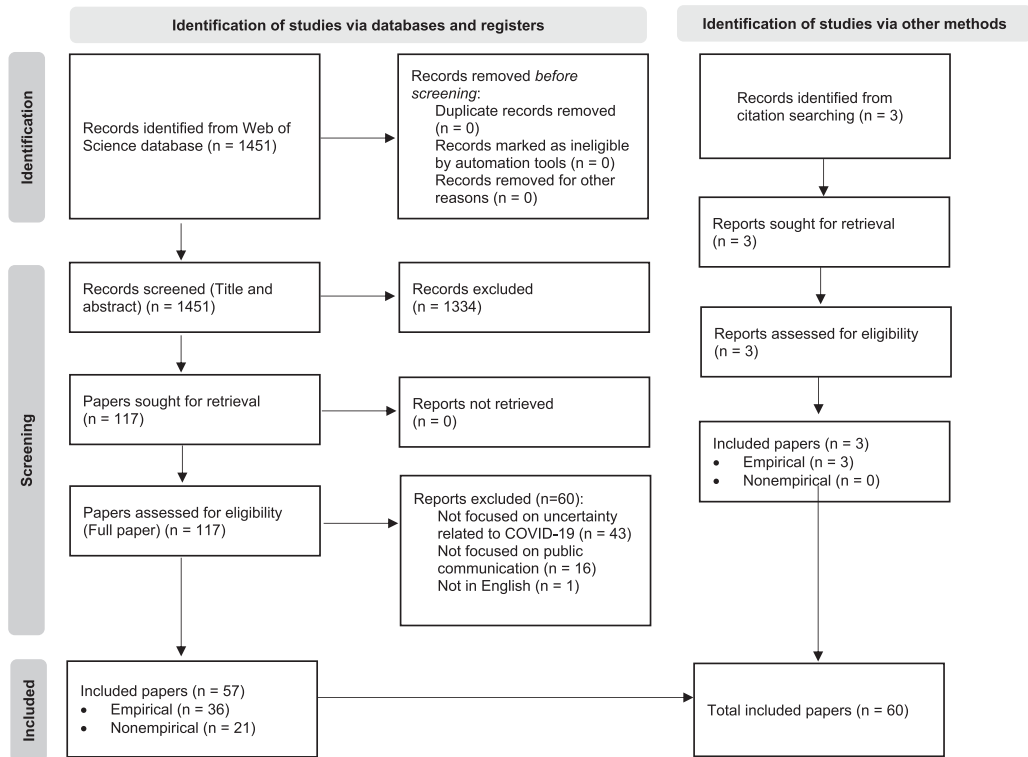


Figure 1. PRISMA flow diagram. *Note.* We performed the literature search in line with Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines. For more information, visit: <http://www.prisma-statement.org/>.

time period, study type, sample type, sample size, number of studies, use of preregistration, and communication setting; 92% for type of uncertainty, whether specific theory was mentioned, and name of specific theory; 83% for conceptual treatment of uncertainty and message source; 75% for COVID-19 topic; and 67% for how theory was used.

For categories with agreement above 80%, discrepancies were resolved by a third coder. For the two categories with agreement below 80%, a second coder extracted data for all remaining papers (CR, RW) and agreement was recalculated. Ultimately, we had difficulty extracting reliable data for these two categories given ambiguous reporting in some papers, and interrater agreement was minimally improved. We therefore present details qualitatively in text as described by the paper authors, where possible, but we do not report quantified data for these two categories or present them in the tables. The challenges in coding theory use in communication research have been previously documented (DeAndrea & Holbert, 2017; Slater & Gleason, 2012) and we reflect on this in the Discussion.

Results

Characteristics of the Literature (RQ1)

Of 60 included papers, 39 papers were empirical and 21 were nonempirical. We highlight overall trends below and report specific details for each paper in Tables 1 and 2.

Empirical papers

Among empirical papers, 13 presented experimental data (4 of which included multiple experiments, and 4 of which were preregistered), 12 presented survey data (9 cross-sectional and 3 longitudinal or

multi-wave), 11 presented an analysis of media content (e.g. content analysis, discourse analysis), 2 presented results of focus group interviews, and 1 was a meta-analysis of studies. As shown in Table 1, many studies were conducted during the first six months of the pandemic (i.e. January–June 2020; see CDC, 2021).

More studies ($N = 11$) were focused solely on the United States than any other single country. Other studies in North America had a Canadian focus ($N = 3$). A few studies were focused on Asian countries (China, $N = 8$; Singapore, $N = 1$) or European countries (Germany, $N = 4$; the United Kingdom, $N = 1$; Denmark, $N = 1$; Netherlands, $N = 1$). Other studies ($N = 7$) included samples from multiple countries. Only 2 papers had an international focus (i.e. presented data from many countries).

Most participant-based studies used samples drawn from the general population, while four relied on student samples, or a combination of adult and student samples. Two used a specific population for their sample (i.e. Texas residents or employees). Across study types, sample size ranged from very small (around 50–100 participants or messages) to very large (thousands of participants or units of analysis).

Several authors employed rigorous designs, such as using large national or multinational samples to strengthen the generalizability of their findings. Two papers used the same sample of participants from Singapore, South Korea, and the United States to create comparisons of culturally variable traits such as government trust and reaction to misinformation (Ahn et al., 2021; Kim et al., 2020). Three papers reported the results of two nonidentical studies (Gretton et al., 2021; Kerr et al., 2021; Petersen et al., 2021), and Kreps and Kriner (2020) conducted five related experiments to investigate participants' reactions to uncertainty in COVID-19 projections under different circumstances.

Many studies ($N = 10$) focused on public communication settings broadly, mentioning multiple channels (e.g. social media, government websites, and news). Subsets focused specifically on news media ($N = 7$), social media ($N = 5$), or communication by public health departments ($N = 8$). Others focused on the internet ($N = 3$), generic informational messaging ($N = 2$), public statements and press releases ($N = 3$), and apps ($N = 1$). Among studies examining communication or information seeking from a specific source, many were focused on journalists or government public health authorities, while some were focused on politicians, scientists or a mix of all the above. A few papers examined content from a particular entity, such as the U.S. CDC (Lambrecht, 2021) or statements attributed to former U.S. president Donald Trump (Rafkin et al., 2021).

Many papers did not assess or describe a specific aspect of COVID-19 uncertainty, making it difficult to code and report details for specific COVID-19 topics, as previously noted. Empirical studies were more likely than nonempirical papers to focus on uncertainty pertaining a specific topic, such as the efficacy of mask-wearing or COVID-19 vaccines, the accuracy of epidemiological models, or the status of public health guidelines. Yet many had a broader focus, such as general uncertainty surrounding COVID-19 or scientific uncertainty pertaining to a range of COVID-19-related evidence.

Nonempirical papers

The nonempirical papers ($N = 21$) provided commentary or guidance on communication related to uncertainty surrounding the global pandemic. Of these, some ($N = 6$) focused on the United States, while others ($N = 5$) had an explicit international focus. European countries of focus included the United Kingdom ($N = 2$), Germany ($N = 1$), Sweden ($N = 1$), and Austria ($N = 1$). Only two papers focused on the Asia Pacific region (South Korea, $N = 1$; Australia, $N = 1$). A few ($N = 5$) did not have an explicit focus on any particular country or region.

Most nonempirical papers ($N = 14$) specified a communication setting in which their perspectives or guidance applied, while seven did not. Half ($N = 7$) of the papers that did specify a communication setting addressed more than one setting. Communication settings included the news ($N = 8$), public health messaging ($N = 7$), and social media ($N = 6$).

The nonempirical papers generally did not concentrate on a specific topic within COVID-19 uncertainty. Some mentioned scientific uncertainty as a topic of interest. There was less emphasis on

Table 1. Empirical Papers Included in Review.

Paper	Country	Time period	Study type	Sample type	Type(s) of uncertainty addressed	Conceptual treatment of uncertainty	Communication setting	Message/Info Source*	Theory used to examine uncertainty
Ahn et al., 2021 ^a	South Korea, Singapore, US	2020 Feb-Mar	CS	Gen pop.: S. Korea (N = 1500); SG (N = 1023); US (N = 419)	Experienced	Knowledge gap & emotional state	Various (e.g. news, social media, health websites)	Not Applicable	RISP
Blom et al., 2021	Denmark	2020 Jan-Mar	MCA	News interviews (N = 43)	Communicated	Knowledge gap	News (TV), press meetings	Government/Public Health, Scientists, Journalists	Theoretical Model of Interactional Speculations
Capurro et al., 2021	Canada	2020 Mar-Jul	MCA	News stories (N = 1,143)	Communicated	Knowledge gap	News (online & print; hard news, opinion)	Journalists	None
Chen et al., 2021	China	2020 May-Jun	E	Gen pop. (N = 413)	Communicated	Knowledge gap	News	Not specified	Prospect Theory
Chu et al., 2022	International	2020	M	Studies (N = 47)	Experienced	Knowledge gap & emotional state	News, social media	Not specified	RISP
Crowley et al., 2021	US	2020 Mar	CS	Gen pop. (N = 1,000)	Experienced	Knowledge gap	News, social media	Not specified	TMIM
Daoust & Bastien, 2021	Canada	2020 Jun	E	Gen pop. (N = 1,002)	Communicated	Knowledge gap	Public health messages	Government/Public Health, Scientists	None
Fleerackers et al., 2021	International	2020 Jan-Apr	MCA	News stories (N = 457)	Communicated	Knowledge gap	Online news	Journalists	None
Gretton et al., 2021	Canada, US	2020 Oct-Dec	E ^{M,P}	Gen pop.: CA (N = 190); US (N = 1509)	Communicated	Knowledge gap	Public health messages	Politicians, Government/Public Health	None
Han et al., 2021	US	2020 May-Jun	E	Gen pop. (N = 1,497)	Communicated & experienced	Knowledge gap & emotional state	Public health messages	Not Specified	Competence Hypothesis
Huang & Liu, 2021	US	2020 Dec	E	Houston TX residents (N = 382)	Experienced	Knowledge gap	Social media	Government/Public Health	UMT, Prospect Theory
Huang & Yang, 2020	US	2020 Apr	LS	Gen pop. (N = 381)	Experienced	Knowledge gap	Internet, news (radio, TV)	Not Applicable	UMT, UIT, RISP
Janssen et al., 2021	Germany	2020 May	E	Gen pop. (N = 398)	Communicated	Knowledge gap	Public statements	Politicians, Scientists	None
Kelp et al., 2021	US	2020 Dec	E	Student (N = 117)	Communicated	Knowledge gap	Public health messages	Not Specified	None
Kerr et al., 2021	UK	2021 Jan-Feb	E ^{M,P}	Gen pop. (N = 4,314)	Communicated & experienced	Knowledge gap	Social media, public health websites	Government/Public Health	None
Kim et al., 2020 ^a	South Korea, Singapore, US	2020 Feb-Mar	CS	Gen pop.: S. Korea (N = 1500); SG (N = 1023); US (N = 419)	Experienced	Knowledge gap	Various (e.g. news, social media, health websites)	Not Applicable	RISP
Kreps & Kriner, 2020	US	2020 May-Jun	E ^M	Gen pop. (N = 6,817)	Communicated	Knowledge gap	Informational message	Politicians	None
Lambrecht, 2021	US	2020 Jan-Apr	MCA	CDC message (N = 147)	Communicated	Knowledge gap	Press releases	Government/Public Health	None
Li & Zheng, 2022	China	2020 Jan-Feb	CS	Gen pop. (N = 741)	Experienced	Emotional state	Internet	Not Applicable	RISP
Lin et al., 2020	China	2020 Jan-Feb	CS	Student (N = 780)	Experienced	Knowledge gap	Internet	Not Applicable	None
Logar et al., 2022	France, Italy, Spain, UK, US	2020 Mar	MCA	Google trends (23-day period)	Experienced	Emotional state	Internet	Not Applicable	None

(Continued)

Table 1. Continued.

