ABSTRACT

SPEICHER, NOLAN. The Public Communication of Researchers Using CRISPR: Where Frequency Meets Form (Under the direction of Dr. Andrew Binder).

CRISPR genome editing is a powerful biotechnological tool whose political, economic, and social implications have inspired calls for scientists to engage in meaningful communication with diverse publics. Using a sampling frame derived from the Web of Science (WoS) database, this study collected data from a random sample of researchers using CRISPR (N = 120) and proceeded with two central aims. First, it examined the frequency of public communication across three categories of activity—gated media, self-directed media, and face-to-face activities. Here, a series of logistic regression models demonstrated that both demographic and social psychological variables influenced the probability of communication across some activities, but that only one independent variable—a researcher's publications involving CRISPR—exhibited effects across all three categories. Beyond frequency, the current study also explored whether past participation in these activities influenced the form of scientists' communication. Here, a series of MANOVAs and t-tests demonstrated that active participants differed from inactive participants in their intentions to use eight communication objectives; however, these results also varied across the three categories of activity. Overall, this work invites a closer examination of what yields *opportunities* for scientists to communicate and emphasizes the importance of clearly conceptualizing public communication prior to studying it. Furthermore, science communication scholars should find both my sampling procedures and analytical approach to be useful in their future work. Taken together, the project offers diverse theoretical and methodological contributions to the existing literature on scientists' public communication.

The Public Communication of Researchers Using CRISPR: Where Frequency Meets Form

by
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DEDICATION

To Marcey Hand and Susan Considine, my high school science teachers who let me get away with too much. To Evelyn Speicher and Carol Garvis for always believing in their grandson. To my older sister Cassidy for her resilient and adventurous spirit that leads me every day. To my mom Robin for her sacrifice, and for helping me up after every fall. And finally, to Kelly, who forever changed my life with her kindness, curiosity, and teachings of self-compassion. The strength and guidance of each of these women kept me on the right path throughout my life and I could not have achieved this goal without them.

BIOGRAPHY

Nolan Speicher was born in Des Moines, Iowa, and grew up in Cedar Falls, Iowa. In 2015, he earned his B.S. in neurobiology at the University of Iowa and soon began working at Integrated DNA Technologies (IDT) in Coralville, Iowa. During his time at IDT, Nolan worked as both a science writer and digital marketing analyst, and in 2019 he moved to Raleigh to pursue the M.S. in communication at NC State. During his time at NC State, he has studied science and environmental communication from a variety of theoretical and methodological perspectives, spanning both the humanities and social sciences. In addition to working as a research assistant for Dr. Jean Goodwin, he has worked as a teaching assistant for the undergraduate courses Science Communication and Public Engagement (COM 289) and Public Speaking (COM 110). In the fall of 2021, Nolan will begin his doctoral education at NC State, where he will be housed in the Communication, Rhetoric, and Digital Media (CRDM) program. He is also a member of the 2022 AgBioFEWS cohort at NC State, where Ph.D. candidates across multidisciplinary fields examine the science, policy, and public engagement aspects and impacts of agricultural biotechnology on food, energy, and water.

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CHAPTER 1: INTRODUCTION

Dating as far back as the origins of agriculture, humans have sought to manipulate genes through selective breeding of plants and animals. The 1950's, however, brought the discovery of DNA's double-helix structure, and with it came the imagination of scientists who pondered the possibilities of making precise, site-specific changes to the genomes of cells and organisms (Doudna & Charpentier, 2014). Over the past several decades, this endeavor included multiple technological approaches which, for various reasons, fell short despite early signs of promise. However, the 2012 discovery of an adaptive bacterial defense system known as CRISPR (clustered regularly interspaced palindromic repeats) quickly elevated genome modification capabilities to new heights, resulting in what some have termed "the CRISPR craze" (Pennisi, 2013). Indeed, since its arrival, CRISPR has become a fixation of the scientific community and mass media alike. In 2015, *Science* magazine named the technology as their "Breakthrough of the Year", and in that same year, one geneticist wrote, "CRISPR is turning everything on its head" (Ledford, 2015, p. 20). In 2020, the technology's co-creators Jennifer Doudna and Emmanuelle Charpentier were awarded the Nobel Prize in Chemistry. Meanwhile, CRISPR has become a routine focus of the popular press (APPC, 2018; Maron et al., 2017), in addition to the subject of multiple documentary films (Bolt, 2019; Kaufman & Egender, 2019).

Of course, prior to all of this, there already existed a long-standing and contentious societal conversation existed around genetically modified (GM) foods (see Frewer et al., 2013; Burchell, 2007). CRISPR will likely intensify such debates, or perhaps already has, because of the now expanded realm of plant and animal characteristics that can be modified with higher precision and less cost. Moreover, CRISPR may ultimately take on its own narrative because of the fact that it greatly increases the feasibility of two applications—human genome editing and gene drives. The ethical and ecological impacts of these technologies arguably incite even higher levels of societal concern than GM foods, and in 2018, some of these concerns were fully realized when a Chinese scientist, He Jiankui, announced he had used CRISPR to (illegally) modify DNA in human embryos.

Aside from Jiankui, and to some extent *because* of Jiankui, the scientific community at large is approaching CRISPR with caution. Nevertheless, its widespread utility in both experimental and applied biological systems will almost certainly make it a defining technology of the 21st century. As Barrangou and Doudna (2016) put it, the technology "will not only serve as a fundamental component of the biologist's toolkit, but could also affect almost every aspect of life, and provide inspiration for future technological breakthroughs" (p. 939). Perhaps nothing signifies this more than the recent surge of financial investment in CRISPR. A full review of these is certainly outside the scope and capabilities of this thesis; however, it is at least worth mentioning that companies like Editas Medicine, CRISPR Therapeutics, Caribou Biosciences, and others—many of which are headed by scientists—have received hundreds of millions of dollars in private investments. In addition, federal funding for CRISPR-related research has increased at a dramatic rate, growing from $5 million in 2011 to $1.1. billion in 2018 (Gallo et al., 2018). Such investments have yielded proliferation of CRISPR-related publications, with over 6,000 in 2020 alone (Clarivate Analytics, 2020).

Overall, CRISPR-driven advances in genetic modification offer world of promise. At the same time, they reflect a multitude of social, economic, moral, and ecological dilemmas which have been laid out in more detail by the National Academies of Sciences (2016a, 2016b, 2017). According to Scheufele et al. (2017), these reports have all called for "societal debates that progress well beyond technical aspects of genome editing" (p. 554). Indeed, if there were ever a scientific issue ripe for “upstream public engagement” (Rogers-Hayden & Pidgeon, 2007; Wynne, 2006;), it is the newly realized genetic modification prowess made possible by CRISPR, which might be a kind of poster child for what Ravetz (1993) called “post-normal” science. While the substantial demand for a dialogue with publics appears to be realized (Brossard et al., 2019; Burall, 2018; Jasanoff et al., 2015; Scheufele et al., 2017; Taylor & Dewsbury, 2019; Wirz et al., 2020), less research has explored how these activities are actually being carried out by CRISPR’s advocates.

The current study seeks to address this gap by exploring how researchers using CRISPR approach the public communication of science. The project is comprised of two distinct but intersecting aims. First, it asks how scientists’ public communication is distributed across various types of activities, and what factors predict that activity. Here, focus is given to non-policy informing “public communication” as defined by Rowe and Frewer (2005), and activities are further categorized into “gated”, “self-directed”, and “face-to-face” activities. Second, it explores scientists’ intentions to use various science communication objectives and asks how those intentions relate to their public communication activity. Derived from work in public relations, science communication objectives have been central to a recent line of research (Dudo & Besley, 2016; Besley, Dudo, & Yuan, 2018; Besley et al., 2019), however the authors and other scholars have repeatedly encouraged future studies to focus on particular science contexts (Besley & Nisbet, 2013, p. 656; Dudo & Besley, 2016, p. 6).

In Chapter 2, a more detailed review of relevant literature is presented, where the project’s conceptualization of public communication is made explicit and its research questions are clearly stated. In Chapter 3, I describe my methods. This includes the specific sampling procedures used to isolate this group of researchers, a brief introduction to the questionnaire design, and a detailed description of the project's measures. In Chapter 4, I report the main findings of my analyses through a series of tables and figures. Finally, in Chapter 5, I aim to put these results into conversation with past and future work in this space. This begins with an explanation of the study's limitations and moves on to a discussion of its theoretical and methodological implications, where I make recommendations for future inquiries along the way.

CHAPTER 2: SCIENTISTS AS PUBLIC ACTORS

The current study is positioned at the intersection of two distinct, but related lines of recent research. Bennett and colleagues (2019) label these studies as investigations into the "quantity" and "quality" of scientist-public interactions (p. 13, p. 17), however I will use the terms "frequency" and "form". This is in recognition that that the word "quantity" implies a measurement of volume, or fullness, that is alternatively not implied by the term frequency. After all, researchers in this line of work commonly ask scientists how many times they have done something, and while the resulting data is certainly numerical, this measure of occurrences as a function of time is more accurately described by the term frequency. Furthermore, the term "quality" is highly contingent on one's positionality. That is, what constitutes a quality interaction for a scientist or researcher might be quite different from that of lay audiences. Alternatively, the current study uses the term "form" in an effort to not imply that one's definition of quality is the "correct" one.

