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COVID-19 AND SCIENCE COMMUNICATION

How public perceptions of social distancing evolved over a critical time period: communication lessons learnt from the American state of Wisconsin

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Abstract

Understanding how individuals perceive the barriers and benefits of precautionary actions is key for effective communication about public health crises, such as the COVID-19 outbreak. This study used innovative computational methods to analyze 30,000 open-ended responses from a large-scale survey to track how Wisconsin (U.S.A.) residents' perceptions of the benefits of and barriers to performing social distancing evolved over a critical time period (March 19th to April 1st, 2020). Initially, the main barrier was practical related, however, individuals later perceived more multifaceted barriers to social distancing. Communication about COVID-19 should be dynamic and evolve to address people's experiences and needs overtime.

Keywords

Health communication; Public perception of science and technology; Risk communication

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Introduction

As of June 2020, social distancing[1] is a crucial practice that still needs to be implemented and sustained around the world to decrease community transmission of COVID-19. Indeed, despite the consensus among scientists and health professionals on the effectiveness of social distancing to decrease community transmission [Courtemanche et al., 2020; Greenstone and Nigam, 2020; Centers for Disease Control and Prevention, 2020b], extensive evidence shows that many people around the world, and in the U.S. specifically, are not taking social distancing seriously and "under-responding" to the health crisis [Farber and Johnson, 2020]. In particular, as the majority of U.S. states have allowed businesses

[1]The terms 'social distancing' and 'physical distancing' are both regularly used to describe the practice of keeping at least six feet between yourself and others when in public places. For the sake of clarity, we only use 'social distancing' in this paper to refer to this practice.

to reopen in late May 2020 while relaxing the restrictions put in place to limit the spread of COVID-19, the number of new confirmed cases has significantly increased, for example, California and Texas continue to hit their daily records between June 15th to June 30th [Centers for Disease Control and Prevention, 2020a].

Research from the social sciences can help explain why people do not follow expert recommendations, such as practicing social distancing. A wide range of factors have been shown to impact public perceptions and related behaviors in the context of health and other science related issues — ranging from practical to psychological, political to economic, and cultural to religious [Andersen, 2020; Baum, Jacobson and Goold, 2009; Huynh, 2020; Jaja, Anyanwu and Iwu Jaja, 2020; Oosterhoff et al., 2020; Saluja, 2020; Villa, 2020]. These factors are especially relevant for the ongoing COVID-19 outbreak because it is a complex public issue that involves trade-offs between different ideologies, value systems, cultural backgrounds, socioeconomic status, and lifestyles [Krause et al., 2020; Scheufele et al., 2020]. Scholars in sociology of science have defined this type of complex issue as "wicked problems", where there is no clear solution and the issues are not tame or benign [Rittel and Webber, 1973]. A wicked problem is highly complex because "facts are uncertain, values in dispute, stakes high, and decisions urgent" [Ravetz, 1999, p. 649]. To address wicked problems, scholars have advocated for the importance of collecting community input to inform policy design and implementation [Dietz, 2013; Raisio, 2010; Centers for Disease Control and Prevention, 2018; Fishkin, 2018]. Understanding public attitudes is a necessary step that will help scientists, science communicators, and policymakers recognize how different publics perceive the various risk dimensions of the wicked problem, how they weigh the costs and benefits of the precautionary actions to cope with these risks and ultimately design better public policy responses.

The COVID-19 pandemic is a particularly interesting wicked problem. Although the expert community constantly emphasizes social distancing as one of the most important precautions to protect oneself from the virus [Courtemanche et al., 2020; Greenstone and Nigam, 2020; Centers for Disease Control and Prevention, 2020b], little is understood on how the public perceives the barriers and benefits of social distancing in coping with various risks. Moreover, scholars have noted that the public's perception of risks is dependent on social context and time [Alaszewski, 2005; Duff, 2003; French, 2005]. This highlights the importance of studying public risk perception over time when the public is facing a rapidly changing environment such as the COVID-19 pandemic.

This paper aims to address the important, but less understood, questions about what the American public (specifically, American people in a midwestern state) think when they weigh the benefits of and barriers to performing social distancing to help contain the spread of COVID-19 and how their attitudes evolve over time as cases increased rapidly. To answer these questions, we analyzed open-ended survey responses of over 30,000 Wisconsin residents collected between March 19th and April 1st, 2020, a time when confirmed cases surged and social distancing became necessary. In particular, we examined how public attitudes related to social distancing evolved over this critical time period, when the American state of Wisconsin, like other states in the U.S., started to introduce social distancing policy and state order to curb the damaging consequences of COVID-19. The primary research question for this study is the following: *How has the public's risk perceptions*

of COVID-19 and attitudes related to social distancing evolved over a critical period in Wisconsin? This paper contributes to our understanding of the nuances of public attitudes related to wicked problems, how these attitudes evolve in a rapidly changing information environment, such as during a pandemic and how this knowledge can inform science communication practice.

Context

COVID-19 as a wicked problem

Wicked problems are inherently complex, as they involve many relevant groups with different priorities, ideal outcomes, and experiences, and require a great deal of purposeful engagement [Brossard, Belluck et al., 2019]. Another important aspect of wicked problems is that they do not have a single 'right' answer. There are likely to be many possible solutions and strategies that are advocated for by different groups, many of which will likely be in conflict with one another. To be effective, communication around these issues requires an understanding of the attitudes and experiences of different target audiences, as they likely vary widely across groups.

The ongoing COVID-19 outbreak is a great example of wicked problem with many actors and no clear, single solution. As Scheufele et al. [2020] stressed, it is extremely "difficult to identify the 'best available science' for any given policy choice in the middle of an emerging crisis." Facing an unprecedented global pandemic, health professionals suggest keeping social distancing to reduce health threats before vaccines are available. However, social distancing conflicts with values of civil liberty in the United States and locks down the economy, leading to financial difficulties for many people, especially vulnerable minorities. There is no clear-cut answer about the exact dates to start and end social distancing. Instead, policymakers must make compromises to balance several important factors at once, including health uncertainties, cultural values, and economic difficulties. One crucial way to help address this wicked problem is engaging with lay audiences in a way that can inform policy design and implementation [Brossard, Belluck et al., 2019; Dietz, 2013; Raisio, 2010; Centers for Disease Control and Prevention, 2018; Fishkin, 2018; Boulianne, Chen and Kahane, 2020].

Putting public at the center of science communication

One of the goals of science communication is to help individuals make informed decisions. To be effective, this communication must be able to navigate complex, evolving media landscapes [Brossard, 2013] and political dynamics [Scheufele, 2014]. Effective science communication must also provide different publics with the information necessary to "evaluate science policy issues" and aid "the individual's ability to make rational personal choices" [Nelkin, 1995, p. 2]. Three models of science communication have dominated the literature over time [see Brossard and Lewenstein, 2009, for a discussion]: (1) a *deficit* model (science communicators disseminate scientific knowledge in a one-way, top-down direction to the public) [Trench, 2008], (2) a *dialogue* model (a two-way direction between science communicators and the public where the public is consulted about their perceptions and concerns) [Wynne, 2006; Trench, 2008], and (3) a *participatory* model (the science communicators and the public are ideally equal in creating,

sharing, and reflecting on science issues) [Bubela et al., 2009; Miller, Fahy and the ESConet Team, 2009].

Many have stressed the shortcomings of a deficit model approach to science communication [Akin and Scheufele, 2017], including in the COVID-19 context [Krause et al., 2020]. Indeed, although people are likely to often encounter information from the expert community about what precautionary actions they should take, many still do not follow these suggestions even for a variety of reasons [National Academies of Sciences, Engineering and Medicine, 2016]. Some have stressed that a dialogue model for science communication is required under "post-normal science" contexts [e.g., Welp et al., 2006], flagging the importance of listening to laypersons to understand their values on the wicked problems and to better inform science policymaking [Brossard and Lewenstein, 2009; Jamieson, Kahan and Scheufele, 2017]. Furthermore, for communications to be effective, communicators must first understand people's existing beliefs systems as well as recognize the multiple factors influencing an individual's processing of and response to information presented to them over time [Dahlstrom, Dudo and Brossard, 2012; Rose, Brossard and Scheufele, 2020; Scheufele, 2014].

Public's risk perception of wicked problems

Scholars have highlighted the importance to understand risks in general and health risks in particular as multi-dimensional and embedded in one's social context [Krause et al., 2020]. Indeed, individuals respond to risk information in ways that are dependent to a specific social context [Alaszewski, 2005; Duff, 2003; French, 2005]. Far from being "the ideal" rational actors who base their risk-related decision-making primarily on scientific knowledge, people rely on heuristics, values, and needs when reasoning about and acting on risk information [Alaszewski, 2005; French, 2005; Kunda, 1990].