Paper	Country	Time period	Study type	Sample type	Type(s) of uncertainty addressed	Conceptual treatment of uncertainty	Communication setting	Message/Info Source*	Theory used to examine uncertainty
Lu et al., 2021	China	2020 Jan-May	MCA	Weibo posts (N = 570)	Communicated & experienced	Knowledge gap	Social media	Internet/Social Media	Unnamed novel theory
Müller et al., 2021	Germany, UK	2020 Feb-May	MCA	News stories (N = 23,108)	Communicated	Knowledge gap & emotional state	News	Journalists	None
Ngai et al., 2020	China	2020 Jan-Mar	MCA	Weibo posts (N = 608)	Communicated	Knowledge gap	Social media	Government/Public Health, Journalists, Internet/Social Media	None
Oldeweme et al., 2021	Germany	2020 Jun-Jul	LS	Gen pop. (N = 1,003)	Experienced	Knowledge gap	Mobile app	Not Applicable	URT
Park & Shapiro, 2021	US	2020 May & Sept	E	Gen pop. (N = 570)	Communicated	Knowledge gap	Informational message	Not Specified	Implicit Self-Theories
Pentzold et al., 2021	Germany, UK, US	2020 Feb-Aug	MCA	News stories (84)	Communicated	Knowledge gap	News (online major outlets)	Journalists	None
Petersen et al., 2021	Denmark, US	2020 Feb-Mar & Oct	E ^{M,P}	US (N = 6914) DK (N = 6877)	Communicated	Knowledge gap	Public health messages	Not Specified	None
Post et al., 2021	Germany	2020 Apr	CS	Gen pop. (N = 1,513)	Communicated	Knowledge gap	News	Not Applicable	None
Prettner et al., 2021	Netherlands	2020 Mar-May	MCA	Press meetings (N = 26), Tweets (N = 200)	Communicated	Knowledge gap	Press meetings, social media	Politicians, Internet/Social Media	None
Rafkin et al., 2021	US	2020 Apr	E	Gen pop. (N = 1,900)	Communicated	Knowledge gap	Govt public statements	Politicians	Bayesian Updating Framework
Simonovic & Taber, 2022	US	2020 Mar-Apr	E ^P	Student (N = 150), Gen pop. (N = 299)	Communicated	Knowledge gap	Public health messages	Not Specified	Competence Hypothesis
Tandoc & Lee, 2020	Singapore	2020 Feb	FG	Student (N = 89)	Experienced	Knowledge gap & emotional state	Social media	Lay Individuals, Internet/Social Media	URT
Wegwarth et al., 2020	Germany	2020 Jul	CS	Gen pop. (N = 2,011)	Communicated	Knowledge gap	Public health messages	Not Applicable	None
Xu & Sattar, 2020	China	2020 Feb	CS	Gen pop. (N = 1,537)	Experienced	Knowledge gap & emotional state	News, social media	Not Applicable	None
Yoon et al., 2021	US	2020 Apr	LS	Employees (N = 180)	Experienced	Knowledge gap & emotional state	News	Not Applicable	URT, Unnamed novel theory
Zhang et al., 2021	Canada	2020 Apr-May	FG	Gen pop. (N = 47)	Experienced	Knowledge gap	Public health messages	Not Applicable	None
Zhao & Liu, 2021	China	2020 Feb	CS	Gen pop. (N = 1,946)	Experienced	Knowledge gap	Various channels	Not Applicable	PRISM, PRIA
Zhou et al., 2021	China	2020 Jan-Mar	MCA	Weibo posts (N = 12,101)	Communicated	Knowledge gap	Social media	Internet/Social Media	None

Notes. A total of 39 empirical papers were included.

Study type is coded as follows: CS = Cross-sectional survey, E = Experiment, FG = Focus group, LS = Longitudinal survey (or data gathered at multiple timepoints), M = Meta-analysis, MCA = Media content analysis.

Sample size reflects total combined for multiple studies, except where studies used different sample types or nationalities.

^M = multiple nonidentical studies

^P = preregistered study

Theory use refers to explicit use of theory related to uncertainty. Abbreviated theories are: UMT = Uncertainty Management Theory, URT = Uncertainty Reduction Theory, UIT = Uncertainty in Illness Theory, TMIM = Theory of Motivated Information Management, RISP = Risk Information Seeking and Processing Model, PRISM = Planned Risk Information Seeking and Avoidance Model, PRIA = Planned Risk Information Avoidance Model

* Papers share a sample but report different sets of results so we include both papers.

* Not applicable was noted for papers that did not address a specific message or message type.

Table 2. Nonempirical Papers Included in Review.

Paper	Country of focus	Type(s) of uncertainty addressed	Conceptual treatment of uncertainty	Communication setting	Message/Info Source*	Theories discussed relevant to uncertainty
Balog-Way & McComas, 2020	International	Communicated	Knowledge gap	Public health messaging	Not Specified	None
Caniglia et al., 2021	International	Communicated	Knowledge gap	Various (e.g. social media, news, public health messaging)	Scientists	None
Caulfield et al., 2021	International	Communicated	Knowledge gap	Social media, news	Government/Public Health, Scientists, Journalists, Lay Individuals	None
Dunwoody, 2020	US	Experienced	Knowledge gap	Social media, news	Journalists, Lay Individuals	Extended Parallel Process Model
Escandón et al., 2021	Not specified	Communicated	Knowledge gap	Public health messaging, news	Not Specified	None
Fernandes, 2021	Not specified	Communicated	Knowledge gap	Public health messaging, news	Not Applicable	None
Finset et al., 2020	Not specified	Experienced	Knowledge gap & emotional state	Not specified	Not Applicable	None
Gesser-Edelsburg, 2021	Not specified	Communicated & experienced	Knowledge gap & emotional state	Social media	Government/Public Health	None
Guttman & Lev, 2021	Not specified	Communicated	Knowledge gap	Not specified	Government/Public Health, Politicians	None
Hanson et al., 2021	UK, Sweden, Germany	Communicated	Knowledge gap	Various (e.g. public health messaging, news, internet)	Government/Public Health	Resilience Framework
Ho & Huang, 2021	US	Communicated	Knowledge gap	Public health messaging	Government/Public Health	None
Hyland-Wood et al., 2021	International	Communicated & experienced	Knowledge gap	Public health messaging	Government/Public Health, Politicians	None
Krause et al., 2020	US	Not specified	Knowledge gap	Not specified	Not Applicable	None
Lasser et al., 2020	Austria	Communicated	Knowledge gap	Not specified	Not Applicable	None
Lilleker & Stoeckle, 2021	US	Communicated	Knowledge gap	Not specified	Politicians	None
Malecki et al., 2021	US	Not specified	Knowledge gap & emotional state	News, public health messaging, social media	Government/Public Health, Scientists, Journalists	None
Paek & Hove, 2020	South Korea	Communicated & experienced	Knowledge gap	Not specified	Not Applicable	URT, UMT, PIT
Pearce, 2020	UK	Communicated & experienced	Knowledge gap	Not specified	Government/Public Health, Scientists	None
Rajkhowa, 2020	Australia	Communicated & experienced	Knowledge gap & emotional state	News	Government/Public Health, Scientists, Journalists	None
Sauer et al., 2021	US	Communicated & experienced	Knowledge gap & emotional state	Public health messaging	Government/Public Health, Scientists, Politicians	None
Vraga & Jacobsen, 2020	International	Communicated & experienced	Knowledge gap	News, social media	Government/Public Health, Scientists, Journalists	None

Notes. A total of 21 nonempirical papers were included

* Not applicable was noted for papers that did not address a specific message or message type.

Theory use refers to explicit mention of theory related to uncertainty. Abbreviated theories are: UMT = Uncertainty Management Theory, URT = Uncertainty Reduction Theory, PIT = Problematic Integration Theory

communication with the goal of behavior change toward prevention behaviors such as masking and vaccination, and more emphasis on communication to maintain trust in public health officials and the scientific community. Most papers addressed communication from a range of sources (e.g. government and public health officials, politicians, scientists, and journalists), while one paper focused on communication from scientists and one from politicians. For some papers, no communication source was specified or source was not applicable.

Treatment of the Concept of Uncertainty (RQ2)

Empirical papers

Roughly half of empirical papers ($N=21$) addressed only communicated uncertainty, while 15 addressed only experienced uncertainty. A small subset of papers ($N=3$) examined both types of uncertainty, describing features of uncertainty communication as well as individual interpretations of uncertainty (e.g. Kerr et al., 2021). The majority of papers ($N=30$) treated uncertainty solely as a state of lacking knowledge, where information about risks, benefits or the future is not known. Two papers described uncertainty solely as a negative emotional or psychological state akin to anxiety (Li & Zheng, 2022; Logar et al., 2022), while several ($N=7$) referred to uncertainty as having both cognitive and affective aspects and examined these either separately or with a combined measure or message.

For studies investigating experienced uncertainty, this construct was sometimes termed ‘information discrepancy’ or ‘information sufficiency’ and measured by calculating the difference between measures of participants’ current and desired levels of knowledge (e.g. Ahn et al., 2021; Crowley et al., 2021; Zhao & Liu, 2021). Other studies used perceived uncertainty scales that asked participants how uncertain they felt, or how uncertain the state of knowledge seemed to be, regarding a variety of COVID-19 topics (e.g. Yoon et al., 2021). Uncertainty was also operationalized as a metacognition of risk perception (i.e. as level of confidence in one’s risk assessment; Huang & Yang, 2020) and as difficulty in determining the authenticity of online COVID-19 information (i.e. ‘information uncertainty’; Lin et al., 2020). Operationalizations with questionable validity included representing uncertainty as a high volume of Google searches for ‘coronavirus’ (Logar et al., 2022) and as a cluster of variables that included perceived risk, ‘social cognition of the virus,’ and whether people thought the government appropriately handled the crisis (Xu & Sattar, 2020, p. 249). Some papers also treated uncertainty and risk interchangeably. Elsewhere, scholars specifically noted that while uncertainty is inherent in risk (Krause et al., 2020), these concepts are distinct and not interchangeable (Dunwoody, 2020; Lilleker & Stoeckle, 2021).

Studies examining the communication of uncertainty operationalized this in vastly different ways. Some used lexical hedges such as ‘could’ or ‘might’ to represent uncertainty (e.g. Blom et al., 2021; Janssen et al., 2021; Müller et al., 2021). Others operationalized it as explicit statements that information is lacking; for instance, conveying that evidence is preliminary (e.g. Fleerackers et al., 2021) or that epidemiological models inherently contain uncertainty (e.g. Kreps & Kriner, 2020). Müller et al. (2021) used a corpus linguistics analysis to identify a vast range of ways uncertainty was communicated in newspapers. In other variations, Chen et al. (2021) operationalized ‘outcome uncertainty’ as conveying low probability of a positive outcome (i.e. 20% effectiveness of the vaccine compared to 80%), and Park and Shapiro (2021) operationalized the concept as uncertainty about whether the crisis will be temporary or permanent. In a content analysis of news frames, there was no description of how the uncertainty frame was operationalized (Ngai et al., 2020).

Authors’ labeling of uncertainty message features varied considerably. For example, when comparing ‘low’ and ‘high’ uncertainty, some papers used the term ‘low uncertainty’ to describe messages of *certainty* (e.g. Kelp et al., 2021), while others used this term to describe messages containing a small number of hedged or uncertain statements (e.g. Janssen et al., 2021), which is a more common approach (Jensen, 2008).

Nonempirical papers

Roughly half ($N = 10$) of nonempirical papers offered perspectives solely on the communication of uncertainty, while only two papers focused solely on experienced uncertainty. Several papers ($N = 7$) provided commentary and perspectives related to both communicated and experienced uncertainty. In two papers it was unclear whether the focus was communicated or experienced uncertainty. The majority of nonempirical papers ($N = 16$) treated uncertainty as a lack of knowledge, while five treated it as both a knowledge gap and affective state.

Use of Theoretical Frameworks (RQ3)

We present details of referenced theories in [Tables 1](#) and [2](#) and describe the most commonly used theories below, focusing first on use of theory in empirical papers.