This chapter proceeds in three sections. First, I review literature pertaining to the frequency of scientists' public communication. From there, I move onto discussing the form of scientists' communication, where particular focus is given to scientists' intentions to use strategic communication objectives. Following these two sections, I clearly state the current study's research questions which lie at the intersection of communication frequency and form. Lastly, before describing my methods in Chapter 3, I make explicit mention of this study's conceptualization of public communication, as it has important implications for how some variables were operationalized for data analyses.

Frequency of Public Communication of Science

Even beyond the contentious area of genetically modified organisms, demands for scientists to engage publics are on the rise. Bauer and Jensen (2011) referred to this trend as the "mobilization of scientists" (p. 3), and perhaps nothing exemplifies it more than the National Science Foundation's "broader impacts" initiative, which is now moving beyond marginal consideration for funding criterion to one more directly tied to funding success (National Alliance for Broader Impacts, 2018; National Science Foundation, 2014; Risien & Storksdieck, 2018). Indeed, some have gone as far to say that the question for science is no longer whether to engage publics, but rather how to do so (Pielke, 2007). In the midst of a global pandemic, an environmental crisis, and a "polluted" science communication environment (Kahan, 2012), it seems reasonable to suggest that science communication is at the core of one of the more fascinating (and potentially troubling) timepoints in modern history.

With these imperatives in mind, there has been a recent proliferation of research into the factors that predict or influence scientists' participation in public life. The overarching premise here is that "to get more scientists involved in communication, we need to better understand the circumstances leading scientists to engage in public outreach" (Bennett, 2019, p. 11). A majority of this work views a scientists' decision to communicate as a planned behavior, and therefore uses some version of the theory of planned behavior (TPB) to address drivers of that decision (see Bennett, 2019, p. 11 for a review). According to the TPB, the strongest determinant of behavior is a person's behavioral intention, which itself is determined by 1) their attitude toward a behavior, 2) the subjective norm associated with that behavior, and 3) the perceived (and actual) behavioral control (Ajzen, 2012). This third construct was a more recent addition to the original theory of reasoned action and is closely related to Bandura's (1977) concept of "self-efficacy" in social cognitive theory. Other studies have adhered less to the TPB, particularly those which more narrowly focus on scientists' relationship to media institutions and technologies (Crettaz von Roten, 2011; Dudo, 2012, 2015; Dunwoody et al., 2009; Jünger & Fähnrich, 2020) and those who probe institutional factors within science itself (Crettaz von Roten, 2011; Rose et al., 2020). Still, much of the insight gained from these studies could theoretically feed into future work with the TPB, namely because of their attention to scientists' control of behavior (both perceived and real).

Collectively, research in this space has pointed to three interrelated categories of factors which are thought to predict a scientists' communication activity. These are demographic factors, social psychological factors, and previous communication activity which is thought to "feedback" into one's thoughts around future activity (Azjen, 2012; Besley, Dudo, Yuan, & Lawrence, 2018). In terms of some demographic factors, results are mixed. For instance, in a recent review, Bennett and colleagues (2019) cited nine studies which found that older scientists are more likely to engage than younger scientists. These same nine studies also found that male scientists are more likely to engage than female scientists. Yet, the review also noted eight studies which found the opposite pattern or no difference at all (p. 13). On scientific status, research is more consistent in finding that higher status is associated with more frequent communication (Dudo, 2012); however, there are discrepancies in how researchers operationalize status. Some work defines status as academic experience or academic rank (Bauer & Jensen, 2011), while others include measures of publications (Dudo, 2012; Dudo et. al., 2018). Furthermore, some studies either assume or discover that status is highly correlated with age, and therefore do not include it as a distinct variable in their analyses (Besley, Dudo, Yuan, & Lawrence, 2018).

Beyond demographic factors, research frequently suggests the importance of social psychological constructs, most notably attitudes, efficacy, and norms around engagement itself.

It is thought that these are the more actionable variables for communication trainers and those looking to coerce scientists into communicating, or even getting certain individuals to engage less (Bennett et al., 2019). Other research has pointed to social psychological variables centered on perceptions of the public, rather than on engagement activities themselves. Indeed, Besley and colleagues (2018) point to a broad literature pertaining to notions of trust and fairness which suggests that how scientists' view the public may shape their desire on whether (and how) to act (p. 566). The current study adopts a similar perspective and considers this second area of attitudinal variables as opposed to the first. More specifically, it examines a collection of social psychological variables which center on scientists' sense of an 'imagined public' (Maranta et al., 2003) in conjunction with demographic variables of age, sex, and status. This is not to suggest scientists' attitudes, efficacy, and perceived norms around engagement are unimportant. Instead, it merely reflects the current study's interest in the relatively ambiguous and less explored domains of this line of work. Having now situated this project within the broader field of research on the frequency of scientists' public communication, I will now move on to a discussion of the extant literature on the form of that communication.

Form of Public Communication of Science

Research focused on how scientists think about, talk about, and actually carry out public communication is not a novel endeavor, by any means. As Bauer and colleagues (2007) explained, large-scale survey research first began in the 1960's by assessing the public's "scientific literacy", where psychometric measurements of factual and methodological knowledge (i.e., "education") served as the indicator of quality science communication (p. 81). By the mid-1990's, public attitudes were considered alongside knowledge as important components to the "public understanding of science" (PUS). Here, the notion that "the public is not positive enough about science and technology" fueled investigations into the contributors and consequences of public attitudes (p. 83). Of course, these included close examinations of the complex relationship between scientific literacy and pro-science attitudes (Einsiedel, 1994; Evans & Durant, 1995).

The literacy and PUS eras, also referred to as "paradigms", gave rise to widespread criticism of the "deficit model" of science communication (Ahteensuu, 2012; Bauer et al., 2007; Sturgis & Allum, 2004). Generally speaking, this approach to communication is predicated on emphasizing public deficiencies related to science. Delineating this further, Ahteensuu (2012) explicated on four major assumptions:

> First, the public is ignorant of science. Second, the public has negative attitudes towards (specific instances of) science and technology. Third, ignorance is at the root of these negative attitudes. Fourth, the public's knowledge deficit can be remedied by predominantly one-way science communication from scientists to citizens. (p. 298)

More recently, in recognition that "public communication of science is more complex than what the knowledge deficit model suggests" (Simis et al., 2016, p. 401), the literacy and PUS paradigms of old have been replaced by one of "public engagement". As opposed to its predecessors, public engagement stresses negotiation and two-way dialogue between scientists and non-scientists, even allowing for publics to participate in the decision-making process (Ahteensuu, 2012, p. 296). Still, deficit model thinking has persisted within the scientific community, as observed by a substantial volume of multi-methodological studies (Besley & Nisbet, 2013; Simis et al., 2016; Wynne, 2006).

Reliance on the deficit model not only "fans the flames of science conflicts" (Nisbet & Scheufele, 2009), but also reflects a direct contradiction to the conclusions drawn from empirical evidence, which has shown that factual scientific knowledge has but a relatively modest relationship to public attitudes (Allum et al., 2008). In an attempt to nudge scientists in new directions, recent research has explored the utility of tenets from strategic communication and public relations. More specifically, scholars have turned to a “Tactics-Objectives-Goals” model (Bennett et al., 2019, p. 15) to describe the various choices available to a science communicator.

This line of research includes a series of studies which have investigated which communication objectives scientists are most willing to prioritize, and why (for a review of these objectives, see Besley, Dudo, & Yuan, 2018, p. 711-712). This work has repeatedly found that scientists continue to prioritize the dissemination of knowledge and see other “non-informing” objectives, such as boosting excitement, building trust, and strategically framing issues, as less important (Besley, Dudo, & Storksdieck, 2015; Besley, Dudo, & Yuan, 2018; Besley et. al, 2019; Dudo & Besley, 2016).

Much of the extant research into scientists’ prioritization of communication objectives has used members from large scientific organizations as their study participants. Most often, this has been the American Association for the Advancement of Science (AAAS) (Besley, Dudo, & Storksdieck, 2015; Besley et. al, 2019; Dudo & Besley, 2016), although one study also compared scientists across geophysical, geological, ecological, biological, and general scientific disciplines (Besley, Dudo, & Yuan, 2018). Still, the authors have repeatedly made calls for future research to be conducted in more specific contexts (see Besley, Dudo, & Yuan, 2018, p. 725; Dudo & Besley, 2016, p. 6), and even prior to that, Besley and Nisbet (2013) wrote, “scientist surveys may need to avoid generalities and either focus on views about communication on specific topics or focus on sampling scientists in specific fields” (p. 656). Beyond the realm of strategic communication, this sentiment has been taken up by recent surveys which narrow their focus to experts in particularly contentions scientific fields (Su et al., 2016). This includes surveying experts in nanotechnology (Besley et al., 2008; Corley et al., 2009, 2013, 2016; Ho et al., 2011; Kim et al., 2012) and synthetic biology (Rose et al., 2018) in ways that are reminiscent of case studies often seen in the niche of Science, Technology, and Society (STS). Overall, more focused examinations of scientists in emerging technological spaces are upheld by the assumption that the nuanced views and activities of researchers will be vital to public opinion formation and policy-making in those specific domains (Rose et al., 2018, p. 783). A similar rationale was carried into the current study, which situates itself within one of the most contentious technoscientific conversations of our time.