In fact, even experts are not immune to the influence of social context. For example, factors such as levels of control and responsibility play a powerful role in mediating how health professionals apply scientific evidence to risk management [French, 2005]. Risk is a "social rationality" in the sense that it is not only an object of scientific knowledge and a calculation of probability, but also an object of experience and a lived reality of modern societies [Beck, 1992; Duff, 2003]. As the lived reality and social context change, perceptions of and reactions to risk are also likely to evolve. Indeed, risk characteristics interact with psychological, institutional, social, and cultural processes in forming and transforming risk perceptions, as information about the risk transfers among and is processed by individuals and social groups (e.g., scientists, media, public agencies, advocacy groups) [Kasperson et al., 1988]. The risk-as-a-social-rationality proposition suggests that the public's understanding of risk is at least partly shaped by and evolved with the changing social reality. Furthermore, it dictates a deflection from the expert-oriented risk management approach where communication is concerned with only rendering lay risk perceptions to resemble those of the experts more closely to a model that emphasizes multiple-way communication and pays attention to views of diverse publics. Therefore, theories in risk communication stress that risk by nature is evolving, multifaceted, and requires a deep understanding of public perceptions. It is crucial to investigate how individual's

assessment of risk is intertwined with their living experiences and how these perceptions evolve as the environment that affects people's living experiences changes.

Objective

This paper responds to a persistent call in science and risk communication to use the science of science communication in applied settings [National Academies of Sciences, Engineering and Medicine, 2017] by investigating how lay citizens perceive wicked problems and their attitudes towards related behaviors. To understand lay citizens' perceptions and attitudes, we used innovative computational methods to study large-scale responses people wrote to open-ended survey questions that asked them to reflect upon the barriers and benefits they faced with performing social distancing, and what messages they wanted to hear from experts to persuade them to perform social distancing. To understand the complexity and the changing dynamics of public discourse about the risks and rewards of performing social distancing, we drew from the literature on risk communication to investigate the various risk dimensions of social distancing, including social, psychological, and physical aspects.

This paper contributes to theories in science and risk communication in several manners. First, although understanding public perception has been stressed as a key component for science communication to be effective, empirical evidence on how the public weigh various trade-offs of wicked problems still lacks [Bächtiger, 2018, p. 660]. It is even less understood what persuasion messages people want to hear from practitioners to change their behaviors on different facets of risky issues. For instance, despite experts' consensus on the importance and necessity of social distancing, this policy has encountered difficulty in enforcement in the early days of the pandemic. Considering this gap between experts' suggestions and citizens' actions, it is crucial to understand how the public navigated the benefits and barriers of a specific risk prevention policy, social distancing. We argue that studying the responses of lay audiences allows us to understand the role of people's value systems and trade-offs during a pandemic by particularly focusing on those who are reluctant to engage in a desired action [Campbell and Brauer, in press; Lee and Kotler, 2019].

Secondly, this paper contributes to the risk communication literature by showing how people's risk perceptions and attitudes quickly evolved over time at the earlier phases of the pandemic in the state of Wisconsin in the United States and thus demonstrates the necessity for communication campaigns to respond to this changing dynamic of public opinions. Since the social context people encounter is changing over time, it is important to understand risk perception as a concept dependent on time.

Last but not least, we introduce a state-of-the-art automated text analysis method to demonstrate how machine learning can help researchers analyze large-scale public opinion data to not only identify trends in what the public discussed and how they discussed it, but also how public discussion evolution over time. Unsupervised learning methods do not pre-define any categories, which is crucial when studying wicked problems that researchers and experts do not even know a full scope of the issues on what the public think.

Context of inquiry

Public risk perception is highly contextual. This paper uses a midwestern state in the U.S. as context of inquiry to demonstrate how public discussion can evolve over a critical period, even within one state. We focus on the U.S. state of Wisconsin, which is a typical agricultural midwestern state known as 'America's Dairyland.' Over 87% of its population is white and over 97% are U.S. citizens [U.S. Census, 2019]. Wisconsin is also one of the states that has the highest income gaps, and one of the most racially segregated state in the U.S. [McCann, 2019]. Politically, Wisconsin has been known as a swing or battleground state that could be won by either Democrat or Republican presidential candidates [Abramowitz, 2020]. Just like other U.S. states, Wisconsin is governed by a state government, and the state is responsible for their own public health. The state governor serves as the chief executive officer who can issue executive orders to state agencies, providing rules and regulations often in response to emergencies.

Wisconsin is a particularly relevant context of inquiry for understanding COVID-19 communication because it exemplifies many of the underlying dynamics that complicate communication at the national and international level. Specifically, Wisconsin represents a lot of the tensions and complexities that have arisen from increasing partisan polarization and urban-rural tensions [Cramer, 2016]. These factors are highly relevant for communication surrounding COVID-19, as partisanship and community-type are key experiences that communicators must navigate in order to be successful.

Compared to other states, Wisconsin had relatively fewer reported cases since its first reported case in late February 2020 through June 2020. Figure 1 presents the timeline of major events related to COVID-19 that occurred in Wisconsin from March 12th to April 1st, 2020, the timeline of our study. On March 12, 2020, Wisconsin declared a public health emergency due to COVID-19 as the number of confirmed COVID-19 cases increased to 8. On March 17th, 2020, the Wisconsin Governor issued another emergency order prohibiting mass gathering of 10 people or more. Two days later, he confirmed the first two COVID-19 deaths. As the number of confirmed cases and deaths increased, the Governor issued the Safer-at-Home Executive Order[2] on March 24th. This order required all Wisconsin residents to stay at home as much as possible and non-essential businesses to close temporarily. On March 31st, 2020, the Governor requested a Presidential Disaster Declaration in response to the COVID-19 pandemic, allowing the state to access critical programs and receive federal assistance. In sum, the period of March 19th to April 1st 2020 is of great value to examine because of the rapid changes in the COVID-19 cases and the corresponding state actions and order issued and enforced.

Methods

Identification of key dates over the critical time period in Wisconsin

This study aims to compare survey participants' responses to the three open-ended survey questions between March 19th and April 1st, 2020. Investigating opinion

[2] In May 2020, there has been some legal challenges to the Governor's Safer-at-Home orders. The state Supreme Court has overturned it.

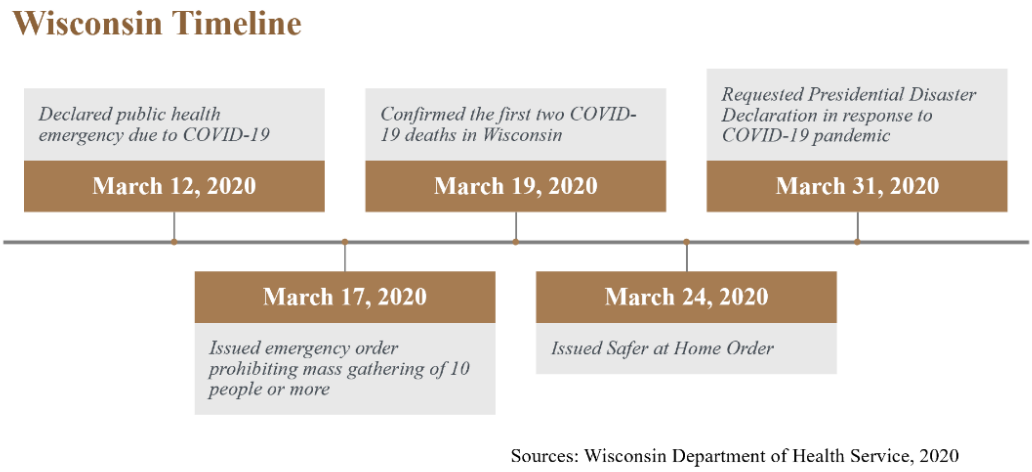

Figure 1. Timeline of COVID-19 Major Events in Wisconsin.

changes might provide explanations for people's change in social distancing behavior. We used Wisconsin citizens' real behavior mobility data as well as the date of the Safer-at-Home state order to identify the key dates when our survey participants might have changed attitudes and opinions. The first key date of March 22nd, 2020 was chosen based on people's mobility behavior in Wisconsin.

The mobility data was obtained from the GeoDS Lab at the University of Wisconsin-Madison. Researchers in this lab have been collaborating with a third-party organization, SafeGraph, to use aggregated mobile data to track people's mobility patterns across counties and cities in Wisconsin and across the United States. Figure 2 presents the median of max travel distance (in km) of residents in the Wisconsin state from March 1st to April 9th, 2020. Since our convenience sample study was launched between March 19th and March 24th, 2020, we focused on this time period. We found that there was a drop in residents' mobility on March 21st and March 22nd(near 0km mobility) and an increase from March 23rd.[3] For the current study, we therefore used March 22nd as a cutoff date considering there was a substantive change in mobility (2km) that happened on that date. Thus, for the first cutoff date, we compared peoples' answers between from March 19th to March 22nd with people's answers on March 23rd and March 24th, 2020.