Overall, slightly less than half of empirical papers ($N = 18$ of 39) mentioned at least one theory related to their examination of uncertainty. The remaining 21 made no mention of a specific uncertainty-related theory. Theories were explicitly used in all longitudinal surveys ($N = 3$ of 3) and roughly half of cross-sectional ($N = 5$ of 9), experimental ($N = 6$ of 13), and focus group ($N = 1$ of 2) studies. Only one media content analysis ($N = 1$ of 11) was guided by a theory (Blom et al., 2021), but many of these analyses were descriptive rather than explanatory in nature and instead used a variety of analytic frameworks not counted as meeting our definition of theory. Notably, authors using more robust study methods, such as large sample sizes, multiple studies, and preregistration, were less likely to report using theory to guide their examination of uncertainty.

Risk information seeking and processing models

The most commonly referenced framework was the Risk Information Seeking and Processing model ($N = 5$). This theoretical model posits that several factors drive individuals to seek information when facing a risk, including affective responses (e.g. experiencing ‘worry, anger, and uncertainty’), which influence information insufficiency (i.e. experiencing uncertainty as a knowledge gap; Griffin et al., 1999, p. S236). While the meta-analysis (Chu et al., 2022) only mentioned this model to discuss the landscape of uncertainty scholarship more broadly, the remaining papers explicitly used it to guide research questions, hypotheses, selection of study variables, and interpretation of results. Of these, two studies used extended versions of the model: Li and Zheng (2022) borrowed attitudes towards behavior and behavioral intentions from the Theory of Planned Behavior and incorporated them into the Risk Information Seeking and Processing model, whereas Huang and Yang (2020) tested an existing extended version of the model incorporating experienced uncertainty as a metacognition.

Information insufficiency was examined in three studies that tested the Risk Information Seeking and Processing model. This variable was treated similarly conceptually and operationally across studies, but findings differed. While Ahn et al. (2021) found that trust in government (considered a precursor to the affective responses mentioned above) did predict information seeking, information insufficiency did not mediate this relationship. Moreover, in contrast to the model’s predictions, information insufficiency led to information avoidance. Li and Zheng (2022), however, found a significant relationship between information insufficiency and online information seeking during COVID-19. While this was in line with model predictions, they did not find a significant relationship between information insufficiency and affective responses (Li & Zheng, 2022). Kim et al. (2020) used the model to examine the effects of misinformation during the pandemic, finding that individuals who encountered misinformation had *decreased* information insufficiency and engaged in more heuristic processing and information avoidance.

A sixth paper (Zhao & Liu, 2021) used two formal adaptations of the Risk Information Seeking and Processing model—the Planned Risk Information Avoidance model and Planned Risk Information

Seeking model—to predict that information insufficiency would lead directly to *either* information seeking or information avoidance. Results supported neither, as all relationships were nonsignificant.

In all, this collection of results may suggest that adaptations of the Risk Information Seeking and Processing model and related models are needed for the study of uncertainty in contexts like COVID-19. Further, Kim et al. (2020) noted that conclusions about causal relationships among misinformation exposure, information insufficiency, and information seeking cannot be made with cross-sectional data. A majority of studies examining information seeking in our review used a cross-sectional survey design, leading us to join Kim et al. (2020) in calling for experimental and longitudinal designs to probe the impact of misinformation and other types of messaging on experienced uncertainty and information seeking processes.

Uncertainty management theories

The second most commonly referenced theory was Uncertainty Reduction Theory ($N = 4$), followed by Uncertainty Management Theory ($N = 3$). Uncertainty Reduction Theory posits that people manage uncertainty by trying to reduce it (that is, by seeking more information; Berger & Calabrese, 1975), while Uncertainty Management Theory posits that people may want to reduce or maintain uncertainty depending on their goals and therefore may seek or avoid information (Brashers, 2001). In our review, seven papers explicitly relied on one of these theories of uncertainty management to guide their research questions and hypotheses. Of these seven papers, four also used one of these to interpret study results, while three only made brief references to one or both theoretical frameworks. These studies assessed individuals' strategies for managing uncertainty during the pandemic, focusing on information seeking (Huang & Yang, 2020; Tandoc & Lee, 2020), information avoidance (Tandoc & Lee, 2020), or the impact of these uncertainty management strategies on individuals' perceptions and behavior during the pandemic (Huang & Yang, 2020; Oldeweme et al., 2021; Yoon et al., 2021). Across studies, key variables in the Uncertainty Reduction Theory and Uncertainty Management Theory frameworks, including experienced uncertainty and information seeking, were operationalized in vastly different ways. Further, these theories served more as loose frameworks through which to understand audience responses rather than to create testable predictions about how audiences would respond under given circumstances.

Study findings pointed to potential gaps within these theoretical frameworks. Huang and Yang (2020) found support for an extended version of Uncertainty Management Theory that incorporates risk perceptions, arguing that (experienced) uncertainty is a reflection of individuals' confidence in their own risk perceptions. Their extended Uncertainty Management Theory model was a better fit to their data and accounted for more variance in information seeking than their extended Risk Information Seeking and Processing model. The researchers argued that with the addition of risk perceptions, Uncertainty Management Theory offers a more generalizable and comprehensive framework in the context of an ongoing crisis related to public health (Huang & Yang, 2020). Other authors also raised critiques of these oft-used frameworks. For instance, the premise of Yoon et al. (2021) was to demonstrate Uncertainty Reduction Theory's lack of utility in a pandemic context. Their findings showed that individuals' news consumption (i.e. information seeking) exacerbated rather than reduced their uncertainty during COVID-19, leading the researchers to conclude that Uncertainty Reduction Theory's basic propositions do not hold up in a rapidly evolving pandemic context (Yoon et al., 2021). Although Uncertainty Reduction Theory does not stipulate that uncertainty reduction attempts should always be successful, it is the case that information seeking as an uncertainty reduction strategy has been challenging during COVID-19, when there often hasn't been more information available to allow individuals to close the knowledge gap.

Notably, risk information seeking and processing theories were not applied in any experimental studies in this review, and uncertainty management theories were applied in only one (Huang & Liu, 2021, in conjunction with Prospect Theory and Theory of Planned Behavior). This is perhaps not surprising, as these theoretical frameworks focus on effects of experienced uncertainty but do not incorporate postulates about how these effects relate to features of communicated messages.

Prospect theory

Two studies tested loss/gain framing based on tenets of Prospect Theory, which holds that people are motivated to avoid loss in situations of uncertainty (Kahneman & Tversky, 1979). Chen et al. (2021) tested whether pairing messages conveying certain or uncertain vaccine efficacy with a gain or loss frame about vaccination consequences (i.e. the pros/cons of getting/not getting vaccinated) would influence vaccine intentions and attitudes for members of the Chinese public. Similarly, Huang and Liu (2021) tested gain versus loss framing of vaccine consequences alongside a priming task designed to heighten uncertainty to examine the impacts on vaccine beliefs and intentions. While Chen et al. (2021) did not find participants to be more motivated by the loss frame (there was no impact of any frame), Huang and Liu (2021) found loss frames were more effective in those with heightened psychological uncertainty, whereas gain frames were more effective for participants with low psychological uncertainty.

As the findings of Chen et al. (2021) were inconsistent with the propositions of Prospect Theory (that is, loss frames were not more effective for uncertain vaccine messages), the scholars noted that this theoretical framework may be limited in terms of its explanatory power, particularly for the unusual and unprecedented context of COVID-19. Similar to the arguments set forth by Yoon et al. (2021) about Uncertainty Reduction Theory, Chen et al. (2021) suggested that Prospect Theory and other existing theories may not be well suited for examining responses to uncertainty in the pandemic context, which is an assessment that we concur with (see Discussion).

Other, novel, and no theories

Other theories referenced in empirical papers included the Competence Hypothesis ($N = 2$), Theory of Motivated Information Management ($N = 1$), and Uncertainty in Illness Theory ($N = 1$). The Competence Hypothesis, which holds that people dislike uncertainty because it lowers their perceived competence, was mentioned in two paper introductions to guide the hypothesis that framing scientific uncertainty as normal should reduce ambiguity aversion (Han et al., 2021; Simonovic & Taber, 2022). The Theory of Motivated Information Management was explicitly tested and expanded, as Crowley et al. (2021) sought to go beyond examining information seeking as the outcome by testing its relationship with COVID-19 precautionary behaviors. Counter to the theory's predictions, they found that feeling anxiety about lack of knowledge led to information seeking rather than avoidance, and seeking information, in turn, was associated with precautionary behaviors. Uncertainty in Illness Theory (Mishel, 1990), which suggests that people can appraise uncertainty as a danger or an opportunity, was mentioned only once, to support an assertion that uncertainty does not always increase information seeking (Huang & Yang, 2020).

Two studies introduced new theoretical frameworks to guide their examinations of uncertainty. Lu et al. (2021) developed a novel framework to examine the relationship between uncertainty and susceptibility to misinformation (Lu et al., 2021). Their findings supported their proposed framework, demonstrating that ambiguity related to preliminary or tentative evidence can potentially contribute to the spread of misinformation on social media. Blom et al. (2021) developed a new theoretical model to guide their content analysis of speculation about COVID-19 in interactions between journalists and experts in the media.

A little over half ($N = 21$ out of 39) of the empirical studies included in this review made no reference to a specific theory in relation to their examination of uncertainty. Similarly, in the meta-analysis included in our review, Chu et al. (2022) found that only two studies applied a specific theory to examine uncertainty-related responses and the use of media during COVID-19, and the authors called for more theorizing in this context. We note that several empirical papers made vague reference to specific theories in their introduction, and while we include these as theory use in Table 1, it was difficult to determine whether the theories guided their research in any way.

Nonempirical papers and (lack of) theory

Three nonempirical papers referenced specific theories related to their discussion of uncertainty. Hanson et al. (2021) used a resilience framework highlighting the ability to anticipate, cope with, and communicate uncertainties as part of a government's resiliency in managing crises such as COVID-19. Dunwoody (2020) referred to the Extended Parallel Process Model to explain that uncertainty can lead people to avoid information as a fear control mechanism. Paek and Hove (2020) mentioned Uncertainty Management Theory, Uncertainty Reduction Theory, and Problematic Integration Theory in order to argue for the necessity of developing new theories.

The vast majority of nonempirical papers ($N = 17$) did not explicitly reference a specific theory related to their examination of uncertainty. A number of papers referenced unnamed 'frameworks' (e.g. Malecki et al., 2021) or described frameworks that were sets of principles or guidelines (e.g. Fernandes, 2021; Lilleker & Stoeckle, 2021; Sauer et al., 2021). Many nonempirical papers offered guidance for communicating about uncertainty to the public without grounding their recommendations in a specific theory. Others offered critiques of uncertainty communication by journalists, scientists, government officials, and/or public health entities during the pandemic, but again, these critiques were not described as being based on any specific theory about public responses to uncertainty communication.

Uncertainty Communication Trends and Effects (RQ4)

Although we present a high-level summary of outcomes reported in the literature, the variability in conceptualization and operationalization of uncertainty limits concrete takeaways about the effects of specific types of uncertainty communication. Therefore, these conclusions should be taken as preliminary.

Narrative reviews, rhetorical critiques, and commentaries

Nonempirical papers—primarily in the form of reviews, rhetorical analyses, and commentaries—offered critiques of or provided recommendations for COVID-19 public communication. Many authors argued that uncertainty should have been better communicated or acknowledged during the early stages of the pandemic (e.g. Hanson et al., 2021; Rajkhowa, 2020; Sauer et al., 2021). For instance, comparing early government response to COVID-19 in Germany, Sweden, and the UK, Hanson et al. (2021) suggested that only Germany's government explicitly communicated uncertainty about how best to manage the pandemic in light of limited evidence. The authors argued this transparency made it easier for the country to adapt its messaging over time, in contrast to the UK, which presented early decision making as 'following the science' without acknowledging tentativeness of the evidence. Nonetheless, the authors concluded that all three governments 'lost trust of their populations during the epidemic due to a mix of communication and transparency failures' (p. 1). Lilleker and Stoeckle (2021) offered a similar analysis of the UK government's communication, concluding that 'attempts to offer certainty despite a situation characterised by volatility, uncertainty, complexity and ambiguity led to numerous U-turns that seriously damaged their credibility' (p. 1). Several papers described former U.S. president Donald Trump's flagrant downplaying of various uncertainties throughout the pandemic (e.g. Balog-Way & McComas, 2020; Caulfield et al., 2021; Sauer et al., 2021).