Conceptualizing Public Communication

To this point, I have introduced CRISPR as a defining technology of the 21st century and outlined two distinct camps of research pertaining to the frequency and form of scientists' public communication. These literatures provide the broader context for this project's primary research questions which will be stated at the closing of this chapter. However, these questions also depend largely on how one conceptualizes "public communication", so before describing my methods and results, it will be useful to clearly define what that term means here.

There are many terms and phrases which have been used to denote scientists' communication with lay audiences. A full account of these is beyond the scope of this project, however some of the notable occurrences in the literature include "public outreach" (Mathews et al., 2005; Crettaz von Rotten, 2011), "knowledge transfer" (Jacobson et al., 2004), "public understanding of science activities" (Pearson, 2001), "science communication" (Burns et al., 2003), and "science dissemination" (Torres-Albero et al., 2011). More recently, the terms "public engagement" and "PCST"—an acronym for the public communication of science and technology—have become more or less institutionalized and have taken hold in the literature (Canete Benitez, 2014; Dudo, 2012; Peterman et al., 2017; Robertson et al., 2014; Storksdiek et al., 2016).

Although public engagement and public communication are often used interchangeably, not all would agree they are synonymous. For instance, Rowe and Frewer (2005) argue that public engagement is a broad, umbrella term which encompasses three distinct "mechanisms"—only one of which is public communication. More specifically, they assert that these mechanisms are characterized by the directional flow of information between sponsors and publics, where the terms sponsor refers to "the party commissioning the engagement initiative" (p. 254). In public communication, information is conveyed unidirectionally from sponsors to publics. Alternatively, in public consultation, information moves unidirectionally from publics to sponsors, and in public participation, information flow bidirectionally between sponsors and publics. These differences are illustrated in Figure 1.

In examining the public communication of researchers using CRISPR, the current study draws on this conceptualization by Rowe and Frewer (2005), focusing specifically on scientists' participation in activities which are structured for "one-way" information flow from scientists to publics. A key point here is that while, in reality, some form of information should inevitably move from publics to scientists in these activities, the structural characteristics of the activities are such that public feedback is not required or specifically sought. Furthermore, if the public does attempt to provide information, "there are no mechanisms specified a priori to deal with this at any level beyond, perhaps, simply recording the information" (Rowe and Frewer, 2005, p. 255).

Importantly, this study’s conceptualization is a slight deviation from previous studies which have attempted to measure scientists' public communication. For example, Dudo (2012) used Pearson's (2001) definition of any "communication of science by scientists to people not involved with research in their field" (p. 122). Such a definition could, in theory, encompass activities which Rowe and Frewer consider to be public consultation or public participation. Similarly, other studies have sought to measure public engagement without giving attention to how activities are structured in terms of information flow. In doing so, they tend to over-represent communication in relation to consultation and participation (in Rowe and Frewer’s terms, at least). Indeed, much of the literature on scientists’ public engagement leans quite heavily on measuring informal science education (e.g., in schools and museums), mediated activities, and even interventions with policymakers and non-governmental organizations (NGOs) which are unlikely to involve publics in any capacity.

Overall, operationalizing public communication in research is extremely difficult given the wide variety and ever-changing nature of activities one can participate in. This has certainly contributed to the fact that, across all of the research cited here, public communication has rarely, if ever, been measured the same way. Of course, this presents problems for cross-study comparisons, and it may also be one reason why results on some predictive factors (age and sex, for example) have been largely inconsistent. In an effort to not exacerbate this issue, some important disclaimers will be offered before moving on to my methods.

First, this study makes no claims about scientists’ public *engagement*, which (again, using Rowe and Frewer's definition) should include both public consultation and public participation activities in addition to public communication. Second, as opposed to using a broad conception of the public as “every person in society” (Burns et. al., 2003), I draw more heavily on Davies (2016), who describes science communication as a set of "organized processes that seek to engage lay publics with scientific knowledge, but which generally do not seek to directly inform science policy or the practice of research" (p. 163). In other words, public communication as it is defined here does not involve policy-informing activities or those meant to inform future research.

Finally, the current study adds nuance to existing conceptual frameworks of public communication activities. Specifically, I consider face-to-face contact with publics as distinct from those which are mediated through various communication technologies. This distinction is consistent with Rowe and Frewer's (2005) typology as well as a small collection of recent investigations into scientists' public communication activity (Besley, Dudo, Yuan, & Lawrence, 2018; Dudo, et al., 2018; Dudo et al., 2014). In particular, the current study draws on the AAAS definition of a "large group encounter" in operationalizing face-to-face public communication activities (Storksdieck et. al, 2016).

Moreover, I also make a conceptual distinction between "gated" and "self-directed" media activities. The concept of "gated" here can be traced back to gatekeeping theory in mass communication (Shoemaker & Vos, 2009), which holds that media professionals are uniquely positioned in society as information "gatekeepers", where they can not only select and reject information, but also influence the way content is "shaped, structured, positioned, and timed" (p. 11). Within the context of science communication, this has implications for one's intentions and control over behavior. For instance, in gated media activities, the ability to participate does not lie solely with scientists. More often than not, they must be invited to participate in these communication activities. This can be contrasted with a second form of mediated communication—what this project terms "self-directed" media activities—which can alternatively be *initiated* by scientists themselves and are therefore more likely to be determined by scientists' decisions and goals (as opposed to those held by media professionals). Thus, scientists' autonomy was an important consideration for the categorization of mediated activities investigated here.

With these conceptualizations of public communication in mind, the first two research questions proposed by this project are as follows:

RQ1: How does the frequency of public communication by researchers using CRISPR vary across different forms of communication (gated media, self-directed media, and face-to-face activities)?

RQ2: What demographic and social psychological factors are associated with public communication in these different forms?

For RQ2, particular focus is given to demographic variables of age, sex, and status, which are routinely collected and investigated in this line of research. Alternatively, the social psychological variables examined here (discussed more thoroughly in the following chapter) have been studied far less in their relation to activity levels. And while variations of RQ1 and RQ2 have certainly been asked before, this is the first study (to my knowledge) to situate these questions within the domain of CRISPR, genetic technologies, or any other controversial science setting. The uncertainty of this context therefore prompted a more exploratory approach and use of open-ended research questions rather than formal hypotheses. Furthermore, where most studies investigate frequency and form separately as distinct outcomes, less work has focused on their interrelatedness. In an effort to address this, the current study poses a third research question which seeks to interrogate scientists' use of communication objectives as a function of their past communication activity. More formally, this third research question is stated as follows:

RQ3: How does a researcher's public communication activity relate to their intentions to use various science communication objectives?

Next, in Chapter 3, I describe the methods used to investigate these questions . This includes sections on sampling, data collection, questionnaire design, measurements, and my approach to statistical analyses.

CHAPTER 3: METHODS

In order to investigate this project's research questions, data was collected using an online survey questionnaire administered through Qualtrics. The final survey questionnaire, including its consent process and recruitment emails, was approved by the NC State Institutional Review Board (IRB) on November 9, 2020. To construct a sample of researchers with CRISPR experience, this project used the "corresponding author" of scientific publications listed in the Web of Science (WoS) database as a sampling frame. While targeting researchers this way is a deviation from the majority of previous work on scientists' public communication, the sampling methods outlined here have been previously used to survey experts in particular fields, including nanotechnology (Corley et al., 2009) and synthetic biology (Rose et al., 2018). In addition to the research questions posed in the previous chapter, one broad aim of this project was to explore the feasibility and usefulness of this approach—this idea will be revisited in Chapter 5's discussion.

Sampling Procedures and Data Collection

On October 13, 2020, a search in WoS using the keyword "CRISPR" and the filters shown in Table 1 yielded 9,740 publications. These specific filters were implemented in accordance with the study's focus on researchers based in the U.S. who were actively involved in biological research using CRISPR.

These 9,740 publications and their associated WoS fields were exported to Microsoft Excel for data cleaning. First, 1,372 publications were removed which did not list any corresponding email address. This resulted in 8,368 publications which yielded 11,208 email addresses (some publications listed more than one address) before any examination of duplicates took place. From there, duplicate email addresses were removed, yielding 7,255 unique entries.

Even with the Country/Region WoS filter, some non-U.S. email domains appeared amongst these 7,255 entries. Considering this study's focus on U.S. scientists, these email addresses were removed, leaving 5,543 email addresses which ended only in ".edu", ".com", ".net", ".gov", ".org", or ".bio" domains. Finally, in the last step of data cleaning, an additional ~500 email addresses were removed because they were in fact duplicates of corresponding authors. That is, the same author had two (or more) publications in which they listed distinct corresponding email addresses. In these cases, the publication year was used to determine the most recently used email address and the older addresses were removed. The final sampling frame contained 5,079 unique researchers whose last name and email addresses were uploaded to a Qualtrics contacts list.