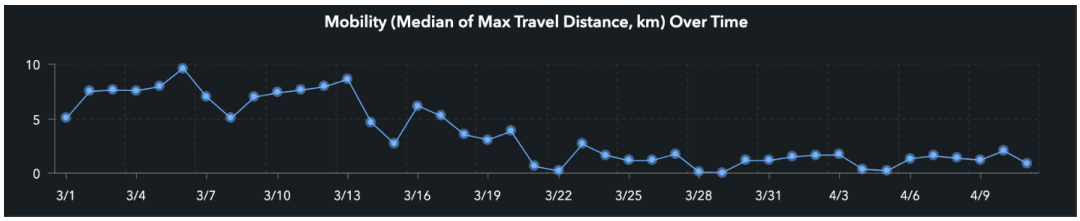

Figure 2. Mobility patterns of Wisconsin residents. Source: https://geods.geography.wisc.edu/covid19/physical-distancing/.

[3]For median and quantile values of mobility patterns of Wisconsin residents for March 21st to March 23rd, please see appendix -> Mobility data: median and quantiles.

As a second key date for comparing public discussion content, we chose the date of the Governor issued the Safer-at-Home order, which was March 24th, 2020. We compared peoples' answers between from March 19th to March 24th with people's answers between March 25th and April 1st, 2020.

Table 1. Comparing public perception and attitudes on social distancing around two key dates.

Key Dates	Comparison period
First key date: March 22nd	March 19th to March 22nd vs March 23rd and March 24th
Second key date: March 25th	March 19th to March 24th vs March 25th to April 1st

Timeframe limitation

Before discussing our methods for data collection in detail, we want to acknowledge several limitations on the study timeframe (March 19th to April 1st, 2020). For the first key date (March 22nd, 2020), we observed a drop in mobility and chose to compare public perception before and after this date. This drop could be because March 21st and March 22nd were weekend days (Saturday and Sunday) and people might move less on weekends compared to weekdays. Ideally, we would have data from a week before and after each of the cut off dates to analyze how responses on weekends compare to those on weekdays. However, we do not have data for that timeframe. We made a necessary tradeoff in precision to better serve the rapid response communication task force at our institution, which was the primary user of the data. Because information was needed urgently to communicate about the outbreak, we used this design to ensure we had timely, high-quality data to provide to those developing and circulating messaging.

Survey data

Data for the current study came from the "COVID-19 and Social Distancing" survey conducted between March 19th and April 1st, 2020, by an interdisciplinary group of scholars and NGOs (https://news.wisc.edu/covid-survey/). The survey collected self-report data on individuals' attitudes, beliefs, and behaviors related to social distancing. A link to the online survey was posted on multiple social media platforms between March 19th and March 24th. This snowball sampling resulted in an extremely large number of responses (N = 49,029), indicating that people were eager to help and flagging the urgency to hear public voices. Among those responses, 30,687 were from Wisconsin. A follow up probability-based sample was conducted using a Qualtrics Panel and was fielded from March 25th to April 1st, 2020 (n = 2,251). Among those who completed the second survey, 521 were Wisconsin residents. This paper used both surveys to study how Wisconsin residents changed their perceptions on social distancing from March 19th to April 1st.

Sample and target participants

In our analyses, we identified "target participants" primarily based on their responses to the question "Do you currently practice social distancing (in other words: do you deliberately increase the physical space between you and people to

avoid spreading illness)?" [1 = "No, not at all" and 5 = "Yes, very much"]. Respondents who selected 1, 2 and 3 to the question (i.e. did not practice social distancing optimally) were labeled as "target participants". These target participants were compared to the entire participants in subsequent analysis. Table 2 presents the number of entire participants and target participants we analyzed for the two key dates. We did not conduct a comparison for the target participants for period from March 25th to April 1st because there were not enough target participants in this period which influences the interpretability of the structural topic model.

Table 2. Number of participants and target participants we compared from two key dates.

Key Dates	Number of entire valid participants	Number of target participants
First key date: March 22nd, 2020	26,406 (March 19th to March 22nd) 3,928 (March 23rd and March 24th)	2,288 (March 19th to March 22nd) 298 (March 23rd and March 24th)
Second key date: March 25th, 2020	30,398* (March 19th to March 24th) 519 (March 25th to April 1st)	NA

* We specifically considered the differences between target participants (categorized by their answers to a behavioral question on how participants performed social distancing) and the entire sample when analyzing the first key date. People who did not answer this behavioral question were thus excluded in this first key date analysis. When we performed the second key date analysis, since we did not compare the entire participants with target participants due to a small sample size of target participants after March 25th, we did not exclude the respondents from March 19th–March 24th who did not answer this behavioral question. Therefore, the number of answers before March 25th analyzed for the first key date are slightly fewer than that for the second key date.

Survey questions

The survey included questions on media habits, effective messaging, self-reported social distancing behavior, barriers to social distancing, and socio-demographic information. This paper focused on analyzing participants' responses to three open-ended questions listed below. The first question aimed to know how the public can be persuaded to perform social distancing, which was essential for communication campaigns for some of our partners. The second and the third questions aimed to understand how the public weighs the pros and cons of performing social distancing.

1. "What could someone say to you that would make it more likely that you practice more social distancing?"
2. "Why is it difficult to practice social distancing?"
3. "What benefits would you personally derive if you were to do more social distancing?"

Analyzing public perception from large-scale open-ended survey questions

Before analysis, we performed a sample balance check, which is described in more detail in the appendix. Then, to analyze how public perceptions, attitudes and opinions related to social distancing evolved over the critical period under study and the responses to the open-ended questions, we used a state-of-the-art

automated text analysis method, Structural Topic Model [Roberts, Stewart and Tingley, 2019]. Building off traditional topic models such as the latent Dirichlet allocation model (LDA), Roberts and her colleagues [2019] developed STM as a means for incorporating meta data into topic models. Metadata are independent variables in the model and are not text data. Examples of metadata are gender, race, or time. By studying the relationship between the metadata and the text data, this model allows social scientists to not only study what the public talks about, but also identifying factors affecting what people say.

In this paper, we used two main functions from STM: "stm" and "estimateEffect". These two functions help us to understand the topic differences around the two key dates of interest. In our STM model, time is the main independent variable. If an answer was written on and before the key date, it was coded as 0 and if an answer was written after the key date, it was coded as 1. Gender and race are control variables.[4] Respondents' gender was identified as male or female. Respondents who at least partly identified themselves as white/Caucasians were categorized into "white", while others as "non-white". The dependent variables are people's answers to the open-ended survey questions. These covariates allow us to detect how certain meta data influence the discussed frequency of a topic when we examine the topic prevalence.

We chose this automated text analysis methods for two reasons. One is that STM model has been demonstrated to make "analyzing open-ended responses easier, more revealing, and capable of being used to estimate treatment effect" [Roberts, Stewart, Tingley et al., 2014, p. 1] compared to the traditional method of human ethnographic coding of open-ended survey questions. Secondly, for wicked problems, it is crucially important to not use pre-defined categories by researchers or experts to understand public perception. This unsupervised learning method serves this purpose. We suggested that for wicked problems, it is not only important to hear what the lay citizens think, but also important to choose analysis methods that have few pre-assumptions as possible. Even though researchers in manual content analysis read a sample of citizens' opinions to develop categories, these categories could be biased by existing predispositions from researchers and are limited when the data scale is large.[5]

To reduce the risk of Type I error caused by our large sample size, we set our alpha level to 0.01 and concentrated our interpretations on findings that met this threshold.

[4] We added gender and race as control variables for two reasons. First, gender and race experienced a slight change when we compared different samples before and after our key dates. Secondly, we also conducted a STM analysis comparing how women participants answered the persuasion survey questions differently from participants identifying as men. Table 18 in the appendix shows that men are slightly more likely to mention the risk of the virus for people when considering persuasive messages to make them perform social distancing (e.g. topic 2, 9 and 10), and women wanted to hear messages about how they can still perform work and life necessities (e.g. topic 3, and 8), and expressed their concerns about their friend and loved ones (topic 7).

[5] To determine the number of topics we would use from STM to analyze people's answers, we compared the held-out likelihood, residual, semantic coherence of models with 5 to 20 topics. The model with 10 topics yielded the most intuitive results and forms the focus of subsequent analysis. Several researchers hand labeled each topic by reading documents associated with the topic, by examining the words that appear with the highest probability in that topic, and by examining the words that are frequent and exclusive to that topic. To ensure that the interpretation of the topic model is as comprehensive as possible, three researchers read and interpret the output of topic models.

Results

How public perception on "persuasive messages" to perform social distancing evolved

We found that for all participants, as well as our target participants (i.e., those who have not performed social distancing well), there was a small shift in the content that could persuade them to perform more social distancing over the critical time period of March 19th to April 1st, 2020. In the early days when social distancing was just introduced to people (March 19th to March 24th, 2020), changes in public opinion regarding persuasive messages are small and are not significant at the 0.01 level. We observed a larger change in public discussion after the State enacted the Safer-at-Home order on March 24th, 2020. Participants began to point out that messages about the infection rate such as how COVID-19 is impacting different communities in Wisconsin would be more persuasive.

Small changes in participants' opinions around March 22nd on persuasive messages

Table 6 (row March 22nd cutoff)[6] presents how the time variable (i.e. March 19th–March 22nd vs March 23rd–March 24th, 2020) influences the prevalence of topics, which summarizes participants' answers to the persuasion question.