Many authors emphasized that uncertainty should be conveyed more transparently in future pandemic messaging (e.g. Caulfield et al., 2021; Escandón et al., 2021; Finset et al., 2020; Paek & Hove, 2020; Vraga & Jacobsen, 2020), while a few described the need to strike a balance between conveying too little and too much uncertainty (Balog-Way & McComas, 2020; Lasser, 2020). Authors argued that being transparent about unknowns will enhance public trust in government entities and health communicators (Caulfield et al., 2021; Ho & Huang, 2021; Hyland-Wood et al., 2021; Malecki et al., 2021) and help citizens to better manage uncertainty by fostering realistic expectations (Finset

et al., 2020; Gesser-Edelsburg, 2021; Rajkhowa, 2020). Some papers described challenges associated with communicating uncertainty, such as the rapidly evolving nature of the pandemic (e.g. Balog-Way & McComas, 2020; Krause et al., 2020), the rise of misinformation (e.g. Dunwoody, 2020; Escandón et al., 2021; Fernandes, 2021; Krause et al., 2020), and the potential for causing confusion among audiences (e.g. Balog-Way & McComas, 2020; Guttman & Lev, 2021; Vraga & Jacobsen, 2020). Others gave specific recommendations for how to frame uncertainty, such as by providing context about why scientific disagreements occur and explaining what actions are being taken to reduce uncertainty (Paek & Hove, 2020) and by helping the public to understand that decisions are based on the current best available evidence, which will inevitably evolve during a pandemic (Caulfield et al., 2021; Ho & Huang, 2021). Rajkhowa (2020) cautioned that journalists and commentators should take care, when highlighting information gaps or inconsistencies in public health guidance, to contextualize these limitations in order to avoid deleterious effects on public health efforts, including harming public trust in health advice from the government.

Media content analyses

Among empirical analyses of media communication, much attention was paid to the ways that journalists and public health experts framed and explained uncertainties. Among news coverage of COVID-19 in Canada, uncertainty emerged as a ‘master frame,’ with additional framing strategies such as ‘dueling experts’ and ‘mixed messaging’ indicating journalists’ critiques of public health guidelines and communication (Capurro et al., 2021). A content analysis of 15 major digital media outlets found that only half of stories covering COVID-19-related preprint research framed the science as uncertain (i.e. noting that the study was a preprint, unreviewed, preliminary, or in need of verification; Fleerackers et al., 2021). Examining the Dutch government’s treatment of uncertainty in official press conferences and public response in Twitter posts, Prettner et al. (2021) found that failure to acknowledge consensus uncertainty among experts and uncertainty in the science resulted in a mass of tweets criticizing the government and expert communication.

Some papers compared the differences in communication strategies between various countries (e.g. Müller et al., 2021; Pentzold et al., 2021), including notes on how each country’s media responded to public health discourses and guidelines. The importance of the relationship between journalists and experts was also examined, with authors noting that both parties should function as checks and balances on each other when raising speculative questions or assertions (Blom et al., 2021). Pentzold et al. (2021) observed journalists as ‘knowledge brokers’ tasked with assimilating and comparing multiple sources of epidemiological data in order to offer data visualizations and data-driven forecasts to help the public and policymakers make sense of uncertainty about the course of the pandemic and the ambiguous messaging environment.

Lambrecht (2021) analyzed CDC press releases from the first months of the pandemic and observed that risk levels were communicated with unwarranted certainty; for example, pronouncements of ‘low risk’ for some population groups were conveyed without appropriate tentativeness despite the early stage of the evidence. The author argued that conveying uncertainty about these risk levels could have influenced a more appropriate level of caution among the U.S. public early in the pandemic.

Effects of communicated or perceived uncertainty

Among experimental studies, neutral or unfavorable effects of *communicated* uncertainty were more common than favorable effects. In experimental, cross-sectional, and focus group studies, *experienced* uncertainty similarly had mostly neutral or undesirable effects on outcomes such as trust and emotional coping. We highlight predominant trends below.

Trust in science and in expert guidance. Several studies found that communicating uncertainty, particularly about the science or about guidelines, reduced trust and related variables such as

perceived credibility and expertise (e.g. Gretton et al., 2021; Kreps & Kriner, 2020; Rafkin et al., 2021; Simonovic & Taber, 2022). For example, Simonovic and Taber (2022) found that conveying unknowns about the nature of COVID-19 (as opposed to conveying only what scientists know) generated lower trust in public health officials in a US adult sample (but not a college student sample). Across multiple experiments, Kreps and Kriner (2020) found that acknowledging and explaining uncertainty in epidemiological models generally decreased public trust and support for science. Conveying changes in guidance also produced lower trust in several studies. Rafkin et al. (2021) found that messaging highlighting changes in COVID-19 guidance hurt perceived credibility of the government among US adults. Similarly, Gretton et al. (2021) found that describing COVID-19 guidance as having changed, rather than as being consistent, led both U.S. and Canadian participants to perceive scientists and public health authorities as less credible. Across multiple experiments with U.S. and Danish participants, Petersen et al. (2021) found that 'vague' communication about a fictional COVID-19 vaccine (i.e. a message acknowledging that the vaccine was likely effective, but there was insufficient information to compare the vaccine against the common flu vaccine) decreased vaccine acceptance compared to messages that conveyed positive or neutral information about the vaccine with greater certainty.

In a qualitative study with Canadian adults, Zhang et al. (2021) found that experienced uncertainty, caused by inconsistencies and ambiguity in public health messaging about face masks, fostered a sense of participant mistrust in public health entities.

Other studies found no impact of messages conveying uncertainty. For example, in a study with German adults, Janssen et al. (2021) found that communicating uncertain efficacy of wearing masks to prevent the spread of COVID-19 had no impact on perceived trustworthiness or expertise of the communicator. Similarly, Kelp et al. (2021) found that conveying certainty or uncertainty about vaccine efficacy did not influence U.S. students' trust in the vaccine information or its source.

In one study, Oldeweme et al. (2021) found that uncertainty reduction measures, such as providing transparent and accurate information about a government-supported contact tracing app, were associated with greater trust in the app, and this trust was related to actual adoption of the app. This appears to be a positive effect of closing people's knowledge gaps, rather than of transparent communication about uncertainty. No study reported positive effects of communicating or experiencing uncertainty on trust in information or sources.

Emotional coping, information seeking, and information preferences. Several studies examined how participants managed uncertainty in terms of emotional and information related responses. Undesirable outcomes of experienced or communicated uncertainty were more common. For example, Yoon et al. (2021) found that news consumption led employees to feel greater uncertainty, which in turn led to less productivity and creativity in the workplace. Han et al. (2021) found that communicating scientific uncertainty about the COVID-19 pandemic increased 'ambiguity averse' responses such as worry and perceived likelihood of getting COVID-19, which did not increase intentions toward risk-reducing behaviors or vaccination. Simonovic and Taber (2022) observed that messages conveying ambiguity about COVID-19 produced lower self-efficacy (i.e. confidence in one's ability to prevent COVID-19 infection) than messages conveying only certain or known information, but only for adults, not college students.

Crowley et al. (2021) found that experienced uncertainty in the form of a knowledge gap was associated with anxiety about the uncertainty and worsened communication efficacy and coping efficacy, but increased cognitive reappraisal, information seeking, and precautionary behaviors. However, Huang and Yang (2020) found that experiencing 'severity uncertainty' led to lower information seeking. Other studies described in the theory section found mixed results, with experienced uncertainty associating with information seeking in some studies and avoidance in others. In one study, conveying ambiguity about the duration of the pandemic facilitated some participants' ability to adjust (Park & Shapiro, 2021).

Two cross-sectional survey studies assessed information preferences regarding uncertainty communication in German samples. Post et al. (2021) found that those with a need for definite

information and a view of science as unchanging preferred concrete information about COVID-19, while those with a desire to form their own opinions preferred journalists to challenge policy and scientific guidelines, and rejected the idea that policy should be determined by scientists. Wegwarth et al. (2020) found that citizens indicated a desire for disclosure of scientific uncertainty by reporting that they would be more motivated to adhere to recommended guidelines when these were presented with fuller uncertainty disclosure.

Attitudes and intentions toward precautionary behaviors. Many studies found no impact of communicating uncertainty on attitudes and intentions toward precautionary COVID-19 behaviors. Communicating uncertainty about vaccine efficacy had no impact on vaccination attitudes and intentions in a Chinese sample (Chen et al., 2021). Several studies with US participants also found that conveying scientific uncertainty about the COVID-19 vaccine, or about COVID-19 in general, had no impact on US participants' intentions to perform risk reducing behaviors or get vaccinated (Han et al., 2021; Kerr et al., 2021; Simonovic & Taber, 2022). Daoust and Bastien (2021) found no treatment effect of conveying uncertainty with confidence intervals in people's support for preventative measures. These studies generally found no differences between messages of certainty and uncertainty on attitudes and intentions, which could, in a sense, be interpreted as a favorable finding.

Effects were negative in some studies, however. Whereas Kelp et al. (2021) found no impact on trust, conveying uncertainty (vs. certainty) about the COVID-19 vaccine led to worse perceptions of vaccine safety, efficacy, and necessity. It also generated lower intention to get vaccinated among the vaccine hesitant. Gretton et al. (2021) found messaging that highlighted changes (vs. consistency) in COVID-19 guidance reduced intentions to download a contact tracing app among Canadian (but not U.S.) participants; however, this negative effect was mitigated with a forewarning, as described below.

Message Frames

A key goal of this research is to understand how to effectively communicate uncertainty. Therefore, we summarize results of experiments testing specific message frames below.

Forewarning and normalizing frames

Studies found mixed evidence for the utility of providing audiences with information that *normalizes* the uncertain nature of science or *forewarns* that guidance may change, which was expected to mitigate negative outcomes of uncertainty disclosure. Han et al. (2021, p. 3) found that 'ambiguity-averse' psychological responses to uncertainty disclosure were neutralized when the disclosure was paired with 'language emphasizing the unknowability of these various aspects of COVID-19 and the expected nature of scientific uncertainty.' While this frame neutralized participants' worry about COVID-19 and perceived likelihood of contracting it, compared to the standard disclosure, it did not increase intentions to adhere to recommended precautionary behaviors. Whether this is a positive or negative effect in terms of inspiring participants to take appropriate precautions is unclear. Across two studies, Simonovic and Taber (2022) found that adding a normalizing frame produced minimal differences compared to the standard ambiguous message (conveying what is unknown about COVID-19) and the control message (conveying only what is known). It did not improve participants' self-efficacy, trust in public health officials or doctors, or vaccine intentions. The authors suggested their manipulation may have been too subtle to generate an effect.

A set of experiments found that preceding a message highlighting changes in COVID-19 guidance with a forewarning, which informed the audience that updates to public health guidelines are normal given the evolving science, neutralized the undesirable effects on opinions of scientists and public health officials and precautionary behavior intentions (Gretton et al., 2021).

Loss/gain framing

Two studies examined the impact of loss/gain framing on public reactions to uncertainty. Huang and Liu (2021) found that loss/gain framing interacted with participants' levels of uncertainty to influence their vaccine beliefs and intentions. When U.S. participants were in a state of high uncertainty, messages emphasizing a loss (i.e. risking your health and increasing your chances of getting infected with COVID-19) produced more beneficial vaccine beliefs and intentions, while participants in a low uncertainty state responded more favorably to messages emphasizing a gain (i.e. reducing your risk of infection and serious illness). However, when Chen et al. (2021) conveyed uncertain information about vaccines in a Chinese sample, whether the uncertainty was gain- or loss-framed made no difference in vaccination intentions.