In order to protect the identities of the participants, a random sample of 3000 email addresses was generated in Qualtrics. This group of 3000 researchers, labeled "Final Contacts", was invited to participate in the project by way of an initial invitation sent on November 11, 2020, and three follow-up emails which were sent to non-respondents on November 18, November 25, and December 2, 2020. Upon clicking the link to access the survey, participants were asked for their consent before seeing any questionnaire items. To ensure the sample included researchers who fit within the scope of the study, the following language was included in the consent form:

> *You must be 18 years of age or older and reside in the United States to participate in this study. You must also have, at any point currently or in the past, conducted research related to CRISPR and/or gene editing.*

If participants did not meet these criteria, it was assumed they would not continue beyond the consent form.

Participants

The recruitment process yielded 172 participants who accessed the survey link from any of their four invitation emails, resulting in a minimum contact rate of 5.7% (AAPOR, 2016). Of these, 52 participants had missing or unusable data, resulting in a final sample size of 120 and a minimum response rate RR1 of 4.0% (AAPOR, 2016). This was a lower response rate than expected, but still not far off from rates seen in major public opinion polls (Pew Research Center, 2021). The final sample (*N* = 120) characteristics are shown in Table 2.

Questionnaire Design

The online questionnaire consisted of six major sections (not including the consent form). First, an introductory set of questions focused on the participants' proximity to science communication research, their perceptions of public trust, and their media use. From there, participants moved into a series of four blocks, where they were asked about their past participation in four categories of public communication activities (gated, self-directed, social media, and face-to-face). Based on their activity levels in each category, participants received different versions of a follow-up question. More specifically, if they reported any activity in the category, they were asked to think of the most recent occurrence and rate the extent that they intended to use eight strategic communication objectives. If they reported zero activity in the category, they were asked to imagine a hypothetical scenario in which they would be participating in one tomorrow. Like the active participants, they rated their intention to use eight communication objectives in this hypothetical activity.

This structure repeated itself throughout the four public communication categories with the exception of the third block, pertaining to social media, which assessed past activity differently. More specifically, a series of questions asked about participants' social media behaviors “in a typical week”. One question from this block centered on general browsing activity was treated as an independent variable in this study (see Measures section, next). Following the introductory questions and the four public communication blocks, the sixth and final section of the questionnaire captured the participants’ demographics. In the next section, we will take a closer look at the specific measures used in the questionnaire’s six sections.

Measurements

This section outlines the measures used in the current study’s inferential statistics which will be described in more detail in Chapter 4. In addition to the measurements listed here, some were captured by the survey questionnaire but not ultimately included in statistical analyses. For instance, as seen in Table 2, data was collected on participants’ race/ethnicity, their primary research application/specialization, as well as their primary institutional affiliation. These categorical variables were not included in inferential statistics due to the low number of participants in some categories. The current study also captured participants’ political orientation, but a preliminary analysis revealed no correlations with the outcome variable of public communication activity, so it was not included in later inferential statistics. Finally, the measure of *career level* (also seen in Table 2) was not included in later statistical analyses due to its high correlation with age in this sample ($r = 0.75$, $p < 0.001$). Next, I describe the measures that were included in statistical analyses, beginning with the outcome (dependent) variables.

Dependent Variables

Public Communication Activity

In three distinct sections of the survey questionnaire, participants saw a list of communication activities and were given the prompt, “Thinking only about communication activities that involved CRISPR and/or gene editing, have you ever…” (1 = Yes, 0 = No). The three lists of items, pertaining to gated media, self-directed media, and face-to-face activities are shown in Table 3 along with their response distribution.

The original survey questionnaire asked about of a total of 16 activities however two were removed from statistical analyses, resulting in the 14 seen in Table 3. One of the removed items directly asked about policy-informing activities and therefore clearly fell outside of the current study's conceptualization of public communication. The other asked participants about giving talks at colleges and universities, which, remembering the idea of non-research-informing activities from Davies (2015), may have also included activities that fell outside this project's conceptualization of public communication. Furthermore, this item of "giving talks at colleges/universities" saw a participation rate of 88.3%, which was twice that of the second-highest rate (~44%). This was taken to be an outlier and indicative of a measurement validity issue. That is, where the other questionnaire items of the face-to-face category assessed activity outside a researcher's home institution, this item did not—at least not explicitly. Indeed, the way this question was written, it is possible that participants' considered lectures at their own institutions as public communication activity. For these reasons, I took a more conservative approach to measurement and removed the item from statistical analyses.

Intention to Use Communication Objectives

Participants were asked to rate their intention to use eight communication objectives (1 = Not at all, 5 = A great deal). The phrasing of each objective as it was written in the questionnaire is shown in Table 4. These were derived from the Strategic Science Communication Project (SSCP, 2021) but included some modifications. First, the objective of correcting misinformation was treated as a distinct objective from increasing factual knowledge/awareness. Second, the objectives of explaining risks and benefits were included for their relevance to emerging technologies, and to reflect the more recent iteration of objectives laid out by Bennett and colleagues (2019, p. 15). With these two additions, the original conception of objectives in this study included 10 objectives. In an effort to reduce this number and simplify the questionnaire, the SSCP objectives of conveying shared values, competence, and warmth and respect, were combined into a single objective of building trust in the scientific community. This resulted in the final list of eight seen in Table 4.

By nature of the questionnaire design, participants were asked about these objectives four times, once in each block of communication activities. If they reported activity in any one category, they were asked, “To what extent did you intend to…”. Alternatively, if they were inactive in the category, they were asked, “To what extent would you intend to…”. Table 5 lists the eight objectives and their respective averages within each activity category, as well as their composite means across all categories. These averages include the responses from both active and inactive participants, comprising the entire sample (N =120).

Independent Variables

Demographics

Age was measured by subtracting participants’ birth year, which they selected from a drop-down menu, from 2020 (M = 48.99, SD = 11.72). *Sex* was measured as a dichotomous variable with male coded as “0” (68.3%) and female coded “1” (31.7%).

Status

Two variables related to status were used in statistical analyses. *CRISPR Years* (M = 5.52, SD = 2.00) was measured by asking participants “In what year did you start using or investigating CRISPR?” and subtracting that value from 2020. Finally, *CRISPR Publications* (M = 7.58, SD = 7.25) was measured by asking participants to estimate their “total publications involving CRISPR and/or gene editing." Two potential outliers in the CRISPR publications variable were identified (values of 41 and 51) and converted into an "over 21" data point. This modification resulted in a slightly lower average (M = 7.18) and smaller standard deviation (SD = 5.53).

Science Communication Research and Media Use

When scientists contemplate whether to formally engage with publics and how they might do so, they invoke "imagined lay persons" (Maranta et al. 2003). The current study aimed to capture scientists' use of three information sources which could, in theory, inform such conceptions of laypeople—those being science communication research, traditional mass media, and social media. This led to the use of four variables in statistical analyses which are described next.

Proximity to Science Communication Research (M = 3.60, SD = 0.70; Cronbach's α = 0.86) was measured as a four-item index which asked participants to rate their "familiarity with…" and "attention to research on…" both "public engagement" and the "public understanding of science and technology". *Print/Online News Readership* was measured as a dichotomous variable with no coded as 0 (17.5%) and yes coded as 1 (82.5%). This was assessed by asking participants, "In the past week, have you read…" 1) printed newspapers/magazines and 2) online news/magazines for which you have a subscription (r = 0.25, p < 0.01). Participants responding yes to either of these were coded as 1. Considering the likelihood that participants might consume news through one of these mediums and not the other, the weak correlation between these items was deemed unproblematic. *TV News Viewership* was measured similarly measured as a dichotomous variable, where no was coded 0 (34.2%) and yes was coded 1 (65.8%). This was assessed by asking participants, "In the past week, have you watched…" 1) local TV news and 2) national TV news/talk shows (r = 0.46, $p < 0.001$). Participants responding yes to either of these were coded as 1. *Facebook/Twitter Browsing* (M = 2.55, SD = 2.89) was measured by asking participants, "In a typical week, on how many days do you browse your…" 1) News feed and 2) Twitter feed. Whether a participant received the Facebook or Twitter version of this question depended on their response to an earlier questionnaire item in which they were asked if they held accounts on either platform. Participants who held accounts on both were randomly administered the Facebook or Twitter version, and if participants reported not having either a Facebook or Twitter account, they were given a value of 0. These platforms were selected specifically for their popularity amongst U.S. adults and relevance to science communication (Lee & VanDyke, 2015; Su et al., 2017; Walter et al., 2019; Jünger & Fähnrich, 2020).

Perceived Public Confidence

The current study included an explanatory variable which (to my knowledge) has not been previously investigated in relation to scientists' public communication activity or prioritization of communication objectives. This measure was inspired by the Pew Research Center (Funk & Kennedy, 2020), who routinely probes Americans' confidence that scientists act in the public interest. In the current study, it was hypothesized that a scientist's perception of public confidence could have some influence on the nature of their public communication. To measure Perceived Public Confidence (M = 3.22, SD = 0.74), participants were instructed to "Take a moment to think broadly about the majority of adults residing in the U.S". This was followed by asking, "How much confidence do you think they have in scientists to act in the best interests of the public?" (1 = None at all, 5 = A great deal).