We found that topic 7 was more likely to be raised after March 22nd, 2020. Keywords and responses that are highly associated with topic 7 are examined for an understanding of the content. Based on an analysis of the sample answers listed in Table 7, we found that topic 7 is related to participants' discussion of their affective feelings (e.g., "freak out"). Participants also requested that more information related to personal relevancy need to be provided in order to be persuaded to perform social distancing. It is worth noticing that the effect size for this topic is small (0.3%) and the p-value is 0.02, which is not significant at the 0.01 level. Regarding our target participants that reported little social distancing practice, their opinions about persuasive messages around March 22nd did not significantly change, similar to the other participants.

More salient changes in participants' opinions around March 25th: from everyday essentials (i.e., living experiences) to health-related persuasion

Unlike the small changes in public opinion around March 22nd, 2020, we observed relatively larger changes in what the public wanted to hear around the March 25th cutoff when the state enacted the Safer-at-Home order. Table 6 (row March 25th cutoff) shows how all of our participants changed their answers to the persuasive question around March 25th. For instance, topic 1 is 5% more likely to be raised after March 25th and topic 5 is 4% more likely to be raised before March 25th (both topics are significant at the 0.01 level).

Table 9 lists the keywords associated with these topics, and the example responses participants wrote. Prevalent topics before March 25th are more likely associated with a warrant for living experiences issues related to everyday essentials. Topic 5 pointed out that some participants already practiced social distancing a lot. Topic 8 included discussions about everyday essentials such as their jobs, daily grocery supplies, and families. This suggests that participants were worried about the

[6] For details on tables in this result section, please refer to appendix.

multi-layered challenges when the launch date of state's Safer-at-Home order (March 25th, 2020) approached. As a result, participants requested persuasive messages to attend to not only their health but also their living experiences. Likewise, topics more prevalent on and after March 25th, 2020 showed that participants demanded persuasive messages to provide more information about the infected statistics (topic 2).

How public perception on "barriers" to perform social distancing evolved

All participants, including our target participants, raised different types of barriers for performing social distancing over the critical time period from March 19th to April 1st, 2020. The most prominent difference regarding barriers over time was that participants highlighted emotional/psychological difficulties associated with the absence of socialization after social distancing was introduced for several days (March 23rd–March 24th, 2020). When social distancing was just introduced (March 19th–March 22nd, 2020), participants focused more on barriers related to their obligations as a social and family member (e.g., essential workers). These practical daily life barriers also became more salient after the state enacted the Safer-at-Home order (March 25th to April 1st, 2020).

Comparing participants' opinions around March 22nd: from basic living needs to emotional barriers

Table 10 (row March 22nd cutoff) shows the effect of time on topic prevalence for our 10 labeled topics regarding how Wisconsin participants discussed the barrier question. While working in essential industries, such as healthcare (topics 3 and 8) is more likely to be raised by participants before and on March 22th, 2020, topic 6 (socialization as human nature) is more frequently discussed among participant after March 22nd, 2020. According to the keywords and examples of these topics (Table 11), we found that when thinking about what the barriers were for practicing social distancing, participants' opinions shifted from focusing on one's obligations as a social and family member when social distancing was just introduced to one's emotions and needs after they practiced social distancing for several days.

Though we observed similar changes in perceived barriers between all participants and target participants in our survey, the effect size of changes was more pronounced among target participants around March 22nd, 2020. Topic 3 (mental health) is 2% more likely to be raised after March 22nd, 2020. For instance, some respondents felt isolated and depressed about staying at home; some pointed out that socializing is a necessity of current lifestyles (Table 12). On the contrary, topic 2 (the inability to work at home) is 4% more prevalent before and on March 22nd, 2020. These changes are all significant at the 0.01 level. Interestingly, we see that our respondents' discussion of barriers moved up the hierarchy ladder, from basic living needs to the self-fulfillment and psychological needs.

Comparing participants' opinions around March 25th: continuous multi-level challenges

Table 10 (row March 25th cutoff) presents opinion changes from Wisconsin participants around March 24th. All changes are significant at the 0.01 level. Before

the state issued the Safe-at-Home policy on March 25th, worries about social distancing's disruption to their work (topic 3) are 3% more likely to be discussed. Besides, other frequently mentioned barriers before March 25th include doing home essentials (topic 1 and topic 7) and psychological barriers (topic 9). Topics more prevalent after March 25th, 2020 also addressed difficulties to change work and lifestyles (topics 5 and 8) and their need to interact with other people (topics 6 and 10). These findings demonstrate the continuous multi-level barriers participants faced with before and after March 25th, 2020.

How public perception of "benefits" to perform social distancing evolved

We found that all Wisconsin participants, including our target participants, pointed out different types of benefits of performing social distancing over the critical time period from March 19th to April 1st, 2020. In the early days when social distancing was just introduced (March 19th to March 22nd, 2020), participants were mentioning public health benefits such as lowering the chance of infection. On March 23rd to March 24th, 2020, people started to realize more personal improvement benefits. For instance, participants mentioned that staying at home allowed them to do things they never had a chance to do before the pandemic. After the state enacted the Safer-at-Home order (March 25th, 2020), participants started to point out more about how social distancing can benefit not only themselves but also their families and the community.

Small changes in participants' opinions around March 22nd on benefits

Table 14 (row March 22nd cutoff) shows how answers on benefits of practicing social distancing shifted among all our Wisconsin participants. Topic 1, 6, and 9 are more likely to be raised on and before March 22nd, 2020 and topic 10 is more likely to be raised after March 22nd, 2020. Although the shift in topics is statistically significant at the 0.01 level, the effect size of each topic is small (1%-2%). Before March 22nd, 2020, participants noted health benefits for themselves and the public. For instance, topic 1 discusses the benefit of (personal) health that social distancing could prevent people from being exposed to the virus. Topic 6 refers to people's discussion on their inner peace of mind from staying healthy thanks to social distancing. Also, the health condition of others or community health was a more frequently discussed benefit on and before March 22nd, 2020 (topic 9). Topic 10, more prevalent after March 22nd, 2020, suggests that participants were not identifying specific benefits of social distancing but emphasized that they were already practicing it.

Examining the change of target participants on perceived benefits of social distancing around March 22nd, 2020, the only significant shift in topic content at the 0.01 level was topic 2. After March 22nd, 2020, target participants are more likely to mention benefits of protecting themselves and their loved ones and practicing hobbies at home that they do not have time to do before. Compared to other participants who reported higher degrees of social distancing, target participants showed a delay of recognizing health-related benefits for themselves and loved ones.

More changes in participants' opinions around March 25th: from better allocation of personal time at home to family and community benefits

Table 14 (row March 25th cutoff) shows the effect of time on topic prevalence regarding all our participants' answers to the benefits question. Topics 1, 4, 5, 7, 9, and 10 are more prevalent on and after March 25th, and topic 8 is more likely to be raised by participants before March 25th, 2020. These changes are all statistically significant at the 0.01 level. Table 17 lists the keywords associated with these topics and example responses. A substantial (8%) prevalence of topic 8 before March 25th, 2020 is especially noteworthy. Topic 8 is about respondents' taking advantage of staying at home to get things done. For instance, they had more spare time to do time-consuming housework that they could not do before the pandemic. After March 25th, 2020, respondents pointed out benefits including physical health benefits such as decreasing virus infection in order to avoid negative impacts on work and to protect families, friends, and communities (topic 1, 4, 5, 7, and 9) , and their feeling of peace in mind from protected physical health (topic 6).

Discussion and implication

Implications for risk and science communication theories

This paper used automated text analysis method to investigate 30,000 open-ended responses among Wisconsin residents regarding what they perceived as effective persuasion, barriers, and benefits for practicing social distancing. We focused on the evolvement of attitude change on two important dates between March 19th to April 1st, 2020. One is the significant decline of mobility among citizens (March 22nd, 2020) and the other is the announcement of Safer-at-Home order (March 24th, 2020).

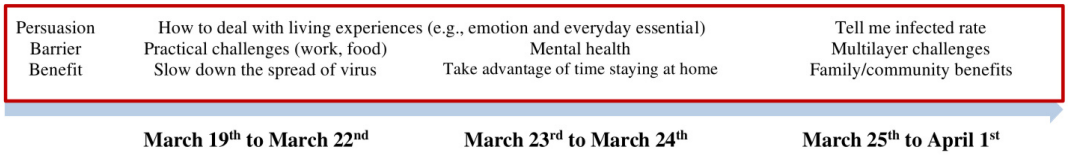

Figure 3. How public perception on effective persuasion, barriers, and benefits evolved.

Figure 3 summarizes how public perception of effective persuasion, as well as attitudes related to barriers and benefits, evolved. In the very early days (March 19th to March 22nd, 2020), people wanted to hear persuasive messages that can attend to their living experiences including emotion and everyday essential. They talked about societal-level benefits of social distancing, such as slowing down the spread of the virus and taking advantage of time staying at home for personal improvements. Practical barriers were salient such as unable to work at home or not having enough groceries. Concerns about mental health was a crucial barrier that people raised about social distancing. After the Safer-at-Home policy was in effect, people's perception on the barriers became multilayered including practical challenges and mental challenges. And people began to point out that social distancing not only benefited themselves but also their family members and the larger community.