Uncertainty presentation formats

Several studies investigated the impact of different numerical uncertainty formats. Chen et al. (2021) compared responses to number formats, presenting probability of effectiveness of a COVID-19 vaccine as either a frequency (e.g. 20 out of 100) or a percentage (e.g. 20%). Their study found no significant difference between the two presentations, even when numeracy skills were tested as a potential moderator. In other studies, using confidence intervals to represent uncertainty surrounding projections (in place of using point estimates alone) had no significant impact on support for COVID-19 infection models (Kreps & Kriner, 2020) or on perceived reliability of data or support for public health measures (Daoust & Bastien, 2021). Participants in one survey preferred an uncertainty message communicated with both numerical probabilities and lexical hedges (e.g. unlikely, probably; Wegwarth et al., 2020).

Discussion

Uncertainty has been a central theme of the COVID-19 pandemic. Since the pandemic's onset, scholars from communication and related disciplines have sought to understand how the many facets of uncertainty have been communicated to the public, as well as how communicated and experienced uncertainty have influenced public trust, information seeking, coping, and willingness to perform precautionary measures to slow the spread of the virus. In this scoping review, we summarized communication insights published between January 2020 and February 2022. In line with the special issue's theme, we used this review to highlight strengths of the field's theories and concepts for examining uncertainty communication, as well as to identify areas where further research and theorizing are needed to adequately address COVID-19 and future high-uncertainty crises.

Characteristics of Studies and Nonempirical Papers

Approximately two-thirds of papers included in this review were empirical and one-third were nonempirical. Nearly all empirical studies collected data during the initial months of the pandemic. This may be due to the nature of the academic publishing process, with studies conducted at later time-points not yet published at the time of our review. Nonetheless, time period is an important factor to keep in mind when evaluating results in this context.

Studies used a range of methodologies, with experiments, media content analyses, and cross-sectional surveys being the most common. Very few papers presented qualitative participant data. While investigations spanned a breadth of countries, there was a concentration of studies focused on the US and China. Low research quality has been of particular concern during the COVID-19 pandemic (Quinn et al., 2021). In this review, use of multiple studies and preregistration of study plans were uncommon. However, few studies relied on student samples, and sample size ranged from

under 100 to several thousand, leading us to conclude that low rigor characterized only some rather than a majority of the research.

While some media content analyses captured communication patterns over time, only three studies collected data from participants at multiple time points, and none of these were testing message effects. Given the frequently-voiced concern that the effects of downplaying uncertainty may be positive in the short term but detrimental in the long term (e.g. Caulfield et al., 2021; Gretton et al., 2021; Kreps & Kriner, 2020; Saitz & Schwitzer, 2020), measuring audience reactions to communication of uncertainty over time will be essential to test the veracity of these claims. We return to this point later in the Discussion.

A range of public communication settings were considered in empirical and nonempirical papers, including many forms of news media, social media, and government communication. Among papers that focused on specific communication sources, these included government and public health officials, politicians, journalists, and scientists, with one paper mentioning the role of doctors in communicating to the public during the crisis (Finset et al., 2020).

The topic of uncertainty was often general or multifaceted. When specific COVID-19 topics were examined, these often related to scientific uncertainty, such as uncertainty about the nature of the SARS-CoV-2 virus, the accuracy of epidemiological forecasts, or the efficacy of vaccines and other precautionary behaviors. Another common topic was uncertainty caused by inconsistent messaging or shifting public health guidelines. Despite the potential for public audiences to respond differently to uncertainty depending on what is uncertain and who communicates it, many papers were either inexplicit about these details or combined multiple uncertainty topics or sources into a single message or measure, making it difficult to reliably code and compare papers along these dimensions.

Treatment of the Concept of Uncertainty

Experienced uncertainty was most often treated as a lack of knowledge or as having both cognitive and affective components (i.e. a knowledge gap and a negative emotional response). Some papers described or measured people's anxiety *about* uncertainty, while a few treated uncertainty as synonymous with anxiety, worry, or panic. In empirical papers examining information seeking/avoidance as an uncertainty management strategy, the term 'information insufficiency' was used to represent either a perceived knowledge gap or the extent to which a person wants to close a perceived knowledge gap (that is, how uncertain do they want to be). A few studies examined metacognitions of uncertainty, such as how uncertain people were about their lack of knowledge. In empirical papers, operationalizations of experienced uncertainty varied considerably and, as previously described, some had questionable validity.

Communicated uncertainty was primarily treated as conveying unknowns in both empirical and nonempirical papers. As noted above, some authors examined messaging about general or multi-layered pandemic uncertainty, while others focused on communicating uncertainty about specific aspects of COVID-19. While many typologies exist for classifying health and science related uncertainties in order to facilitate theory building and systematic comparison (e.g. Gustafson & Rice, 2020; Han et al., 2011; Ratcliff, 2021), most papers in our review did not provide enough information about specific type(s) of communicated uncertainty for us to classify COVID-19 uncertainty messages using these typologies. Experimental messages tended to be short, and few studies used similar message manipulations or coding frameworks, limiting the possibility for synthesizing results.

In sum, while we were generally able to categorize papers' treatment of uncertainty according to our coding scheme, there was considerable variation in how uncertainty was defined and measured. Off-the-cuff measurement and manipulation of uncertainty were common in empirical studies. The difficulty in clearly defining uncertainty and 'pinning it down' for the purpose of analysis has certainly been acknowledged (e.g. Anderson et al., 2019; Bradac, 2001; Han et al., 2011). Nonetheless, creating well-developed, validated measures and coding frameworks for capturing experienced and

communicated uncertainty is needed to build a coherent and useful body of knowledge in this area. The potential for the term ‘uncertainty’ to mean so many things under the broad umbrella of unknown information also underscores the importance of making its particular meaning(s) and operationalizations clear in a given paper.

Lastly, we question whether it is appropriate to use the term ‘uncertainty’ to refer to an affective state, especially a negative one. At a high level, uncertainty is generally agreed upon to be a cognitive state characterized by lack of information (Bradac, 2001; National Library of Medicine, n.d.[a]). While experienced uncertainty may be inextricably linked with emotion, it is not typically defined as an affective state (Anderson et al., 2019; Bradac, 2001). Moreover, scholars acknowledge that emotions associated with uncertainty are not always negative: uncertainty about a bad outcome may be preferable to *certainty* of a bad outcome, and therefore people may prefer uncertainty as it allows them to feel relief or hope, for example (Anderson et al., 2019; Brashers, 2001). Given these points, treating uncertainty and related affective responses as distinct, such as by referring to ‘anxiety about uncertainty,’ seems preferable (e.g. when testing the Risk Information Seeking and Processing model; Griffin et al., 1999).

Theory Use

In all, we observed a lack of theory-driven scholarship addressing COVID-19 uncertainty and public communication related processes, especially for testing the effects of communicated (rather than experienced) uncertainty and for undergirding recommendations for communication. Only half of empirical papers included explicit use of a theoretical framework to analyze communication of uncertainty and audience responses. Among papers that did reference specific theories, several only mentioned the theory briefly in their introductions. Many other papers made vague references to ‘frameworks’ or ‘communication theories.’ Limited application of theory was similarly observed by Chu et al. (2022), whose meta-analysis examined studies of media use and uncertainty-related responses to COVID-19; the authors noted that only two of the 47 studies in their review were explicitly underpinned by a theory. In our review, nonempirical papers were especially likely to neglect theory (or neglect to mention it), with only three papers making reference to specific theories related to uncertainty.

It is possible that communication scholars simply continue to do a poor job of clearly articulating how we apply theory (DeAndrea & Holbert, 2017). Yet it is also possible that existing theories in communication are no match for uncertainty in the complicated, rapidly evolving, and multifaceted COVID-19 landscape. This possibility was acknowledged by Yoon et al. (2021) and Chen et al. (2021) when explaining why their study results were inconsistent with the theories that guided their research (Uncertainty Reduction Theory and Prospect Theory, respectively). Lilleker and Stoeckle (2021, p. 3) described the pandemic as a ‘wicked problem’ characterized by ‘radical uncertainty,’ remarking that ‘crisis and risk communication theory has not engaged with the concepts of radical uncertainty’—that is, with situations that are complex, interdependent, ambiguous, and highly unpredictable. Given the lack of theory in pre-COVID-19 risk and crisis uncertainty communication research (Liu et al., 2016; Sopory et al., 2019), it may be that *most* public crisis and risk situations are too complex for our discipline’s current uncertainty theories to address.

Gaps in our discipline’s uncertainty theorizing appear to extend beyond radically uncertain contexts, however. In commentaries, Caniglia et al. (2021) argued that we need new theoretical perspectives to guide communication that embraces and manages, rather than downplays, scientific uncertainty, while Paek and Hove (2020) argued that we need to better understand how people process uncertainty in general. Prior work similarly highlighted a lack of cognitive process models to explain how people make decisions under uncertainty, as opposed to risk (Volz & Gigerenzer, 2012).

Many of the theories used in COVID-19 uncertainty communication research were not initially developed to study uncertainty, while others were not developed for public health or

multifaceted contexts. For example, as Huang and Yang (2020) note, the Risk Information Seeking and Processing model was designed to examine how people manage risks, not uncertainty about risks, and uncertainty is not a central component of the model (Griffin et al., 1999). Other theories that were applied, such as Uncertainty Reduction Theory (Berger & Calabrese, 1975) and Theory of Motivated Information Management (Afifi & Weiner, 2004), were developed to understand how people manage uncertainty in interpersonal interactions. Prospect Theory, meanwhile, is a behavioral economics theory created to explain why people are willing to choose riskier options to avoid a loss than to obtain a gain (Kahneman & Tversky, 1979). In Prospect Theory, uncertainty is defined as risk expressed as a statistical probability, and its tenets are not applicable to most situations of real-world uncertainty (Volz & Gigerenzer, 2012). It is perhaps not surprising that attempting to apply these frameworks in the pandemic context seems to have yielded largely unfruitful results.

Overall, information seeking and uncertainty management theories had little predictive power in the studies we reviewed, which found that people managed uncertainty by seeking or avoiding information (or, in some cases, neither). Uncertainty management frameworks were often cited to suggest that uncertainty can be appraised negatively or positively and were applied to examine or explain audience reactions but not to test specific predictions about them. Further, these theories were applied only to examine the impacts of subjective uncertainty, not communicated uncertainty. This supports Bradac's (2001) criticism of Uncertainty Management Theory and other uncertainty theories, which he described as 'relatively open systems' and 'incomplete' frameworks, where the expected outcomes and mechanisms of the impact of language on perceived uncertainty remain largely unspecified. As Bradac (2001, p. 467) pointed out, 'What is spun is webs of possibilities, instead of logically compelled theorems. The theory exists as a kind of cognitive heuristic for understanding problematic cognitive-affective states.' Greater specification of these theories could allow us to do more than expect that people will use different information behaviors to manage uncertainty during public crises.

It is also the case that there is sometimes no additional information to seek during a crisis. In the early stages of the COVID-19 pandemic, information about the science and future course of the pandemic was unknown not only to citizens, but also to scientists, public health officials, and government leaders. Thus, we need formal theorizing about how public audiences manage uncertainty even when they cannot close the knowledge gap. What factors influence public attitudes, behaviors, and trust? And what is the relationship between communicated and experienced uncertainty? In this review, the authors of commentaries argued that communicators will earn public trust by acknowledging uncertainty rather than downplaying it, by contextualizing uncertainty as normal, and by forewarning that changes to evidence and protocol are likely (e.g. Caulfield et al., 2021; Hanson et al., 2021; Rajkhowa, 2020). These claims were supported by some empirical evidence showing positive effects of forewarning and normalizing statements, suggesting a promising avenue for more theorizing and continued study. Many authors also recommended that public officials speak with a unified voice and use consistent messaging in order to avoid causing confusion and loss of credibility (e.g. Finset et al., 2020; Sauer et al., 2021). Given the difficulty in achieving one voice in the marketplace of ideas, especially amidst an evolving crisis, it may also be productive to identify ways to help public audiences make sense of consensus uncertainty and manage the inevitability of experts with different viewpoints.