Analytical Approach

Statistical analyses were carried out with IBM SPSS v27 and proceeded in two sequential steps. First, a series of three binomial logistic regression models was conducted to examine predictors of activity in gated media, self-directed media, and face-to-face activities. In these three logistic regressions, communication activity was treated as a dichotomous dependent variable (participants had done *any* of the activities or *none* of the activities) while four blocks of independent variables were entered into the model separately in their assumed causal order (demographics, status, research/media use, and perceived public confidence). As opposed to linear regression where the outcome variable is continuous, a logistic regression model uses an outcome variable that is dichotomous (a value of 0 or 1). The model reports a logit coefficient and an odds ratios for each of the predictor variables, which is used to predict the probability that an observation falls into either the "0" or "1" category. An estimated odds ratio over 1.00 can be interpreted to mean that as the independent variable's value increases by one unit, the probability of the dependent variable falling in the "1" category increases. Alternatively, an odds ratio greater than 0.00 and less than 1.00 means that as the independent variable increases by one unit, the probability that the dependent variable falls into the "1" category decreases (Binder et al., 2013). An odds ratio of exactly 1.00 means the independent variable is not related to the dependent variable, resulting in an equal chance (50%) of being in the "0" or "1" category of the dependent variable.

Treating communication activity as a dichotomous variable made sense given the distribution of activity in this sample. As seen in Table 6, each category was marked by a sizeable portion (50 – 72%) of researchers who were inactive. Indeed, considering this study's relatively small sample size, the large percentage of "0" values created conditions that were not very well-suited for linear regression and better suited for logistic regression. Furthermore, treating activity as dichotomous in sensible from theoretical perspective, too. Previous research on scientists' public communication has repeatedly pointed to "cyclical" positive relationship between past experiences, current views, and future behaviors. The common notion here is that once communication occurs, it tends to lead to more communication (Besley, Dudo, Yuan, & Lawrence, 2018; Bennet et. al, 2019). If we assume that scientists' communication ultimately self-perpetuates in this way, then the critical juncture becomes participating and not participating, rather than participating more or less often. Since the former is a clear Yes/No response, it is well-positioned to be examined using probabilities derived from logistic regression models.

In the second phase of my analysis, I set out to examine whether the presence or absence of activity had any relation to the intention to use communication objectives (RQ3). This involved the same dichotomously coded public communication activity variables, but here they were treated as independent categorical variables in a series of multivariate analysis of variance (MANOVA) models. These MANOVAs tested whether the independent variable (communication activity) resulted in statistically significant changes in the means of eight dependent variables (communication objectives). While one might consider running eight distinct t-tests (one on each objective), a necessary first step is to examine whether the groups differed across *all objectives* at once. Here, a MANOVA is advantageous because it tests whether two groups are significantly different across a *series* of dependent variables, as opposed to a single dependent variable. Importantly, the three MANOVAs looked *within* each category of activity, investigating whether active and inactive scientists differed in their intention to use communication objectives in that particular category.

Before describing the results of these analyses, it should be noted that in an effort to avoid Type II errors (false negatives), I considered p-values of < 0.10 to be significant results. Deciding a threshold of significance is always a trade-off between Type I and Type II errors (Benjamin et al., 2018); however, considering the small sample size and low cost of a Type I error, a threshold of 0.10 was deemed appropriate.

CHAPTER 4: RESULTS

Research Question One

Prior to any inferential statistics, the first research question posed by this project involved a descriptive account of public communication. More specifically, research question one asked how the public communication of researchers using CRISPR varied across gated media, self-directed media, and face-to-face activities. To address this, I first calculated participants' total number of reported activities within each category. Here, values ranged from 0 to 5, 0 to 3, and 0 to 4, respectively, for gated media (M = 1.36, SD = 1.61), self-directed media (M = 0.41, SD = 0.76), and face-to-face (M = 0.57, SD = 0.97) activities. Next, these data were recoded as dichotomous such that any value greater than or equal to 1 was coded as 1, and the 0 values remained 0. When treated dichotomously, participation rates across gated media, self-directed media, and face-to-face activities were 50.0%, 28.3%, and 34.2%, respectively (see Table 6). Finally, I created a composite measure by summing each participant's total number of activities, regardless of category (M = 2.33, SD = 2.65). As seen in Table 6, 65.8% of the sample was "active" in the sense that they participated in at least one activity.

Research Question Two

Research question two examined the associations of various demographic and social psychological factors with public communication across three categories of activities using series of logistic regression models (see Table 7). The estimated variance explained by the models is the Nagelkerke R^2, a pseudo-R^2 reported by SPSS.

Moving from left to right across Table 7, only one of the variables included the model was significantly associated with the probability to participate in gated media activities (*CRISPR publications*, $e^B = 1.15$, $p < 0.01$). For self-directed media activities, two variables demonstrated positive associations with the probability of participation—*CRISPR publications* ($e^B = 1.08$, $p < 0.10$) and *Facebook/Twitter browsing* ($e^B = 1.1\ 3$, $p < 0.10$). *Print/Online News Readership*, on the other hand, was negatively associated with the probability of participation in these activities ($e^B = 0.29$, $p < 0.05$). That is, news readers were less likely to participate in self-directed media activities than non-readers. Four variables were significantly associated with the probability of face-to-face activity. In terms of demographic factors, females' likelihood of participation in this category was twice that of males ($e^B = 2.20$, $p < 0.10$) and older age was negatively associated with the probability of participation ($e^B = 0.96$, $p < 0.05$). *CRISPR publications* again exhibited a positive association to participation ($e^B = 1.15$, $p < 0.01$), and finally, closer *proximity to science communication research* was significantly associated with an increased likelihood of participation ($e^B = 2.50$, $p < 0.01$).

One takeaway from Table 7 is that different factors affect the probability of participation in different activity categories. For instance, *age*, *sex*, and *proximity to science communication research* were associated with significant changes in the probability of participating in face-to-face activities, but not gated media or self-directed media activities. Similarly, *Facebook/Twitter browsing* was significantly associated with self-directed media activities, but not gated media or face-to-face activities. In fact, only one variable—*CRISPR publications*—was seen to be significantly associated with the probability to participate in all three activity categories.

Figure 2 takes a closer look at the relationship between a scientists' publications involving CRISPR and their probability of participation across gated media, self-directed media, and face-to-face activities. While the direction and magnitude of these associations are quite similar, ($e^B = 1.15, 1.08, 1.15$), Figure 2 illustrates some notable differences across the three activity types. First, looking at the baseline probabilities of participation, we see that a researcher with a single publication is ~30% likely to be involved in a gated media activity, ~15% likely to be involved in a face-to-face activity, and 18% likely to be involved in a self-directed media activity. However, as the number of publications increases beyond five, participation in face-to-face activities becomes more probable than self-directed media activities. Moreover, in comparing when activity becomes more probable than not (> 50% likelihood), the model predicts this to come earliest for gated media activities (8 publications), followed by face-to-face activities (14 publications) and self-directed media activities (21 publications). One important consideration here is the more conservative approach this study took in measuring face-to-face activities. Had I included giving talks in colleges or universities, the participation probabilities associated with face-to-face activity would be higher than both gated media and self-directed media activity.

Research Question Three

My third and final research question asked how past participation in public communication activities related to scientists' intentions to use strategic communication objectives. Here, the dichotomous variables for gated media, self-directed media, and face-to-face activity, which were previously treated as dependent variables, were alternatively used as independent variables. This analysis proceeded in two steps—first, a series of three MANOVAs looked within each category of activity investigating whether active and inactive scientists differed in their intention to use communication objectives in that particular category. Considering the possibility that inactive and active participants might *always* be different regardless of the specific objective, this was a necessary first step prior to examining the effects of participation on each objective individually. In the case of a non-significant MANOVA, however, a second analytical step was taken, where a series of t-tests examined the effects of participation on each objective individually.

As seen in Table 8, one of three MANOVAs yielded a significant result. That is, when asked about the intention to use communication objectives in gated media activities, there was a statistically significant difference between those who had previously participated in at least one gated activity and those who had not, and these differences varied across the objectives, F (8,111) = 9.90, $p < 0.001$; *Wilk's* $\Lambda = 0.584$, *partial* $\eta^2 = .416$.

Statistically significant differences across all eight objectives in can be observed in Table 9 and Figure 3. Here, the largest discrepancies between active and inactive participants were on the objectives of listening to others, F (8,111) = 64.95, $p < 0.001$, building trust, F (8,111) = 53.72, $p < 0.001$, and discussing risks, F (8,111) = 30.87, $p < 0.001$. Differences were also significant, but less pronounced, on objectives of framing issues in new ways, F (8,111) = 3.23, $p < 0.10$, boosting excitement F (8,111) = 6.53, $p < 0.05$, and discussing benefits, F (8,111) = 10.82, $p < 0.01$. In both the active and inactive groups, the highest rated intention was for the objective of increasing knowledge and/or factual awareness (active $M = 3.95$; inactive $M = 4.52$). At the other end of the spectrum, intentions among active participants were lowest for the objective of listening to others ($M = 2.53$), while for the inactive participants, framing issues in new ways was lowest rated objective ($M = 3.90$).