Personal experience and media coverage might explain why these changes took place. Initially, as the COVID-19 broke out in the news, public attention to and

discussion of the impact of the disease were primarily restricted to its health effects. As the crisis escalated over time, and especially after the Safer-at-Home order was in place, the consequences of the pandemic have become more self-relevant, closer to home, and more complex than expected. People realized the multi-layered challenges, including health threats, job insecurity, financial crisis, and difficulties in getting daily necessities. This evolution in risk perceptions went in concert with the unfolding of the social context surrounding the COVID-19 pandemic [Alaszewski, 2005; Beck, 1992; Duff, 2003].

Our findings echoed existing scholarships that stress an essential feature of COVID-19 as its "wickedness" [Scheufele et al., 2020], under which people need to weigh different tensions of culture, lifestyle, physical and mental health, as well as economic costs. The weighing process differs among different publics [Villa, 2020]. These findings suggest the importance of studying how public risk perceptions evolve, which deserves more considerable empirical scholarly attention.

Lessons for (domestic and international) practitioners

This paper provides several important practical implications for health professionals, science communicators, and policymakers in the United States and over the globe. First, science communication needs to attend to the *complexity* of public opinion towards the different risks and uncertainties related to the COVID-19 outbreak, as well as barriers and benefits of practicing social distancing to combat coronavirus. Public attitudes are multi-layered, intertwined with different values, interests, and benefit and risk perceptions. Understanding the nuances of these attitudes is a first step to conduct targeted communication campaigns. As we have discussed, effective communication requires knowing your audience, especially with respect to their values, experiences, and attitudes, and knowing what messages are useful to them, given the barriers and benefits they perceive.

Expanding this crucial understanding of key audiences, our study demonstrates that people faced a wide range of barriers to practicing social distancing, ranging from health to economic reasons. Thus, segmenting audiences into more homogenous subgroups is crucial for developing the right messages to target subgroups' attitudinal and behavioral change. For instance, one important group practitioners need to target are those who rarely practiced social distancing and we demonstrate that this group experienced more substantive opinion changes compared to everyone else throughout the course of the study period. Choosing the right messages to target this group might generate the most substantial effects of health campaigns for achieving higher rates of compliance with social distancing recommendations. In terms of messages, we suggest the following strategies during message campaign design:

1. Make messages directly relevant to people's personal experiences. As we found, participants perceived messages that consider their personal gains and losses to be more persuasive.
2. Recognize and respond to the multi-dimensionality of people's risk perceptions. There is no single risk or relevant consideration related to

COVID-19. For instance, people pointed out multi-layered barriers ranging from mental health to their working situations. As science and health communicators, it is important to investigate a diverse range of barriers people might face when practicing precautionary actions. Barriers that people face might be very different from what the policymakers and communicators assume. These barriers are also contextual and need to adapt to local situations.

3. Frame precautionary action in a positive manner. Instead of using fear to tell the public the consequences of not doing social distancing, positive framing such as self-improvement during stay at home can be effective. For example, our finding on self-improvement as a benefit suggests that one way to persuade people to perform social distancing is by focusing on the positive framing of social distancing, such as on the things people can enjoy during the pandemic. In addition to stressing social distancing is necessary to flatten the curve, which is quite abstract to the lay public, science and risk communicators should also focus on messages that attend to the personal relevancy of people's lives and frame messages in a hopeful way to decrease uncertainties and anxieties among the public. In fact, CDC has reframed "social distancing" to "physical distancing" in April to address the negative framing in the former.

Second, science communication also needs to attend to the *changing dynamics* of public attitudes. As demonstrated by this study, at an early stage, people were not only ambivalent about the potential benefits of social distancing, but also lacked the experience of being socially isolated to deal with an unprecedented pandemic. As the perceived level of personal and societal threats increases, people were more likely to follow the new social norm of staying at home. However, our survey showed that people faced new challenges, such as distancing fatigue and uncertainties of future situations. Health practitioners and communicators need to provide continuous social support and update their messaging to address these new concerns. Public attitudes keep evolving as a combination of external drivers (e.g., case numbers, science discoveries, and overwhelming information) and internal changes (e.g., living demands, staying-at-home experience). It is crucial for practitioners to monitor public attitudes, risk perceptions, and reactions in order to know how communication messages and policies should change with updates from what the public needs.

Third, our study provides an example of how to efficiently track and analyze public opinion changes using a convenient web-survey and computational analysis methods. In the digital media era, social media platforms facilitate data collection that reaches out to a large number of people with low costs in a short period. However, there are two cautions about using web-surveys to understand public opinion during the pandemic. It is important to check the representativeness of the sample compared to the population and interpret findings cautiously. For another, some minority groups who do not have internet access are potentially the people whose voice needs to be heard the most. Health professionals, communicators, and policymakers need to use supplementary methods to know the struggles these people have. More importantly, our analyses showed the efficiency of computer-aided methods in analyzing big data. The open-source tool, structural topic model, used in this study, improves the accuracy and interpretability of

open-ended responses by controlling for respondents' characteristics and allows comparisons between periods and other factors. We suggest practitioners teaming up with data scientists, which will allow them to monitor large-scale public opinion in real time and fast. Moreover, the innovative computational method we used in this paper is valuable to international practitioners. It allows comparative analysis among states and countries, which is particularly important for policymakers to learn about during pandemic, as both the health crisis and public opinion surrounding it is global in nature.

Appendix A. Sample balance check

We conducted a sample balance check for the two key dates to examine to what extent participants around these two dates were similar in terms of gender, race, and age, which are factors that could influence how people experience and perceive COVID-19.[7] Table 1 describes the main demographic characteristics of the Wisconsin samples before and after the first key date (March 22nd, 2020). These two Wisconsin samples are overall similar in terms of gender, race, and age. There is a little difference in gender and race and thus, we controlled for these two demographic characteristics when we compared participants' opinions around March 22nd, 2020.

Table 2 describes the main demographic characteristics of the Wisconsin samples before and after the second key date (March 25th, 2020). We launched two surveys between March 19th to April 1st, 2020. The first survey used a convenience sampling method (conducted from March 19th to March 24, 2020) and the second survey used a probability sampling method (conducted from March 25 to April 1, 2020). Due to the difference in the sampling methods, we observed a substantial difference between these two samples in terms of gender and racial compositions. Therefore, we controlled for these two demographic variables when we compared participants' opinions around our second key date.

Table 3. Compare demographics of WI participants before/on vs after March 22nd, 2020. Note: sample sizes in the table are obtained by limiting to participants who finished the survey and who stated that they are from Wisconsin in the demographic question asking which state they came from.

WI participants (March 19th to March 22nd, 2020) Convenience sample (N=26,718)	WI participants (March 23rd to March 24th, 2020) Convenience sample (N=3,969)
Gender: 85% women, 14% men	Gender: 81% women, 18% men
Race: 95% white race identified	Race: 94% white race identified
Age: 14% (20–29) 70% (30–59) 16% (60 or above)	Age: 16% (20–29) 65% (30–59) 19% (60 or above)

[7] There are many discussions as well surveys about this observation. Some examples include: https://www.nytimes.com/2020/06/24/opinion/sex-differences-covid.html; https://www.pewresearch.org/fact-tank/2020/06/05/black-u-s-adults-follow-many-COVID-19-news-topics-more-closely-discuss-the-outbreak-more-frequently/; https://www.medrxiv.org/content/10.1101/2020.04.08.20057067v1.

Table 4. Compare demographics of WI participants before vs on/after March 25th, 2020.

WI participants (March 19th to March 24th, 2020) Convenience sample (N=30,687)	WI participants (March 25th to April 1st, 2020) Probability sample (N= 521)
Gender: 85% women, 14% men	Gender: 50% women, 50% men
Race: 94% white race identified	Race: 80% white race identified
Age: 14% (20–29) 69% (30–59) 17% (60 or above)	Age: 16% (20–29) 63% (30–59) 21% (60 or above)

Table 5. Mobility data: median and quantiles.

Date	Median	Quantiles
March 21st, 2020	0.62	Q1:0.17 Q3:0.87
March 22nd, 2020	0.18	Q1:0.05 Q3:0.17
March 23rd, 2020	2.66	Q1:1.84 Q3:3.03

Appendix B. Results

Table 6. Coefficients and P-values of the Time Effect on Persuasive Question. Notes: baseline factor is set as "after March 22nd" for the March 22nd cutoff, and "on and after March 25th" for the March 25th cutoff by the STM model. We reported topics that are significant at least at the 0.05 level.