Trends and Effects of Communicated or Experienced Uncertainty

Content analyses found that COVID-19 uncertainty was not often appropriately conveyed or acknowledged by the government, public health officials, or journalists in the early stages of the pandemic, which was a trend that held up across countries and communication settings (Fleerackers et al., 2021; Lambrecht, 2021; Pentzold et al., 2021). Scholars also highlighted the important role

of journalists in helping the public to make sense of uncertainty during the pandemic (Dunwoody, 2020; Fleerackers et al., 2021; Pentzold et al., 2021; Rajkhowa, 2020). Studies on the impacts of experienced uncertainty found that it led individuals to either seek or avoid information, as noted above, and experienced uncertainty typically corresponded with negative psychological responses.

Several authors discussed links between uncertainty and misinformation. One study found that exposure to misinformation reduced people's experienced uncertainty (Kim et al., 2020), while another found that exposure to news, which is likely to present more accurate and realistic information, increased experienced uncertainty (Yoon et al., 2021). Further, Lu et al. (2021) found that uncertainty surrounding scientific evidence can cause individuals to produce misinformation inferred from the evidence through motivated reasoning. This set of results illustrates the potential for public audiences to be especially vulnerable to misinformation under conditions of uncertainty, as noted in commentaries (e.g. Fernandes, 2021; Guttman & Lev, 2021; Krause et al., 2020; Lu et al., 2021). Interventions that help to counter the natural tendency to prefer simple, clear explanations and messages of unwarranted certainty (Nguyen, 2021b) appear critical during a pandemic.

Although a central argument of most nonempirical papers was that transparent messages about uncertainty will promote public trust in experts and facilitate coping (e.g. Caulfield et al., 2021; Finset et al., 2020; Paek & Hove, 2020; Sauer et al., 2021), empirical results generally pointed toward neutral or unfavorable impacts of both communicated uncertainty and experienced uncertainty, aligning more closely with perspectives from Malecki et al. (2021) and Guttman and Lev (2021). Most experimental studies found limited effects of tested message features and frames. Perhaps this demonstrates that designing public messaging to effectively address uncertainty is easier said than done. We do not believe these results should be taken to mean that communicating unrealistic certainty is preferable, however. Instead, a pressing question facing communicators—and communication researchers—is how to communicate uncertainty in ways that do foster realistic expectations, earn reasonable trust in science and in authorities, and promote adherence to public health guidelines. To answer this, we need more systematic testing of an expanded range of communication features, as well as replications of these tests (Popper, 1959), ideally guided by shared operationalizations and theoretical frameworks.

Unfavorable impacts of communicating uncertainty could have emerged in empirical studies because public audiences had *already encountered* messages of certainty in the real world and, therefore, messages of uncertainty felt conflicting or violated expectations and previously earned trust. This possibility underscores the importance of attempting to examine the effects of communicating uncertainty over time, and it points to an additional gap in our current theories, which do not account for temporal effects. Whereas nonempirical essays in the current review were focused on longer-term impacts of uncertainty communication on public trust, experimental studies measured trust and other outcomes immediately after message exposure. Including a temporal perspective in this research would allow for testing and comparison of short- and long-term impacts of communicating uncertainty and provide a better picture of the impacts of transparent communication.

Limitations of Our Review

Several limitations of our approach must be kept in mind. First, the nature of our research questions, combined with the highly varied treatment of uncertainty and sometimes-vague reporting of operationalization and theory use in the literature, meant that our characterizations required a degree of subjective interpretation beyond our predefined coding scheme. Given this and the relatively small pool of papers, we used percent agreement to assess reliability. This means our observations should be taken as exploratory and should not be used to inform policy or make concrete guidelines for communication practice. Instead, we believe our review's primary contribution is in highlighting a need for more conceptually and operationally consistent research in order to produce concrete take-aways about how best to communicate uncertainty.

Second, given the challenges of analyzing theory use (Chavez-Yenter et al., 2021; DeAndrea & Holbert, 2017; Slater & Gleason, 2012), we erred on the side of coding explicit use of specific theories, meaning that nonspecific mention of theory (e.g. 'extant theory,' 'the theoretical literature,' 'theoretical frameworks') and references to broad categories of theory (e.g. 'crisis and risk communication theory,' 'framing theory,' 'behavioral economic theory') were not counted. Even though authors may have cited papers about specific theories in these instances, to attempt to count these in the current project would have been infeasible. As one way to facilitate theory building and testing in our field, we believe it would be helpful for authors to refer to specific theories whenever possible.

Third, our review included only English-language papers published in academic journals. It is the case that many of the included papers described results of studies conducted with non-English speaking samples or examined content in other languages and translated findings to English. Further, some nonempirical papers offered critiques of non-English speaking communication trends. Nonetheless, there are likely insights about uncertainty communication published in other languages which could not be included.

Finally, to fit with the special issue's theme, we limited the scope of our review to public and mass mediated communication. But we acknowledge that a rich body of scholarship has also been produced to examine COVID-19 uncertainty communication in settings such as interpersonal and healthcare contexts. Moreover, while our reviewed pool of papers included communication scholarship published in a breadth of disciplines' journals and work that spanned many subfields of the communication discipline, it is still likely, given the multifaceted nature of the concept of uncertainty, that some work referred to the concept of uncertainty using different terminology and was not captured in our literature search. Additionally, we expect the literature to grow as observations from later phases of the COVID-19 pandemic are published.

Conclusion

Contributing to this special issue on COVID-19, the media, and communication scholarship, we synthesized two years of empirical and nonempirical literature on public communication processes related to uncertainty, a concept at the forefront of the COVID-19 crisis.

While a number of important insights emerged in this literature, we found that Bradac's (2001) critique of insufficient theorizing about uncertainty and communication still applies. Overall, there was limited use of (or utility of) extant theory to guide examinations of communicated uncertainty and experienced uncertainty during the pandemic. Given the importance of theory in guiding social scientific research (DeAndrea & Holbert, 2017; Muthukrishna & Henrich, 2019), this lack of explicit reliance on established theoretical frameworks might point to a need for adjustment of existing communication theories, the development of new theories, better reporting about theory use, or perhaps all of the above. Varied and off-the-cuff operationalizations of uncertainty were also common in this literature, highlighting a need for more validated and shared approaches to measuring and manipulating uncertainty in communication research. Together these practices will help our field offer guidance for better communication during COVID-19 and future high-uncertainty crises.

We do not believe the current body of scholarship points toward specific evidence-based recommendations for communication just yet. More theory-driven research on the effects of message features is needed. Theory could, in particular, help to explain why unfavorable results of transparent communication about uncertainty have been common in COVID-19 studies, while the reverse has been true of studies in other scientific and health contexts (Jensen, 2008; Ratcliff et al., 2021; Steijaert et al., 2021; also see Gustafson & Rice, 2020). Primary sources of uncertainty during the COVID-19 pandemic were a continuously evolving evidence base and constantly changing guidance from public health authorities and government leaders (Kreps & Kriner, 2020). Potentially, this is perceived as 'consensus uncertainty,' which produces less favorable public reactions compared to other types of scientific uncertainty (Gustafson & Rice, 2020). Alternatively, it could

be that during a pandemic, individuals grow fed up with living in a constant state of uncertainty. During COVID-19, citizens grappled with a need to constantly separate fact from fiction and navigate information uncertainty amidst the ‘infodemic.’ Most people also faced personal illness uncertainty, economic uncertainty, and unknowns in many other aspects of life. In this review, we did not observe any studies that compared results of uncertainty communication between COVID-19 and non-COVID-19 topics, or across different COVID-19 topics or time periods. Instead, authors examined a single issue (e.g. vaccine uncertainty), lumped multiple forms of uncertainty together, or described uncertainty in all-encompassing terms. Most studies with participants were conducted at a single time point early in the pandemic, when uncertainty was at its peak. Comparative studies—and, ideally, theories—could help us to better understand the unique and evolving nature of uncertainty during the COVID-19 crisis, in order to determine how best to communicate or provide information in situations of such extreme and multilayered uncertainty.

Acknowledgments

We are grateful to Glen Nowak and Jakob D. Jensen for insights that shaped our research questions and coding framework. We greatly appreciate the thoughtful and constructive comments from the special issue guest editors and reviewers. Any errors are our own.

Disclosure statement

No potential conflict of interest was reported by the author(s).

ORCID

Chelsea L. Ratcliff  <http://orcid.org/0000-0002-8066-1233>

Rebekah Wicke  <http://orcid.org/0000-0003-4047-4748>

References

*Papers denoted with an asterisk are included in the review.

- Afifi, W. A., & Weiner, J. L. (2004). Toward a theory of motivated information management. *Communication Theory*, 14(2), 167–190. <https://doi.org/10.1111/j.1468-2885.2004.tb00310.x>
- *Ahn, J., Kim, H. K., Kahlor, L. A., Atkinson, L., & Noh, G.-Y. (2021). The impact of emotion and government trust on individuals’ risk information seeking and avoidance during the COVID-19 pandemic: A cross-country comparison. *Journal of Health Communication*, 26(10), 728–741. <https://doi.org/10.1080/10810730.2021.1999348>
- Anderson, E. C., Carleton, R. N., Diefenbach, M., & Han, P. K. J. (2019). The relationship between uncertainty and affect. *Frontiers in Psychology*, 10, 1–17. <https://doi.org/10.3389/fpsyg.2019.02504>
- Babrow, A. S. (1992). Communication and problematic integration: Understanding diverging probability and value, ambiguity, ambivalence, and impossibility. *Communication Theory*, 2(2), 95–130. <https://doi.org/10.1111/j.1468-2885.1992.tb00031.x>
- Babrow, A. S., Kasch, C. R., & Ford, L. A. (1998). The many meanings of uncertainty in illness: Toward a systematic accounting. *Health Communication*, 10(1), 1–23. https://doi.org/10.1207/s15327027hc1001_1
- *Balog-Way, D. H. P., & McComas, K. A. (2020). COVID-19: Reflections on trust, tradeoffs, and preparedness. *Journal of Risk Research*, 23(7–8), 838–848. <https://doi.org/10.1080/13669877.2020.1758192>
- Berger, C. R., & Calabrese, R. J. (1975). Some explorations in initial interactions and beyond: Toward a developmental theory of interpersonal communication. *Human Communication Research*, 1(2), 99–112. <https://doi.org/10.1111/j.1468-2958.1975.tb00258.x>
- *Blom, J. N., Rønlev, R., Hansen, K. R., & Ljungdahl, A. K. (2021). The potentials and pitfalls of interactional speculations by journalists and experts in the media: The case of Covid-19. *Journalism Studies*, 22(9), 1142–1160. <https://doi.org/10.1080/1461670X.2021.1925950>
- Bradac, J. J. (2001). Theory comparison: Uncertainty reduction, problematic integration, uncertainty management, and other curious constructs. *Journal of Communication*, 51(3), 456–476. <https://doi.org/10.1111/j.1460-2466.2001.tb02891.x>