On the other hand, the MANOVAs for self-directed and face-to-face activities were non-significant, meaning no such difference existed across *all objectives* in these categories (Table 8). However, there are still noteworthy observations to be made. For example, similar to gated media activities, the intention to increase factual knowledge and awareness was again the highest rated objective in both self-directed media activities (active $M = 4.51$; inactive $M = 4.21$) and face-to-face activities (active $M = 4.39$; inactive $M = 4.34$). This means that across active and inactive participants in all three activity categories, intentions to perform this objective were the ubiquitously the highest. Conversely, at the low end of objective intentions, both active and inactive participants in self-directed media activities reported listening to others as the least-intended objective (active $M = 3.12$; inactive $M = 3.64$). Here, in the active group, the objective of discussing risk held an identical lowest mean ($M = 3.12$). Moving on to the third and final category, face-to-face activities, discussing risk was the lowest rated objective in both the active ($M = 3.20$) and inactive ($M = 3.13$) groups. Overall, either listening to others or discussing risk were the least-intended objective in five of the six group-activity combinations.

Furthermore, since the MANOVAs for self-directed media and face-to-face activities were non-significant, I moved on to a second analytical step involving a series of sixteen independent sample t-tests (two categories of activity x eight objectives). Here, I examined whether any statistically significant differences existed for *individual* objectives. The results of these analyses are described in Tables 10 and 11. In each of these t-tests, Levene's test for equality of variances ($p < 0.05$) was used to determine the appropriate t and significance level.

As seen in Table 10, intentions to perform five objectives in self-directed media activities were significantly different between active and inactive participants. Those objectives include correcting misinformation, $t(118) = 1.98$, $p < 0.05$, increasing factual knowledge/awareness, $t(118) = 2.03$, $p < 0.05$, listening to others, $t(118) = 2.26$, $p < 0.05$, building trust, $t(118) = 2.35$, $p < 0.05$, and explaining risks, $t(118) = 2.87$, $p < 0.05$. Conversely, there were no significant differences in the intention to boost excitement, frame issues in new ways, and explain the benefits of CRISPR, suggesting that both active and inactive participants were more aligned in their intentions to use these objectives in self-directed media activities.

Finally, the t-test involving face-to-face activities (Table 11) resulted in two objectives of significant difference—framing issues in new ways, $t(118) = -1.81$, $p < 0.10$, and building trust, $t(118) = -1.90$, $p < 0.10$. Generally speaking, active and inactive participants were more aligned on objectives in this category than the others. Furthermore, this category seems to be unique in that those who had previously participated in a face-to-face activity reported (slightly) higher intentions than those who had not. Indeed, in both gated and self-directed media activities, this dynamic was the opposite. That is, inactive participants expressed higher intentions than active ones. Next, with the results presented in this chapter in mind, I will move on to a discussion of this project's broader implications for past and future work in this space.

CHAPTER 5: DISCUSSION

The goals of this project were to gain a deeper understanding of the frequency and form of public communication by researchers using CRISPR. It set out with two overarching aims—first, to understand the factors influencing public communication activity and second, to understand how that activity influenced intentions to use communication objectives. While past studies have explored similar research questions with regard to scientists' public engagement broadly, less work has focused specifically on contentious science domains and treated the intersection of frequency and form as its focal point.

First, the results from RQ1 echo past findings which have demonstrated that scientists are active in public communication across a variety of formats, including gated media, self-directed media, and face-to-face activities (Bauer & Jensen, 2011; Besley, Dudo, Yuan, & Lawrence, 2018; Besley & Nisbet, 2013; Dudo et al., 2018). Second, around predictors of activity (RQ2), the current study found that both demographic and social psychological variables were significantly associated with the probability of communication in some activities, but that only one variable—a researcher's publications involving CRISPR—was ubiquitously significant across gated media, self-directed media, and face-to-face activities. Finally, RQ3 asked whether past participation in these categories influenced a scientists' intentions to use a series of eight communication objectives. In gated media activities, a MANOVA showed that a significant difference between active and inactive participants existed across *all objectives*. The same could not be said for self-directed media and face-to-face activities, although subsequent t-tests revealed some significant differences on *individual objectives.* This chapter takes a closer look at these results, giving particular focus to their broader implications and the recommendations that can be made for future studies. However, before elaborating on these, however, some limitations need to be considered.

Limitations

First, we should consider that this sample was relatively small (N=120) due to lower-than-expected contact and response rates (5.7%, 4.0%, respectively). Had the survey not been administered over Thanksgiving break in year defined by a global pandemic and a divisive election, these rates could have been higher. Beyond this, surveys of scientists are also susceptible to nonresponse bias (Bauer & Jensen, 2011; Dudo, 2013). That is, when asking about scientist-public interactions, it is possible that those who are willing to participate in the study are already among the most active public communicators, meaning the activity levels reported and analyzed here may be an inaccurate representation of the broader CRISPR community. However, there are good reasons to think this is less of an issue when surveying researchers from the Web of Science (WoS) database, as opposed to members of AAAS or alternative scientific collectives. One reason is that by simply being a member of an organization like AAAS, researchers are already demonstrating some inclination or affinity for public interaction. After all, AAAS states in its mission statement that its first goal is to “enhance communication among scientists, engineers, and the public” (AAAS, 2021). Second, we should consider that AAAS is not comprised exclusively of scientists—in fact, journalists, educators, and others not actively involved in bench research can be members, too. On the contrary, scientists in the WoS database may or may not be members of organizations with public communication initiatives, and we can be certain that they are involved in research (or at least that they were at some point).

Thus, despite its low size, the final sample here may actually constitute a more diverse (and accurate) range of positions on this topic, if in fact we are looking to examine the public communication of researchers exclusively. Aside from not being able to offer an incentive, I followed best practices in survey research, used random sampling, and made it clear in the recruitment materials that previous public communication activity was not a prerequisite for participation in the study. Overall, considering 35% of participants were *inactive* (by this study's definition), I am less inclined to believe this sample was a dramatic over-representation of activity; however, establishing baseline activity rates of CRISPR researchers or even scientists more broadly could be a site of future examination.

Another limitation revolves around the analysis of RQ3, which compared intentions to use communication objectives across active and inactive participants in three categories of activities. Importantly, it should be noted that the two groups of participants (active and inactive) received slightly different versions of the same question. That is, if a scientist completed an activity in the category they were asked, "to what extent did you intend to…", while those who had not completed an activity in the category were asked, "to what extent would you…" This complicates the intergroup comparisons because it is difficult to know whether the observed results were due to the presence/absence of activity or the wording of the questionnaire item. Indeed, a more useful approach to understanding intergroup differences would have been to ask both the active and inactive groups about the same hypothetical scenario. Nevertheless, if there were effects from the question wording, those effects were not consistent across activity types. For example, in gated media activities, the active group reported using all objectives significantly less than the inactive group anticipated they would have in a hypothetical scenario. Here, it appears that when given the question of "would you" perform some objective, scientists were inclined to report consistently strong intentions to do so in theory, but there was a significant discrepancy in the extent that the active group echoed this in practice. On the other hand, in face-to-face activities, this discrepancy was essentially non-existent, and two objectives even saw the active group report using them more than the inactive group hypothetically would have. Here, it seems that theory and practice may be more aligned, with active scientists matching or even exceeding the extent that inactive scientists would hypothetically use the objectives. Overall, the results presented here are unable to shed light on how active and inactive scientists might think differently about objectives, which was the original aim of the current study. Yet, asking active scientists the extent they previously performed an objective across various activities can alternatively provide insight into whether some activities are actually more conducive to certain objectives in practice, which should prove to be a promising area of future research.

Measuring Public Communication

Finally, we should consider the measurement of public communication activity, which was used both as dependent variable in RQ2 and an independent variable in RQ3. Here, I drew specifically on Rowe and Frewer (2005) and Davies (2015) in conceptualizing public communication as non-policy, non-research informing activities which are designed for information to flow "one-way" from scientists to publics. I also separated these activities into three distinct categories—gated media, self-directed media, and face-to-face activities. This is similar, but not identical to, iterations seen in past work (Besley, Dudo, Yuan, & Lawrence, 2018; Dudo et al., 2018); however, by no means is it the *only* way, nor the "right" way to conceptualize activities (see Storksdieck et al. 2016).

More importantly, it suggests future researchers should be similarly transparent about how and why they conceptualize public communication the way they do. For instance, had I included the two face-to-face activities that I ultimately removed from statistical analyses (see p.

21-22), the percentage of "active" participants would have increased from 65.8% (see Table 6) to 90.8%. Moving beyond descriptive statistics, this has implications for exploring the relationships amongst variables, too. In fact, in a post-hoc analysis (data not shown), both age and sex became non-significant in their associations with face-to-face communication activities when these items were included in the measure. Here again, it is possible that the inclusion or exclusion of these items—particularly giving talks in colleges and universities—may be a contributor to the mixed results seen on these variables in past work. Indeed, the inclusion or exclusion of these items painted quite a different picture here, which suggests that future research should give careful thought to this. Particularly when asking researchers to assess *their own* levels of activity without explicitly defining what that means, it is possible that some may consider activities at their own institution to be public communication, while others may not. Judging from the data presented here, this could be a substantial validity issue depending on whether the researcher considers this activity to be public communication.

Next, in terms of operationalizing public communication, it should be mentioned that the more common method in this line of research is to ask scientists *how many times* they completed a list of activities in the past year (Bauer & Jensen, 2011; Besley et al., 2013; Canete Benitez, 2014; Dudo et al., 2018; Poliakoff & Webb, 2007). Alternatively, the current study assumed the COVID-19 pandemic would have significant effects on the frequency of public communication activities in 2020 and therefore deviated from this approach. Of course, I could have asked participants to estimate their activities carried out in 2019, but to do so in November of 2020 for a list of 16 activities seemed overly taxing. In an effort to avoid these issues, I instead asked participants to consider their entire career and simply respond with a "yes" or "no", given the added caveat that the activity needed to involve CRISPR or gene editing. In the end, this measure perhaps better describes the *diversity* of communication activity rather than it does the frequency, which should be noted when comparing these results to previous studies.