	All participants	Target participants
March 22nd Cutoff	Topic 7 (β = -0.003, p = 0.021)	Topic 2 (β = -0.023, p = 0.028)
March 25th Cutoff	Topic 1 (β = -0.053, $p < 0.001$)	
	Topic 2 (β = -0.009, p = 0.004)	
	Topic 5 (β = 0.040, $p < 0.001$)	
	Topic 7 (β = -0.020, $p < 0.001$)	
	Topic 8 (β = 0.008, p = 0.001)	
	Topic 9 (β = 0.008, p = 0.004)	
	Topic 10 (β = 0.025, $p < 0.001$)	

Table 7. Compare Persuasion Before and After March 22nd (all WI participants). Notes: the time effect on topic 7 is significant at 0.05 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear after March 22nd	Topic 7: make, feel, just, say, also	"More precise location of people infected- when given info based on counties it seems farther away versus city names. If I knew it was in Appleton of Outagamie County and I live there- that freaks me out more and makes me immediately not want to leave home." "I've been doing everything i can but its the people on florida beaches and in new orleans or these white supremacy groups filling bottles with saliva spraying in other races faces that just make me very angry. My family is doing all we can but feel helpless against these people who just dont care"

Table 8. Compare Persuasion Before and After March 22nd (target participants). Notes: the time effect on topic 2 is significant at 0.05 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear after March 22nd	Topic 2: think, feel, serious, say, take	"I think it would be easier to do it if I knew it was for a short time. It's overwhelming to do it feeling like it could go on for months and months. Something like 'you can do anything for a couple weeks' is reassuring"

Table 9. Compare Persuasion Before and After March 25th (all WI participants). Notes: the time effect on all topics are significant at 0.01 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear on and after March 25th	Topic 1: noth, famili, make, possibl, keep	"Keep my loved ones safe, keep medically fragile people safe, keep doctors/nurses safe"
		"I already practice physical distancing because I have high risk family members."
	Topic 2: peopl, infect, know, dont, serious	"I prefer statistics. Knowing the number of people ONE infected person can infect, and then how many people those people infect. It would help to have more asymptomatic people tested!" "There are people in your area that tested positive. There is an increased amount of people in the area you live that have tested positive."
	Topic 7: home, groceri, time, feel, work	"I am already practicing social distancing, but becoming infected would jeopardize the health of my family — husband and two young children. This would also put financial strain on my family." "I'm already practicing social distancing and trying to convince my loved ones to do the same. One of them didn't see what the big deal was until she found out she had been in contact with someone who had been in contact with someone else who had COVID-19."
Topics that are more likely to appear before March 25th	Topic 5: distanc, social, practic, risk, health	"Nothing. I am definitely practicing social distancing for my health and the health of those I love"
		"I am practicing the most social distancing possible. I began before we were asked to because I am at high risk of complications from COVID-19."
	Topic 8: work, groceri, feel, sure, say	"I wish my boss didn't demand I go to work and allowed me to work from home. He says leadership HAS to be at office to show calmness and that it's ok. But I work with conservatives who bought guns instead of groceries. Half arent being careful and still going out and being unsafe with others" "I am not sure how this will apply with in our family. I care for my two year old grandson so my daughter can work. She goes to work or works from home and I babysit. She has interaction at work and I have interaction with both of them. I would stop babysitting if I found out I was a danger to them. The only time I am going outside is to the grocery store or pharmacy. I do walk my dogs but don't interact with anyone."
	Topic 9: social, peopl, will, famili, groceri	"You will still get paid for the time you can't work and you will still have all your benefits. Also, the business will still survive and will suffer few negative effects from closing due to the virus" "More specific information about the likelihood of the virus spreading through various means, like being carried into my home on shoes or clothing, the effectiveness of wiping down doorknobs shopping carts and the like with antibacterial (I know this is a virus) wipes, ."
	Topic 10: much, know, like, COVID, say	"Not sure we could do much more, we're not leaving the house — except for walks together. Extremely limited contacts — ex. Grocery run every 2 weeks, early in morn when store is not crowded.\n\nPlease review survey questions from our perspective, some questions/areas were tricky to complete" "I haven't left my house or had any contact with anyone not living in this house in 8 days. I don't know how much more I can do?"

Table 10. Coefficients and P-values of the time effect on barrier question. Notes: baseline factor is set as "after March 22nd" for the March 22nd cutoff, and "on and after March 25th" for the March 25th cutoff by the STM model. We reported topics that are significant at least at the 0.05 level.

	All participants	Target participants
March 22nd Cutoff	Topic 3 (β = 0.011, $p < 0.001$)	Topic 1 (β = 0.018, p = 0.026)
	Topic 5 (β = -0.002, p = 0.025)	Topic 2 (β = 0.036, p = 0.002)
	Topic 6 (β = -0.008, $p < 0.001$)	Topic 3 (β = -0.023, p = 0.002)
	Topic 8 (β = 0.004, $p < 0.001$)	
March 25th Cutoff	Topic 1 (β = 0.012, $p < 0.001$)	
	Topic 3 (β = 0.034, $p < 0.001$)	
	Topic 5 (β = -0.014, $p < 0.001$)	
	Topic 6 (β = -0.007, $p < 0.001$)	
	Topic 7 (β = 0.010, $p < 0.001$)	
	Topic 8 (β = -0.010, $p < 0.001$)	
	Topic 9 (β = -0.008, $p < 0.001$)	
	Topic 10 (β = -0.036, $p < 0.001$)	

Table 11. Compare Barriers Before and After March 22nd (all WI participants). Notes: the time effect on all topics are significant at 0.01 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear after March 22nd	Topic 6: social, human, enjoy, difficult, natur, virus, forget	"It's difficult to practice social distancing because humans are considered as social animal. It's in our nature or habit as humans that we need socializing."
Topics that are more likely to appear before and on March 22nd	Topic 3: old, sure, still, occasion, prevent, work, public	"I work for public health and I'm still going to work. There are many people working in a small area trying to learn more about what's going on, helping the public and vulnerable populations."
	Topic 8: famili, hang, grandkid, clinic, patient, watch, offic	"I work at a Healthcare Clinic and we have limited our patients, i still have essential patients we need to see. So I am in the clinic fulltime Monday- Friday as well as working at the COVID Clinic on the weekends as needed."

Table 12. Compare Barriers Before and After March 22nd (target participants). Notes: the time effect on all topics are significant at 0.01 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear after March 22nd	Topic 3: hard, health, feel, mental, depress, isol, realli	"I'm already feel isolated, and it's not good for my my existing mental conditions, which are, major depression disorder and panic disorder." "I consider myself to be a pretty extroverted person, and pleasant events and socialization are part of my coping mechanisms for dealing with mental health issues. I expect that there will be challenges ahead for me on the mental health front."
Topics that are more likely to appear on and before March 22nd	Topic 2: work, close, requir, healthcar, patient, hospit, servic	"I work in a hospital. I am in close proximity to my co-workers. There could be patients there that are COVID positive though I do not have close contact with them." "I work at a prison and have been required to go to work even though I am an accountant and non-esse"

Table 13. Compare Barriers Before and After March 25th (all WI participants). Notes: the time effect on all topics are significant at 0.01 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear on and after March 25th	Topic 5: social, difficult, make, keep, one	"There has never been a restriction in my lifetime on gathering in large groups. I have also never witnessed nationwide closing of stores, restaurants, and bars. The concept of extreme social distancing is new to much of the country, and new restrictions require a change in habits (temporarily). A change in habits is difficult for people to do." "I am a manager at a large manufacturing facility. It's difficult to practice social distancing when overseeing over 50 direct reports."
	Topic 6: still, see, stay, interact, person	"Mental and emotional health. Mine and my daughter's. Staying isolated is very hard on people like my daughter who need social interaction to be happy. Seeing my daughter depressed is bad for my well being."
	Topic 8: famili, practic, human, food, contact	"Personally, it is difficult to practice physical distancing because I like in a small apartment with limited sunlight and primarily by myself. The isolation physically from people and the onset of seasonal depression due to lack of sunlight exposure combined with less physical contact with friends and family makes this situation incredibly difficult. Additionally, life does not quite stop because of the virus. For instance, in the last week, my grandmother passed away and my sister gave birth to her first child. The lack of family gatherings for both events make them more difficult to process and I am robbed of these memories with family."
	Topic 10: peopl, hous, requir, life, isnt	"The end of social distancing is not in sight so it's demoralizing. Life will not return to normal for the foreseeable future and gives me a constant feeling of cabin fever"
Topics that are more likely to appear before March 25th	Topic 1: get, friend, other, want, job	"The need for my service. Dog hair does not stop growing when everything else stops (I am a dog groomer) It is especially bad to stop now as dogs that have not been cared for over the winter are getting matted and uncomfortable"
	Topic 3: work, need, distanc, store, also	"I work in an office as a manager. Until upper management determines a way to have all of our employees currently working in the office move to work at home, I need to be in that office too." "I am a single, working mother of a special needs child. Social distancing has eliminated all of the community supports that I have struggled to build for me and my son. I am expected to go into work (I work in a lab in the healthcare industry), support my son's remote learning from 8-2 m-f, help my son cope with all these changes and process all of this for myself with zero respite care and zero support. IT IS ALL ME!"
	Topic 7: home, groceri, time, feel, think	"Grocery shopping, doctor's appointments, and necessary trips out for life-sustaining items. Being in contact with certain items in the store can cause illness."
	Topic 9: hard, miss, don't, day, abl	"Lonely. Boring. Curious about what everyone else is up to. Missing social plans, an upcoming trip. Can't visit my 93 year old dad or mother in law. Want to be helpful but it's hard to find a safe way to. Would like to be able to help with my grandkids but cannot. My daughters have too heavy of a burden and I cannot help them."