- Brashers, D. E. (2001). Communication and uncertainty management. *Journal of Communication*, 51(3), 477–497. <https://doi.org/10.1111/j.1460-2466.2001.tb02892.x>
- *Caniglia, G., Jaeger, C., Schernhammer, E., Steiner, G., Russo, F., Renn, J., Schlosser, P., & Laubichler, M. D. (2021). COVID-19 heralds a new epistemology of science for the public good. *History and Philosophy of the Life Sciences*, 43(2), 1–6. <https://doi.org/10.1007/s40656-021-00413-7>
- *Capurro, G., Jardine, C. G., Tustin, J., & Driedger, M. (2021). Communicating scientific uncertainty in a rapidly evolving situation: A framing analysis of Canadian coverage in early days of COVID-19. *BMC Public Health*, 21(1), 1–14. <https://doi.org/10.1186/s12889-021-12246-x>
- *Caulfield, T., Bubela, T., Kimmelman, J., & Ravitsky, V. (2021). *Let's do better: Public representations of COVID-19 science*. Royal Society of Canada.
- CDC. (2021, August 4). CDC museum COVID-19 timeline. <https://www.cdc.gov/museum/timeline/covid19.html>
- Chavez-Yenter, D., Zhao, J., Ratcliff, C. L., Kehoe, K., Blumling, A., Peterson, E., ... Kaphingst, K. A. (2021). Theory utilization in current communication of cancer genetic testing research: Identified gaps and opportunities. *Social Science & Medicine*, 282, 114144–114144. <https://doi.org/10.1016/j.socscimed.2021.114144>
- *Chen, T., Dai, M., Xia, S., & Zhou, Y. (2021). Do messages matter? Investigating the combined effects of framing, outcome uncertainty, and number format on COVID-19 vaccination attitudes and intention. *Health Communication*, 37(8), 944–951. <https://doi.org/10.1080/10410236.2021.1876814>
- *Chu, T. H., Yeo, T. E. D., & Su, Y. (2022). Effects of exposure to COVID-19 news and information: A meta-analysis of media use and uncertainty-related responses during the pandemic. *Journalism & Mass Communication Quarterly*, 99(1), 89–112. <https://doi.org/10.1177/10776990211068857>
- Coll, M. (2020). Environmental effects of the COVID-19 pandemic from a (marine) ecological perspective. *Ethics in Science and Environmental Politics*, 20, 41–55. <https://doi.org/10.3354/esep00192>
- *Crowley, J. P., Bleakley, A., Silk, K., Young, D. G., & Lambe, J. L. (2021). Uncertainty management and curve flattening behaviors in the wake of COVID-19's first wave. *Health Communication*, 36(1), 32–41. <https://doi.org/10.1080/10410236.2020.1847452>
- *Daoust, J.-F., & Bastien, F. (2021). Should we or should we not include confidence intervals in COVID-19 death forecasting? Evidence from a survey experiment. *Political Studies Review*, 19(2), 302–310. <https://doi.org/10.1177/1478929920985686>
- DeAndrea, D. C., & Holbert, R. L. (2017). Increasing clarity where it is needed most: Articulating and evaluating theoretical contributions. *Annals of the International Communication Association*, 41(2), 168–180. <https://doi.org/10.1080/23808985.2017.1304163>
- de Vreese, C. H. (2021). Ten observations: The 2021 ICA presidential address. *Journal of Communication*, 72(1), 1–5. <https://doi.org/10.1093/joc/jqab040>
- Dietrich, A. M., Kuester, K., Müller, G. J., & Schoenle, R. (2022). News and uncertainty about COVID-19: Survey evidence and short-run economic impact. *Journal of Monetary Economics*, Online ahead of print. <https://doi.org/10.1016/j.jmoneco.2022.02.004>
- *Dunwoody, S. (2020). Science journalism and pandemic uncertainty. *Media and Communication*, 8(2), 471–474. <https://doi.org/10.17645/mac.v8i2.3224>
- *Escandón, K., Rasmussen, A. L., Bogoch, I. I., Murray, E. J., Escandón, K., Popescu, S. V., & Kindrachuk, J. (2021). COVID-19 false dichotomies and a comprehensive review of the evidence regarding public health, COVID-19 symptomatology, SARS-CoV-2 transmission, mask wearing, and reinfection. *BMC Infectious Diseases*, 21(1), 1–47. <https://doi.org/10.1186/s12879-021-06357-4>
- *Fernandes, A. (2021). Communicating corrected risk assessments and uncertainty about COVID-19 in the post-truth era. *Frontiers in Communication*, 6, 1–16. <https://doi.org/10.3389/fcomm.2021.646066>
- *Finset, A., Bosworth, H., Butow, P., Gulbrandsen, P., Hulsman, R. L., Pieterse, A. H., Street, R., Tschoetschel, R., & van Weert, J. (2020). Effective health communication – a key factor in fighting the COVID-19 pandemic. *Patient Education and Counseling*, 103(5), 873–876. <https://doi.org/10.1016/j.pec.2020.03.027>
- *Fleerackers, A., Riedlinger, M., Moorhead, L., Ahmed, R., & Alperin, J. P. (2021). Communicating scientific uncertainty in an age of COVID-19: An investigation into the use of preprints by digital media outlets. *Health Communication*, 37(6), 726–738. <https://doi.org/10.1080/10410236.2020.1864892>
- *Gesser-Edelsburg, A. (2021). Using narrative evidence to convey health information on social media: The case of COVID-19. *Journal of Medical Internet Research*, 23(3), e24948. <https://doi.org/10.2196/24948>
- Gollust, S. E., Nagler, R. H., & Fowler, E. F. (2020). The emergence of COVID-19 in the US: A public health and political communication crisis. *Journal of Health Politics, Policy and Law*, 45(6), 967–981. <https://doi.org/10.1215/03616878-8641506>
- *Gretton, J. D., Meyers, E., Walker, A. C., Fugelsang, J. A., & Koehler, D. J. (2021). A brief forewarning intervention overcomes negative effects of salient changes in COVID-19 guidance. *Judgment and Decision Making*, 16(6), 1549–1574.
- Griffin, R. J., Dunwoody, S., & Neuwirth, K. (1999). Proposed model of the relationship of risk information seeking and processing to the development of preventive behaviors. *Environmental Research*, 80(2), S230–S245. <https://doi.org/10.1006/enrs.1998.3940>

- Gustafson, A., & Rice, R. E. (2020). A review of the effects of uncertainty in public science communication. *Public Understanding of Science*, 29(6), 614–633. <https://doi.org/10.1177/0963662520942122>
- *Guttman, N., & Lev, E. (2021). Ethical issues in COVID-19 communication to mitigate the pandemic: Dilemmas and practical implications. *Health Communication*, 36(1), 116–123. <https://doi.org/10.1080/10410236.2020.1847439>
- Han, P. K., Klein, W. M., & Arora, N. K. (2011). Varieties of uncertainty in health care: A conceptual taxonomy. *Medical Decision Making*, 31(6), 828–838. <https://doi.org/10.1177/0272989X10393976>
- *Han, P. K. J., Scharnetzki, E., Scherer, A. M., Thorpe, A., Lary, C., Waterston, L. B., Fagerlin, A., & Dieckmann, N. F. (2021). Communicating scientific uncertainty about the COVID-19 pandemic: Online experimental study of an uncertainty-normalizing strategy. *Journal of Medical Internet Research*, 23(4), e27832. <https://doi.org/10.2196/27832>
- *Hanson, C., Luedtke, S., Spicer, N., Stilhoff Sørensen, J., Mayhew, S., & Mounier-Jack, S. (2021). National health governance, science and the media: Drivers of COVID-19 responses in Germany, Sweden and the UK in 2020. *BMJ Global Health*, 6(12), 1–15. <https://doi.org/10.1136/bmjgh-2021-006691>
- *Ho, A., & Huang, V. (2021). Unmasking the ethics of public health messaging in a pandemic. *Journal of Bioethical Inquiry*, 18(4), 549–559. <https://doi.org/10.1007/s11673-021-10126-y>
- *Huang, Y., & Liu, W. (2021). Promoting COVID-19 vaccination: The interplay of message framing, psychological uncertainty, and public agency as a message source. *Science Communication*, 44(1), 3–29. <https://doi.org/10.1177/10755470211048192>
- *Huang, Y., & Yang, C. (2020). A metacognitive approach to reconsidering risk perceptions and uncertainty: Understand information seeking during COVID-19. *Science Communication*, 42(5), 616–642. <https://doi.org/10.1177/1075547020959818>
- *Hyland-Wood, B., Gardner, J., Leask, J., & Ecker, U. K. H. (2021). Toward effective government communication strategies in the era of COVID-19. *Humanities and Social Sciences Communications*, 8(1), 1–11. <https://doi.org/10.1057/s41599-020-00701-w>
- *Janssen, I., Hendriks, F., & Jucks, R. (2021). Face masks might protect you from COVID-19: The communication of scientific uncertainty by scientists versus politicians in the context of policy in the making. *Journal of Language and Social Psychology*, 40(5–6), 602–626. <https://doi.org/10.1177/0261927X211044512>
- Jensen, J. D. (2008). Scientific uncertainty in news coverage of cancer research: Effects of hedging on scientists and journalists credibility. *Human Communication Research*, 34(3), 347–369. <https://doi.org/10.1111/j.1468-2958.2008.00324.x>
- Kahneman, D., & Tversky, A. (1979). Prospect theory: An analysis of decision under risk. *Econometrica*, 47(2), 263–292. <https://doi.org/10.2307/1914185>
- *Kelp, N. C., Witt, J. K., & Sivakumar, G. (2021). To vaccinate or not? The role played by uncertainty communication on public understanding and behavior regarding COVID-19. *Science Communication*, 44(2), 223–239. <https://doi.org/10.1177/10755470211063628>
- *Kerr, J. R., Freeman, A. L. J., Marteau, T. M., & van der Linden, S. (2021). Effect of information about COVID-19 vaccine effectiveness and side effects on behavioural intentions: Two online experiments. *Vaccines*, 9(4), 1–22. <https://doi.org/10.3390/vaccines9040379>
- *Kim, H. K., Ahn, J., Atkinson, L., & Kahlor, L. A. (2020). Effects of COVID-19 misinformation on information seeking, avoidance, and processing: A multicountry comparative study. *Science Communication*, 42(5), 586–615. <https://doi.org/10.1177/1075547020959670>
- *Krause, N. M., Freiling, I., Beets, B., & Brossard, D. (2020). Fact-checking as risk communication: The multi-layered risk of misinformation in times of COVID-19. *Journal of Risk Research*, 23(7–8), 1052–1059. <https://doi.org/10.1080/13669877.2020.1756385>
- *Kreps, S. E., & Kriner, D. L. (2020). Model uncertainty, political contestation, and public trust in science: Evidence from the COVID-19 pandemic. *Science Advances*, 6(43), 1–12. <https://doi.org/10.1126/sciadv.abd4563>
- *Lambrecht, K. (2021). Tracking the differentiation of risk: The impact of subject framing in CDC communication regarding COVID-19. *Journal of Business and Technical Communication*, 35(1), 94–100. <https://doi.org/10.1177/1050651920958394>
- *Lasser, J., Ahne, V., Heiler, G., Klimek, P., Metzler, H., Reisch, T., Sprenger, M., Thurner, S., & Sorger, J. (2020). Complexity, transparency and time pressure: Practical insights into science communication in times of crisis. *Journal of Science Communication*, 19(05), 1–21. <https://doi.org/10.22323/2.19050801>
- *Li, J., & Zheng, H. (2022). Online information seeking and disease prevention intent during COVID-19 outbreak. *Journalism & Mass Communication Quarterly*, 99(1), 69–88. <https://doi.org/10.1177/1077699020961518>
- *Lilleker, D. G., & Stoeckle, T. (2021). The challenges of providing certainty in the face of wicked problems: Analysing the UK government's handling of the COVID -19 pandemic. *Journal of Public Affairs*, 21(4), 1–10. <https://doi.org/10.1002/pa.2733>
- *Lin, D., Friedman, D. B., Qiao, S., Tam, C. C., Li, X., & Li, X. (2020). Information uncertainty: A correlate for acute stress disorder during the COVID-19 outbreak in China. *BMC Public Health*, 20(1), 1–9. <https://doi.org/10.1186/s12889-020-09952-3>
- Liu, B. F., Bartz, L., & Duke, N. (2016). Communicating crisis uncertainty: A review of the knowledge gaps. *Public Relations Review*, 42(3), 479–487. <https://doi.org/10.1016/j.pubrev.2016.03.003>