Predictors of public communication

Aside from these considerations of measurement, the findings of this project can still be put into conversation with past work. Looking at RQ2, a series of logistic regression models was used to examine predictors of public communication activity. Here, the current study found that demographic variables of age, sex, and CRISPR publications were significantly associated with the probability of public communication (Table 7). Age and sex were not consistent predictors of every category of activity, however. In fact, of the three categories examined here, age and sex were only seen to be significantly related to face-to-face activities. Indeed, this finding reflects or perhaps even explains the conflicting nature of results seen on these variables in previous research. Moreover, even in past work that has found age and sex to be significantly related to activity, most have concluded that older scientists and male scientists are more likely to communicate (see Bennett et al., 2019, p. 13). In contrast, the current study found that in face-to-face activities, female scientists and younger scientists were associated with higher probabilities of communication.

Whether these findings on age and sex are due to the unique sample or the form of measurement is difficult to ascertain here, but this could be put to the test with replicative studies involving the CRISPR community. Indeed, if the results held consistent for female scientists, one speculation might be that Jennifer Doudna, arguably the “face” of CRISPR research, is inspiring female scientists in this field to be more frequent public communicators relative to other scientific domains. After all, Doudna has been outspoken about what her success has meant for women in science (citation) and has set a fine example for science communicators. As for age, the findings here are line with a study from Dudo and colleagues (2018) who examined the public communication of microbiologists. The authors suggested there that future generations of microbiologists may be relatively more poised for engagement. I might even extend this further to say that, particularly in contentious domains like CRISPR, we should expect younger scientists to see more value in public communication as a form of “activism” than older scientists. This claim is merely speculative, but it could be further examined using samples of researchers involved in other contentious domains, such as climate change or vaccines.

Moving on to the variable of CRISPR publications, the current study found that a higher number of publications was strongly associated with higher probabilities of public communication activity. Indeed, this result held consistent across all three categories of communication activity (Table 7), and it corroborates past work which has seen publications to be a predictor of activity amongst specialized researchers (Dudo, 2013; Dudo et al., 2018). Looking closer at the current study, one important consideration is that the number of publications was not correlated with age (r = 0.108, p = 0.239), and only weakly correlated with career level (r = 0.157, p = 0.087). Although it seems reasonable to assume these other variables would always be closely related amongst scientists, that was not the case here, and this makes sense given the relatively novel nature of CRISPR. That is, since the technology has only existed for a decade, it is quite possible that younger scientists may be publishing as much or even more than older scientists who have familiarity with older approaches to gene modification.

Overall, researcher’s publications are likely to be relevant to their public communication in the sense that publications may lead to increased opportunities. That is, as one’s publications increase, so too does their status, which may ultimately lead to opportunities that simply did not exist before the higher status was obtained. This seems particularly true for gated media activities and face-to-face activities, which may hinge more on scientists being invited to participate. Yet, this study also saw significant associations between publications and the more autonomous self-directed media activities. Again, future research could attempt to replicate these findings with more studies focused on the CRISPR community, but the results presented here suggest that at a minimum, this variable should be collected when examining predictors of public communication activity and explored in their relation to other demographic variables.

Finally, in looking at the social psychological variables examined in RQ2, the current study found that social media browsing activity was positively associated with higher probabilities of participation in self-directed media activities, and that a scientists' proximity to science communication research was positively associated with higher probabilities of participation in face-to-face activities. (Table 7). Like age and sex, however, significant associations were only seen in seen one of three activity categories. To my knowledge, this is the first study to look at how both of these variables relate to a scientists' public communication. Perhaps most interestingly, proximity to science communication research exhibited the strongest effects of any independent variable (eB = 2.43, $p < 0.01$), albeit in a single category of activity. This result falls in line with a notion from Bennett and colleagues (2019) who summarized the extant research by emphasizing the frequent importance of social psychological variables (p. 11). Based on these findings, future research both within the CRISPR community and outside of it should continue investigating these variables and others relating to scientists' perceptions of the public. However, one recommendation for future work would be to use previously established measures of social media use. Indeed, in an effort to tailor the questionnaire to this specific population, the current study neglected to use previously validated indexes or scales which could have increased the reliability and validity of these findings. Moreover, even with the utmost reliability and validity, one difficulty presented by social psychological variables is parsing out the chronological nature of their relationship with public communication activity. For instance, with the methods presented here, we cannot know whether engagement with science communication research occurred before or after the researcher's participation in a public communication activity, which means we should be careful around what we label as a "predictor" of activity. Lastly, it should be mentioned here that RQ2 only investigated direct effects on the outcome variable despite the fact that indirect effects certainly exist (Dudo, 2013). Rather than dig deeper into these indirect effects, the current study instead focused on a second research question related to public communication objectives which will be discussed next, followed by this project's closing statements.

Intentions to Use Communication Objectives

Earlier in this chapter, I discussed some limitations around the inferential statistics used to analyze RQ3. Nevertheless, a descriptive approach to this data still yields interesting insights and recommendations for future work. More specifically, the most and least-intended objectives across each activity category exhibit noticeable trends. First and foremost, "Increasing factual knowledge and/or awareness" was ubiquitously the highest rated objective amongst all participant groups and all activity types (Figures 4-6). Indeed, these results are in in line with past studies (Besley, Dudo, & Yuan, 2018; Dudo & Besley, 2016) which have seen that scientists tend to prioritize deficit-model, education-related objectives. This is not necessarily surprising, however, given the norms of science communication and the novelty of CRISPR technology. Indeed, it seems a difficult task for a scientist to talk about CRISPR with lay audiences and not fall into the habit of explaining what the technology is, which primarily reflects the "informing" objective. This is an important consideration for those who may be making efforts to coax scientists into more creative and strategic forms of communication. There will always be novel developments like CRISPR, and scientists working in these emerging spaces may be particularly inclined to push back on the notion that increasing factual knowledge should not be the primary goal. Still, other objectives such as explaining risks, explaining benefits, framing issues, and boosting excitement should also involve the communication of factual information and it remains to be an interesting finding that this sample collectively ranked these objectives lower than the more neutral informing objective. Perhaps scientists are cognizant of coming on too strong in an advocacy role and are more or less hesitant to take a position one way or another. In such cases, the objective of increasing factual knowledge allows them a middle road in which they can uphold their traditional scientific ethos of ‘objectivity’.

Moving on, either listening to others’ concerns or explaining the risks of CRISPR research was the least-intended objective in five of the six group-activity combinations Thinking about what these two objectives have in common, I suggest these are both expressions of a scientist’s vulnerability. In this view, it is somewhat troubling that researchers using CRISPR consistently placed these objectives lower than all the others because vulnerability is key to earning trust with resistant audiences. Goodwin and Dahlstrom (2014) explain:

> Central to legitimated distrust is the audience’s calculation that the expert appears to have something to gain by being untrustworthy. Central to overcoming distrust is thus creating circumstances in which the expert manifestly has something to lose. (p. 155)

Indeed, listening to laypeople’s concerns about CRISPR and discussing its technological risk similarly puts scientists in a position where they have something to lose. By truly listening, a communicator accepts the possibility that they could ultimately be moved from their original position, and in discussing risks, they accept the possibility of losing support of the layperson.

Considering the social acceptance of CRISPR and other genetic technologies will inherently depend on public trust, these results point to a potential site of intervention. Using these objectives as a starting point, we might look to future investigations of scientists' willingness to be vulnerable. In turn, these could translate into practical applications for science communication trainers and practitioners.

Conclusions

Understanding the nature of scientists' participation in public life is important to those invested in genetic technologies like CRISPR, whose entrenchment with political, economic, and social dynamics has inspired loud demands for public engagement. Although a formidable amount of research has been dedicated to understanding both the frequency and form of scientists' public engagement broadly, less has focused specifically on contentious science domains. Indeed, this project is the first (to my knowledge) to exclusively survey researchers using CRISPR, and therefore hopes to serve as a type of starting point for future research.

The preceding chapters outlined the current study's context, aims, methods, and results. Despite some limitations, there are still important insights to be had both theoretically and methodologically. In particular, the fact that various factors exhibited significant associations with some forms of communication activity and not others hints at a possible explanation for previous mixed results. At the same time, the peculiarities of CRISPR or other contentious domains may yield results which are less aligned with samples derived from AAAS or other broad scientific collectives. Beyond the data presented here, science communication researchers may find both the sampling procedures outlined here and the questions raised around measurement to be useful in their future work. Overall, this should continue to be an exciting and important space for both scientists and communication scholars alike.

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TABLES

Table 1. Web of Science (WoS) filters used to generate the preliminary publications list (N=9,740).

Filter Category	Selection (include)
TOPIC	“CRISPR”
COUNTRY/REGION	USA
DOCUMENT TYPE	Article OR Meeting Abstract OR Early Access OR Review OR Letter OR Editorial Material OR Proceedings Paper
TIMESPAN	All years
INDEXES	SCI-EXPANDED, SSCI

Table 2. Final sample characteristics (N=120).