Table 14. Coefficients and P-values of the Time Effect on Benefit Question. Notes: baseline factor is set as "after March 22nd" for the March 22nd cutoff, and "on and after March 25th" for the March 25th cutoff by the STM model. We reported topics that are significant at least at the 0.05 level.

	All participants	Target participants
March 22nd Cutoff	Topic 1 (β = 0.011, $p < 0.001$)	Topic 1 (β = 0.015, p = 0.028)
	Topic 6 (β = 0.011, $p < 0.001$)	Topic 2 (β = -0.034, p = 0.001)
	Topic 9 (β = 0.007, p = 0.003)	Topic 7 (β = 0.021, p = 0.044)
	Topic 10 (β = -0.026, $p < 0.001$)	Topic 10 (β = -0.029, p = 0.030)
March 25th Cutoff	Topic 1 (β = -0.024, $p < 0.001$)	...
	Topic 4 (β =- 0.014, $p < 0.001$)	
	Topic 5 (β = -0.024, $p < 0.001$)	
	Topic 6 (β = -0.014, p = 0.016)	
	Topic 7 (β = 0.012, p = 0.001)	
	Topic 8 (β = 0.084, $p < 0.001$)	
	Topic 9 (β = -0.014, $p < 0.001$)	
	Topic 10 (β = -0.013, $p < 0.001$)	

Table 15. Compare Benefits Before and After March 22nd (all WI participants). Notes: the time effect on all topics are significant at 0.01 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear after March 22nd	Topic 10: social, distanc, already, can, dont	"I couldn't do more social distancing — I have completely distanced myself for the past week and will continue to do so as long as needed (except to go out for groceries)." "Again, I don't know how I can practice it more. I have only left my apartment to throw away trash, buy gloves and buy food at a grocery store in the last week. I have literally self-quarantined"
Topics that are more likely to appear before and on March 22nd	Topic 1: less, virus, contract, ill, becom	"Less chance of contracting an illness and less stress worrying about illness." "Less chance of becoming sick or dying myself and less chance of infecting someone else. Anyone else, whether I know them or not."
	Topic 6: stay, healthi, non, mind, peac	"Peace of mind that I would stay healthy. " "Stay healthy! Family stays healthy! Friends stay healthy! "
	Topic 9: keep, feel, safe, safer, communiti	"Keeping the general public and my family members safe, keeping society from collapsing" "I just feel we all have to do it to ensure people are safe. I feel safer and feel good about keeping others safe."

Table 16. Compare Benefits Before and After March 22nd (target WI participants). Notes: the time effect on topic 2 is significant at 0.01 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear after March 22nd	Topic 2: one, love, just, already, well	"I could probably catch up on all the homework I'm behind on, grow closer to God, read some books I've been wanting to, and have the opportunity to play guitar more, which I love to do." "Saving lives. Not carrying the guilt of causing harm or death to myself, loved ones or someone else's loved one(s)"

Table 17. Compare Benefits Before and After March 25th (all WI participants).Notes: the time effect on all topics are significant at 0.01 level.

Time	Topic Number	Example Answers
Topics that are more likely to appear on and after March 25th	Topic 1: stay, safe, know, safeti, decreas	"staying safe and healthy, knowing my family is safe and healthy"
		"An increased sense of safety and knowing I am increasing the safety of others"
	Topic 4: keep, health, infect, none, help	"Decrease the potential viral load I would carry around in my community, reducing the chance or spreading it to vulnerable populations in my community and overloading the healthcare infrastructure. Also reducing my own health risks from the virus."
	Topic 5: get, famili, sick, avoid, friend	"I wont get sick, my family wont get sick. "
		"Not getting sick, not getting my family and friends sick."
	Topic 7: like, mind, peac, COVID-, person	"Less likely to become ill and Jane t.o miss work. Less likely to cause illness in family members. \n" "Peace of mind that I wasn't potentially a carrier whose actions were causing another person to become ill."
	Topic 9: less, better, one, COVID, pass	"Less chance of getting sick, less chance of giving stickers to others, less chance of dealing with stupidity"
	Topic 10: chanc, peopl, protect, safer, love	"Living and protecting my immune compromised elders. Protecting my young children. "
Topics that are more likely to appear before March 25th	Topic 8: time, home, hous, work, done	"More self reflection and finally finding the time to do chores around the house, ability to do all the things I never usually have time to do (read, binge-watch a TV show, etc.)"

Table 18. Coefficients and P-values of the Gender Effect on Persuasive Question. Notes: baseline factor is set as "Men" by the STM model. We reported topics that are significant at least at the 0.05 level.

	All participants
March 24th Cutoff	Topic 1 (β = -0.004, $p < 0.001$)
	Topic 2 (β =-0.008, $p < 0.001$)
	Topic 3 (β = 0.005, $p < 0.001$)
	Topic 4 (β = 0.004, $p < 0.001$)
	Topic 6 (β = 0.004, $p < 0.001$)
	Topic 7 (β = 0.004, $p < 0.001$)
	Topic 8 (β = 0.006, $p < 0.001$)
	Topic 9 (β = -0.011, $p < 0.001$)
	Topic 10 (β = -0.006, $p < 0.001$)

References

Abramowitz, A. I. (28th May 2020). *Recent polling in the swing states favors Biden*. URL: http://centerforpolitics.org/crystalball/articles/recent-polling-in-the-swing-states-favors-biden/ (visited on 23rd June 2020).

Akin, H. and Scheufele, D. A. (2017). 'Overview of the science of science communication'. In: The Oxford handbook of the science of science communication. Ed. by K. H. Jamieson, D. M. Kahan and D. A. Scheufele. New York, NY, U.S.A.: Oxford University Press, pp. 25–33. https://doi.org/10.1093/oxfordhb/9780190497620.013.3.

Alaszewski, A. (2005). 'Risk communication: identifying the importance of social context1'. *Health, Risk & Society* 7 (2), pp. 101–105. https://doi.org/10.1080/13698570500148905.

Andersen, M. (2020). 'Early evidence on social distancing in response to COVID-19 in the United States'. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3569368.

Bächtiger, A. (2018). 'A preface to studying deliberation empirically'. In: The Oxford handbook of deliberative democracy. Ed. by A. Bächtiger, J. S. Dryzek, J. Mansbridge and M. Warren. New York, NY, U.S.A.: Oxford University Press, pp. 657–662. https://doi.org/10.1093/oxfordhb/9780198747369.013.57.

Baum, N. M., Jacobson, P. D. and Goold, S. D. (2009). '"Listen to the people": public deliberation about social distancing measures in a pandemic'. *The American Journal of Bioethics* 9 (11), pp. 4–14. https://doi.org/10.1080/15265160903197531.

Beck, U. (1992). Risk Society: Towards a New Modernity. First published in German, 1986. London, U.K.: SAGE Publications.

Boulianne, S., Chen, K. and Kahane, D. (2020). 'Mobilizing mini-publics: the causal impact of deliberation on civic engagement using panel data'. *Politics*. https://doi.org/10.1177/0263395720902982.

Brossard, D. and Lewenstein, B. (2009). 'A critical appraisal of models of public understanding of science: using practice to inform theory'. In: Communicating science. New agendas in communication. Ed. by L. Kahlor and P. Stout. New York, NY, U.S.A.: Routledge, pp. 11–39. https://doi.org/10.4324/9780203867631.

Brossard, D. (2013). 'New media landscapes and the science information consumer'. *Proceedings of the National Academy of Sciences* 110 (Supplement 3), pp. 14096–14101. https://doi.org/10.1073/pnas.1212744110. PMID: 23940316.

Brossard, D., Belluck, P., Gould, F. and Wirz, C. D. (2019). 'Promises and perils of gene drives: navigating the communication of complex, post-normal science'. *Proceedings of the National Academy of Sciences* 116 (16), pp. 7692–7697. https://doi.org/10.1073/pnas.1805874115.

Bubela, T., Nisbet, M. C., Borchelt, R., Brunger, F., Critchley, C., Einsiedel, E., Geller, G., Gupta, A., Hampel, J., Hyde-Lay, R., Jandciu, E. W., Jones, S. A., Kolopack, P., Lane, S., Lougheed, T., Nerlich, B., Ogbogu, U., O'Riordan, K., Ouellette, C., Spear, M., Strauss, S., Thavaratnam, T., Willemse, L. and Caulfield, T. (2009). 'Science communication reconsidered'. *Nature Biotechnology* 27 (6), pp. 514–518. https://doi.org/10.1038/nbt0609-514.

Campbell, M. R. and Brauer, M. (in press). 'Social marketing campaigns to address social problems'. In: The Routledge research encyclopedia of psychology applied to everyday life. Ed. by R. A. R. Gurung. London, U.K.: Routledge.