- *Logar, S., Bednarova, R., Rizzardo, A., & Miceli, L. (2022). Uncertainty in health emergencies: Communicating risks during COVID-19 response. *Frontiers in Communication*, 6, 1–4. <https://doi.org/10.3389/fcomm.2021.662179>
- *Lu, J., Zhang, M., Zheng, Y., & Li, Q. (2021). Communication of uncertainty about preliminary evidence and the spread of its inferred misinformation during the COVID-19 pandemic—A Weibo case study. *International Journal of Environmental Research and Public Health*, 18(22), 1–17. <https://doi.org/10.3390/ijerph182211933>
- *Malecki, K. M. C., Keating, J. A., & Safdar, N. (2021). Crisis communication and public perception of COVID-19 risk in the era of social media. *Clinical Infectious Diseases*, 72(4), 697–702. <https://doi.org/10.1093/cid/ciaa758>
- Mishel, M. H. (1990). Reconceptualization of the uncertainty in illness theory. *Image: The Journal of Nursing Scholarship*, 22(4), 256–262. <https://doi.org/10.1111/j.1547-5069.1990.tb00225.x>
- Müller, M., Bartsch, S., & Zinn, J. O. (2021). Communicating the unknown: An interdisciplinary annotation study of uncertainty in the coronavirus pandemic. *International Journal of Corpus Linguistics*, 26(4), 498–531. <https://doi.org/10.1075/ijcl.21096.mul>
- Muthukrishna, M., & Henrich, J. (2019). A problem in theory. *Nature Human Behaviour*, 3(3), 221–229. <https://doi.org/10.1038/s41562-018-0522-1>
- National Library of Medicine. (n.d.[a]). *Uncertainty*. National Center for Biotechnology Information. <https://www.ncbi.nlm.nih.gov/mesh?term=uncertainty>.
- National Library of Medicine. (n.d.[b]). *Communication*. National Center for Biotechnology Information. <https://www.ncbi.nlm.nih.gov/mesh/?term=communication>.
- *Ngai, C. S. B., Singh, R. G., Lu, W., & Koon, A. C. (2020). Grappling with the COVID-19 health crisis: Content analysis of communication strategies and their effects on public engagement on social media. *Journal of Medical Internet Research*, 22(8), e21360. <https://doi.org/10.2196/21360>
- Nguyen, C. T. (2021a). Transparency is surveillance. *Philosophy and Phenomenological Research*. Online ahead of print. <https://doi.org/10.1111/phpr.12823>.
- Nguyen, C. T. (2021b). The seductions of clarity. *Royal Institute of Philosophy Supplements*, 89, 227–255. <https://doi.org/10.1017/S1358246121000035>
- Oldeweme, A., Märtins, J., Westmattmann, D., & Schewe, G. (2021). The role of transparency, trust, and social influence on uncertainty reduction in times of pandemics: Empirical study on the adoption of COVID-19 tracing apps. *Journal of Medical Internet Research*, 23(2), e25893. <https://doi.org/10.2196/25893>
- O'Neill, O. (2003). *A question of trust*. Cambridge University Press.
- *Paek, H.-J., & Hove, T. (2020). Communicating uncertainties during the COVID-19 outbreak. *Health Communication*, 35(14), 1729–1731. <https://doi.org/10.1080/10410236.2020.1838092>
- *Park, J. K., & Shapiro, S. (2021). Promoting the ambiguity of a public health crisis can facilitate adjustment: The joint influence of an ambiguous message focus and implicit self-theories. *Health Communication*, Online ahead of print. <https://doi.org/10.1080/10410236.2021.1950297>
- *Pearce, W. (2020). Trouble in the trough: How uncertainties were downplayed in the UK's science advice on COVID-19. *Humanities and Social Sciences Communications*, 7(1), 1–6. <https://doi.org/10.1057/s41599-020-00612-w>
- *Pentzold, C., Fechner, D. J., & Zuber, C. (2021). "Flatten the curve": data-driven projections and the journalistic brokering of knowledge during the COVID-19 crisis. *Digital Journalism*, 9(9), 1367–1390. <https://doi.org/10.1080/21670811.2021.1950018>
- Peters, H. P., & Dunwoody, S. (2016). Scientific uncertainty in media content: Introduction to this special issue. *Public Understanding of Science*, 25(8), 893–908. <https://doi.org/10.1177/0963662516670765>
- *Petersen, M. B., Bor, A., Jørgensen, F., & Lindholt, M. F. (2021). Transparent communication about negative features of COVID-19 vaccines decreases acceptance but increases trust. *Proceedings of the National Academy of Sciences*, 118(29), 1–8. <https://doi.org/10.1073/pnas.2024597118>
- Popper, K. (1959). *The logic of scientific discovery*. Routledge.
- *Post, S., Bienzeisler, N., & Lohöfener, M. (2021). A desire for authoritative science? How citizens' informational needs and epistemic beliefs shaped their views of science, news, and policymaking in the COVID-19 pandemic. *Public Understanding of Science*, 30(5), 496–514. <https://doi.org/10.1177/09636625211005334>
- *Prettner, R., te Molder, H., Hajer, M. A., & Vliegthart, R. (2021). Staging expertise in times of COVID-19: An analysis of the science-policy-society interface in the Dutch "intelligent lockdown.". *Frontiers in Communication*, 6, 1–12. <https://doi.org/10.3389/fcomm.2021.668862>
- Quinn, T. J., Burton, J. K., Carter, B., Cooper, N., Dwan, K., Field, R., Freeman, S. C., Geue, C., Hsieh, P.-H., McGill, K., Nevill, C. R., Rana, D., Sutton, A., Rowan, M. T., & Xin, Y. (2021). Following the science? Comparison of methodological and reporting quality of covid-19 and other research from the first wave of the pandemic. *BMC Medicine*, 19(1), 1–10. <https://doi.org/10.1186/s12916-021-01920-x>
- *Rafkin, C., Shreekumar, A., & Vautre, P.-L. (2021). When guidance changes: Government stances and public beliefs. *Journal of Public Economics*, 196, 1–11. <https://doi.org/10.1016/j.jpubeco.2020.104319>
- *Rajkhowa, A. (2020). COVID-19 dissensus in Australia: Negotiating uncertainty in public health communication and media commentary on a pandemic. *Pacific Journalism Review: Te Koakoa*, 26(1), 253–263. <https://doi.org/10.24135/pjr.v26i1.1091>

- Ratcliff, C. L. (2021). Communicating scientific uncertainty across the dissemination trajectory: A precision medicine case study. *Science Communication*, 43(5), 597–623. <https://doi.org/10.1177/10755470211038335>
- Ratcliff, C. L., Wong, B., Jensen, J. D., & Kaphingst, K. A. (2021). The impact of communicating uncertainty on public responses to precision medicine research. *Annals of Behavioral Medicine*, 55(11), 1048–1061. <https://doi.org/10.1093/abm/kaab050>
- Saitz, R., & Schwitzer, G. (2020). Communicating science in the time of a pandemic. *JAMA*, 324(5), 443–444. <https://doi.org/10.1001/jama.2020.12535>
- Saldaña, J. (2013). *The coding manual for qualitative researchers* (2nd ed). SAGE.
- *Sauer, M. A., Truelove, S., Gerste, A. K., & Limaye, R. J. (2021). A failure to communicate? How public messaging has strained the COVID-19 response in the United States. *Health Security*, 19(1), 65–74. <https://doi.org/10.1089/hs.2020.0190>
- *Simonovic, N., & Taber, J. M. (2022). Psychological impact of ambiguous health messages about COVID-19. *Journal of Behavioral Medicine*, 45(2), 159–171. <https://doi.org/10.1007/s10865-021-00266-2>
- Slater, M. D., & Gleason, L. S. (2012). Contributing to theory and knowledge in quantitative communication science. *Communication Methods and Measures*, 6(4), 215–236. <https://doi.org/10.1080/19312458.2012.732626>
- Sopory, P., Day, A. M., Novak, J. M., Eckert, K., Wilkins, L., Padgett, D. R., Noyes, J. P., Barakji, F. A., Liu, J., Fowler, B. N., Guzman-Barcenas, J. B., Nagayko, A., Nickell, J. J., Donahue, D., Daniels, K., Allen, T., Alexander, N., Vanderford, M. L., & Gamhewage, G. M. (2019). Communicating uncertainty during public health emergency events: A systematic review. *Review of Communication Research*, 7, 67–108. <https://doi.org/10.12840/ISSN.2255-4165.019>
- Steijaert, M. J., Schaap, G., & Riet, J. V. (2021). Two-sided science: Communicating scientific uncertainty increases trust in scientists and donation intention by decreasing attribution of communicator bias. *Communications*, 46(2), 297–316. <https://doi.org/10.1515/commun-2019-0123>
- *Tandoc, E. C., & Lee, J. C. B. (2020). When viruses and misinformation spread: How young Singaporeans navigated uncertainty in the early stages of the COVID-19 outbreak. *New Media & Society*, 24(3), 778–796. <https://doi.org/10.1177/1461444820968212>
- Trevisan, M., Vassio, L., & Giordano, D. (2021). Debate on online social networks at the time of COVID-19: An Italian case study. *Online Social Networks and Media*, 23, 1–15. <https://doi.org/10.1016/j.osnem.2021.100136>
- Tsao, S.-F., Chen, H., Tisseverasinghe, T., Yang, Y., Li, L., & Butt, Z. A. (2021). What social media told US in the time of COVID-19: A scoping review. *The Lancet Digital Health*, 3(3), e175–e194. [https://doi.org/10.1016/S2589-7500\(20\)30315-0](https://doi.org/10.1016/S2589-7500(20)30315-0)
- van Dijk, J., & Alinejad, D. (2022). Translating knowledge, establishing trust. In T. K. Lee, & D. Wang (Eds.), *Translation and social media communication in the Age of the pandemic* (1st ed., pp. 26–43). Routledge. <https://doi.org/10.4324/9781003183907-3>
- Volz, K. G., & Gigerenzer, G. (2012). Cognitive processes in decisions under risk are not the same as in decisions under uncertainty. *Frontiers in Neuroscience*, 6, 1–6. <https://doi.org/10.3389/fnins.2012.00105>
- *Vraga, E. K., & Jacobsen, K. H. (2020). Strategies for effective health communication during the coronavirus pandemic and future emerging infectious disease events. *World Medical & Health Policy*, 12(3), 233–241. <https://doi.org/10.1002/wmh3.359>
- *Wegwarth, O., Wagner, G. G., Spies, C., & Hertwig, R. (2020). Assessment of German public attitudes toward health communications with varying degrees of scientific uncertainty regarding COVID-19. *JAMA Network Open*, 3(12), 1–5. <https://doi.org/10.1001/jamanetworkopen.2020.32335>
- World Health Organization. (2021, February 15). *Infodemic*. World Health Organization. Retrieved March 31, 2022, from https://www.who.int/health-topics/infodemic#tab=tab_1.
- *Xu, T., & Sattar, U. (2020). Conceptualizing COVID-19 and public panic with the moderating role of media use and uncertainty in China: An empirical framework. *Healthcare*, 8(3), 1–18. <https://doi.org/10.3390/healthcare8030249>
- *Yoon, S., McClean, S. T., Chawla, N., Kim, J. K., Koopman, J., Rosen, C. C., Trougakos, J. P., & McCarthy, J. M. (2021). Working through an “infodemic”: The impact of COVID-19 news consumption on employee uncertainty and work behaviors. *Journal of Applied Psychology*, 106(4), 501–517. <https://doi.org/10.1037/apl0000913>
- *Zhang, Y. S. D., Young Leslie, H., Sharafaddin-zadeh, Y., Noels, K., & Lou, N. M. (2021). Public health messages about face masks early in the COVID-19 pandemic: Perceptions of and impacts on Canadians. *Journal of Community Health*, 46(5), 903–912. <https://doi.org/10.1007/s10900-021-00971-8>
- *Zhao, S., & Liu, Y. (2021). The more insufficient, the more avoidance? Cognitive and affective factors that relates to information behaviours in acute risks. *Frontiers in Psychology*, 12, 1–11. <https://doi.org/10.3389/fpsyg.2021.730068>
- *Zhou, C., Xiu, H., Wang, Y., & Yu, X. (2021). Characterizing the dissemination of misinformation on social media in health emergencies: An empirical study based on COVID-19. *Information Processing & Management*, 58(4), 1–16. <https://doi.org/10.1016/j.ipm.2021.102554>