Centers for Disease Control and Prevention (2018). *CERC: messages and audiences*. URL: https://emergency.cdc.gov/cerc/ppt/CERC_Messages_and_Audiences.pdf?fbclid=IwAR0a_eKfiSUIu7EJetxitNyubvqpu3-Q3YXYW6wD0cjdJhgWBSW6QV-v-_k.

— (2020a). *CDC COVID data tracker*. URL: https://www.cdc.gov/covid-data-tracker/index.html#learn-more.

— (2020b). *Coronavirus disease 2019 (COVID-19)*. URL: https://www.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/social-distancing.html.

Courtemanche, C., Garuccio, J., Le, A., Pinkston, J. and Yelowitz, A. (2020). 'Strong social distancing measures in the United States reduced the COVID-19 growth rate'. *Health Affairs* 39 (7), pp. 1237–1246. https://doi.org/10.1377/hlthaff.2020.00608.

Cramer, K. J. (2016). The politics of resentment: rural consciousness in Wisconsin and the rise of Scott Walker. Chicago, IL, U.S.A.: University of Chicago Press.

Dahlstrom, M. F., Dudo, A. and Brossard, D. (2012). 'Precision of information, sensational information and self-efficacy information as message-level variables affecting risk perceptions'. *Risk Analysis* 32 (1), pp. 155–166. https://doi.org/10.1111/j.1539-6924.2011.01641.x.

Dietz, T. (2013). 'Bringing values and deliberation to science communication'. *Proceedings of the National Academy of Sciences* 110 (S3), pp. 14081–14087. https://doi.org/10.1073/pnas.1212740110.

Duff, C. (2003). 'The importance of culture and context: rethinking risk and risk management in young drug using populations'. *Health, Risk & Society* 5 (3), pp. 285–299. https://doi.org/10.1080/1369857031000160698 7.

Farber, S. E. and Johnson, J. (17th June 2020). 'New data shows young people need to take social distancing seriously'. *ABC News*. URL: https://abcnews.go.com/Health/data-shows-young-people-social-distancing/story?id=71283384.

Fishkin, J. S. (2018). Democracy when the people are thinking: revitalizing our politics through public deliberation. 1st ed. New York, NY, U.S.A.: Oxford University Press. https://doi.org/10.1093/oso/9780198820291.001.0001.

French, B. (2005). 'Evidence-based practice and the management of risk in nursing'. *Health, Risk & Society* 7 (2), pp. 177–192. https://doi.org/10.1080/13698570500108735.

Greenstone, M. and Nigam, V. (2020). 'Does social distancing matter?' University of Chicago, Becker Friedman Institute for Economics working paper no. 2020-26. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3561244.

Huynh, T. L. D. (2020). 'Does culture matter social distancing under the COVID-19 pandemic?' *Safety Science* 130, p. 104872. https://doi.org/10.1016/j.ssci.2020.104872.

Jaja, I. F., Anyanwu, M. U. and Iwu Jaja, C.-J. (2020). 'Social distancing: how religion, culture and burial ceremony undermine the effort to curb COVID-19 in South Africa'. *Emerging Microbes & Infections* 9 (1), pp. 1077–1079. https://doi.org/10.1080/22221751.2020.1769501.

Jamieson, K. H., Kahan, D. M. and Scheufele, D. A., eds. (2017). The Oxford handbook of the science of science communication. New York, NY, U.S.A.: Oxford University Press. https://doi.org/10.1093/oxfordhb/9780190497620.001.0001.

Kasperson, R. E., Renn, O., Slovic, P., Brown, H. S., Emel, J., Goble, R., Kasperson, J. X. and Ratick, S. (1988). 'The social amplification of risk: a conceptual framework'. *Risk Analysis* 8 (2), pp. 177–187. https://doi.org/10.1111/j.1539-6924.1988.tb01168.x.

Krause, N. M., Freiling, I., Beets, B. and Brossard, D. (2020). 'Fact-checking as risk communication: the multi-layered risk of misinformation in times of COVID-19'. *Journal of Risk Research*, pp. 1–8. https://doi.org/10.1080/13669877.2020.1756385.

Kunda, Z. (1990). 'The case for motivated reasoning'. *Psychological Bulletin* 108 (3), pp. 480–498. https://doi.org/10.1037/0033-2909.108.3.480.

Lee, N. R. and Kotler, P. (2019). Social marketing: behavior chance for social good. 6th ed. Thousand Oaks, CA, U.S.A.: SAGE.

McCann, A. (2nd December 2019). 'States with the most racial progress'. *WalletHub*. URL: https://wallethub.com/edu/safest-cities-in-america/41926/.

Miller, S., Fahy, D. and the ESConet Team (2009). 'Can Science Communication Workshops Train Scientists for Reflexive Public Engagement?' *Science Communication* 31 (1), pp. 116–126. https://doi.org/10.1177/1075547009339048.

National Academies of Sciences, Engineering and Medicine (2016). Science literacy: concepts, contexts and consequences. Washington, DC, U.S.A.: The National Academies Press. URL: https://www.nap.edu/catalog/23595/science-literacy-concepts-contexts-and-consequences.

— (2017). Communicating science effectively: a research agenda. Washington, DC, U.S.A.: The National Academies Press. URL: https://www.nap.edu/read/23674/chapter/1.

Nelkin, D. (1995). Selling science: how the press covers science and technology. New York, NY, U.S.A.: W.H. Freeman.

Nyhan, B., Reifler, J., Richey, S. and Freed, G. L. (2014). 'Effective messages in vaccine promotion: a randomized trial'. *Pediatrics* 133 (4), e835–e842. https://doi.org/10.1542/peds.2013-2365.

Oosterhoff, B., Palmer, C. A., Wilson, J. and Shook, N. (2020). 'Adolescents' motivations to engage in social distancing during the COVID-19 pandemic: associations with mental and social health'. *Journal of Adolescent Health* 67 (2), pp. 179–185. https://doi.org/10.1016/j.jadohealth.2020.05.004.

Raisio, H. (2010). 'The public as policy expert: deliberative democracy in the context of Finnish health care reforms and policies'. *Journal of Deliberative Democracy* 6 (2), p. 6. https://doi.org/10.16997/jdd.111.

Ravetz, I. (1999). 'What is post-normal science'. *Futures — the Journal of Forecasting Planning and Policy* 31 (7), pp. 647–654.

Rittel, H. W. J. and Webber, M. M. (1973). 'Dilemmas in a general theory of planning'. *Policy Sciences* 4 (2), pp. 155–169. https://doi.org/10.1007/BF01405730.

Roberts, M. E., Stewart, B. M. and Tingley, D. (2019). 'stm: an R package for structural topic models'. *Journal of Statistical Software* 91 (2), pp. 1–40. https://doi.org/10.18637/jss.v091.i02.

Roberts, M. E., Stewart, B. M., Tingley, D., Lucas, C., Leder-Luis, J., Gadarian, S. K., Albertson, B. and Rand, D. G. (2014). 'Structural topic models for open-ended survey responses'. *American Journal of Political Science* 58 (4), pp. 1064–1082. https://doi.org/10.1111/ajps.12103.

Rose, K. M., Brossard, D. and Scheufele, D. A. (2020). 'Of society, nature and health: how perceptions of specific risks and benefits of genetically engineered foods shape public rejection'. *Environmental Communication*, pp. 1–15. https://doi.org/10.1080/17524032.2019.1710227.

Saluja, G. (7th April 2020). 'We're not all in this together. Messages about social distancing need the right cultural fit'. *The Conversation*. URL: https://theconversation.com/were-not-all-in-this-together-messages-about-social-distancing-need-the-right-cultural-fit-135427.

Scheufele, D. A. (2014). 'Science communication as political communication'. *Proceedings of the National Academy of Sciences* 111 (Supplement 4), pp. 13585–13592. https://doi.org/10.1073/pnas.1317516111.

Scheufele, D. A., Krause, N. M., Freiling, I. and Brossard, D. (17th April 2020). 'How not to lose the COVID-19 communication war'. *Issues in Science and Technology*. URL: https://issues.org/covid-19-communication-war/.

Trench, B. (2008). 'Towards an analytical framework of science communication models'. In: Communicating science in social contexts. Dordrecht, The Netherlands: Springer, pp. 119–135. https://doi.org/10.1007/978-1-4020-8598-7_7.

U.S. Census (2019). *QuickFacts Wisconsin*. URL: https://www.census.gov/quickfacts/WI.

Villa, V. (27th April 2020). *Most states have religious exemptions to COVID-19 social distancing rules*. URL: https://pewrsr.ch/3bHDndx.

Welp, M., de la Vega-Leinert, A. C., Stoll-Kleemann, S. and Fürstenau, C. (2006). 'Science-based stakeholder dialogues in climate change research'. In: Stakeholder dialogues in natural resources management. Berlin, Heidelberg, Germany: Springer, pp. 213–240. https://doi.org/10.1007/978-3-540-36917-2_8.

Wynne, B. (2006). 'Public Engagement as a Means of Restoring Public Trust in Science — Hitting the Notes, but Missing the Music?' *Community Genetics* 9 (3), pp. 211–220. https://doi.org/10.1159/000092659.

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