	N	%
Sex		
Male	82	68.3%
Female	38	31.7%
Race / Ethnicity		
White	94	78.3%
Asian	24	20.0%
Native American / Pacific Islander	1	0.8%
Hispanic	1	0.8%
Primary Application / Specialization		
Agriculture	10	8.3%
Medicine	69	57.5%
Food Science	1	0.8%
Industrial Biotechnology	6	5.0%
Environmental Science / Ecology	9	7.5%
General Knowledge	25	20.8%
Primary Institutional Affiliation		
Academia	108	90.0%
Industry	4	3.3%
Government	6	5.0%
Non-profit	2	1.7%
Career Level		
Student	0	0.0%
Junior (e.g., within 5 years of receiving last degree or first promotion)	20	16.7%
Mid-career (e.g., promotion to a higher-level position after junior status)	41	34.2%
Senior (e.g., achieving the highest promotion possible in your position)	59	49.2%
	120	100.0%

Table 3. Participation rates across 14 communication activities in 3 categories. (N = 120)

Gated media activities	**% Yes**
Issued a press release with the help of a public information officer (PIO) or any other communication specialist	36.7
Been interviewed for a written news story or magazine article (print or online)	44.2
Authored written works for public audiences at the request of a publisher, editor, or some other third party	21.7
Appeared on television, radio, or podcasts	21.7
Assisted in the production ("behind the scenes") of films, documentaries, TV shows, animations, or any other visual media intended for public audiences	11.7
Self-directed media activities	**% Yes**
Used a personal blog to talk about CRISPR and/or gene editing with public audiences	10.8
"Pitched" and subsequently published written works for public audiences in a print or online publication	17.5
Used platforms such as Facebook Live, YouTube, Vimeo, or something similar to independently produce videos for public audiences	6.7
Held Q & A or Ask Me Anything (AMA) events on Reddit, Voat, Quora, or any other online discussion forum	4.2
Created, hosted, or co-hosted a podcast	1.7
Face-to-face activities (given prepared talks at…)	**% Yes**
Sites of informal science education (e.g., libraries, zoos, aquariums, museums, science centers, national parks)	20.8
Primary schools (K-12)	20.0
Bars, restaurants, cafes, or other local businesses	10.8
Churches, synagogues, mosques, or other places of worship	5.0

Table 4. Communication objectives, as phrased in the survey questionnaire.

Objectives
Correct misinformation
Increase factual knowledge and/or awareness
Boost interest or excitement
Frame concepts or research findings in new ways
Listen to others' thoughts, feelings, or concerns about science
Build people's trust in the scientific community
Explain the risks associated with CRISPR research / development
Explain the benefits associated with CRISPR research / development

Table 5. Average intention to use communication objectives across 3 categories of communication activity (N=120).

Objective	Gated Media		Self-Directed Media		Face-to-face	
	Mean	SD	Mean	SD	Mean	SD
CORRECT	3.48	1.28	3.78	1.10	3.33	1.35
INFORM	4.23	0.91	4.43	0.75	4.36	0.81
EXCITE	3.97	1.00	4.17	0.96	4.17	0.99
FRAME	3.74	0.97	3.99	0.89	4.03	1.07
LISTEN	3.28	1.25	3.49	1.16	3.35	1.21
TRUST	3.87	1.14	4.14	0.86	3.50	1.28
RISKS	3.39	1.30	3.61	1.21	3.15	1.38
BENEFITS	3.98	1.13	4.13	0.99	3.83	1.19

Table 6. Continuous and dichotomous data for 3 categories of public communication (N=120).

Activity Category	Minimum	Maximum	Mean	SD	% YES
Gated Media (5)	0	5	1.36	1.61	50.0
Self-Directed Media (5)	0	3	0.41	0.76	28.3
Face-to-Face (4)	0	4	0.57	0.97	34.2
All activities (14)	0	10	2.33	2.65	65.8

Table 7. Multiple logistic regression examining associations with communication activity. Before-entry coefficients are reported in the left-hand column and final model coefficients are reported in the right-hand column, as odds ratios (eB). $^{\#}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. N=120.

	Gated		**SD**		**F2F**	
	before	after	before	after	before	after
Block 1: Demographics						
Sex (male is reference)	1.36	1.84	1.23	1.74	**1.96#**	**2.38#**
Age	0.99	0.99	0.99	1.01	0.97	**0.96#**
Incremental R^2 (%)		1.5		0.5		6.0#
Block 2: Status						
CRISPR years	1.10	0.99	0.91	0.83	1.10	1.03
CRISPR pubs	**1.15*** **	**1.15** **	1.06	**1.08***	**1.12** **	**1.15** **
Incremental R^2 (%)		**13.7** **		**5.5#**		**10.4** **
Block 3: SciComm Research & Media Use						
Proximity to SciComm Research	1.11	1.12	1.56	1.55	**2.43** **	**2.44** **
Print/Online News Readership (no is reference)	0.43	0.40	**0.33***	**0.29***	0.54	0.53
TV News Viewership (no is reference)	0.98	0.89	1.59	1.33	2.05	1.68
Facebook/Twitter Browsing	1.06	1.06	**1.13#**	**1.16#**	0.98	0.95
Incremental R^2 (%)		3.5		**11.5***		**10.5***
Block 4: Perceived Public Confidence						
Perceived Public Confidence	-	1.25	-	0.76	-	1.64
Incremental R^2 (%)		0.6		0.9		2.4
Final Equation R2 (%)		**19.3***		**18.4#**		**29.3*** **

Table 8. Three MANOVAs examining the effects of public communication activity on objective intentions. In each case, the means of active and inactive participants were compared across eight objectives.

Independent Variable (Yes / No)	**Wilk's Lambda**	**F**	**Hypothesis df**	**Error df**	**p-value**	**Partial Eta Squared**
Gated Media Activity	0.584	9.90	8	111	< 0.001	0.416
Self-Directed Media Activity	0.908	1.41	8	111	0.199	0.092
Face-to-Face Activity	0.925	1.13	8	111	0.348	0.075

Table 9. Mean comparisons between active and inactive participants in self-directed media activities. $^{\#}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. N=120.

	Active (N=34)		Inactive (N=86)					
	Mean	SD	Mean	SD	Mean Diff.	df	*t*	Sig. (2-tailed)
Correct	**2.93**	**1.27**	**4.03**	**1.02**	**1.10**	**118**	**5.21**	**< 0.001*** **
Inform	**3.95**	**0.98**	**4.52**	**0.72**	**0.57**	**118**	**3.60**	**< 0.001*** **
Excite	**3.73**	**1.10**	**4.20**	**0.82**	**0.47**	**118**	**2.63**	**0.010***
Frame	**3.58**	**1.03**	**3.90**	**0.90**	**0.32**	**118**	**1.80**	**0.075#**
Listen	**2.53**	**1.14**	**4.02**	**0.85**	**1.48**	**118**	**8.06**	**< 0.001*** **
Trust	**3.23**	**1.21**	**4.50**	**0.57**	**1.27**	**118**	**7.33**	**< 0.001*** **
Risk	**2.80**	**1.42**	**3.98**	**0.83**	**1.18**	**118**	**5.56**	**< 0.001*** **
Benefit	**3.65**	**1.33**	**4.30**	**0.77**	**0.65**	**118**	**3.29**	**0.001*** **

Table 10. Mean comparisons between active and inactive participants in self-directed media activities. $^{\#}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. N=120.

	Active (N=34)		Inactive (N=86)					
	Mean	SD	Mean	SD	Mean Diff.	df	*t*	Sig. (2-tailed)
Correct	**3.47**	**1.26**	**3.91**	**1.01**	**0.44**	**118**	**1.98**	**0.050#**
Inform	**4.21**	**0.81**	**4.51**	**0.72**	**0.31**	**118**	**2.03**	**0.044***
Excite	4.12	1.01	4.19	0.95	0.07	118	0.35	0.728
Frame	3.85	0.99	4.05	0.85	0.19	118	1.07	0.287
Listen	**3.12**	**1.15**	**3.64**	**1.14**	**0.52**	**118**	**2.26**	**0.026***
Trust	**3.85**	**1.02**	**4.26**	**0.77**	**0.40**	**118**	**2.35**	**0.021***
Risk	**3.12**	**1.45**	**3.80**	**1.05**	**0.68**	**118**	**2.87**	**0.016***
Benefit	3.91	1.24	4.22	0.86	0.31	118	1.56	0.122

Table 11. Mean comparisons between active and inactive participants in face-to-face activities. $^{\#}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$. N=120.

	Active (N=41)		Inactive (N=79)					
	Mean	SD	Mean	SD	Mean Diff.	df	*t*	Sig. (2-tailed)
Correct	3.46	1.25	3.25	1.41	-0.21	**118**	-0.81	0.422
Inform	4.39	0.77	4.34	0.83	-0.05	**118**	-0.31	0.757
Excite	4.37	1.04	4.06	0.95	-0.30	118	-1.60	0.113
Frame	**4.27**	**1.00**	**3.90**	**1.09**	**-0.37**	**118**	**-1.81**	**0.073#**
Listen	3.59	1.14	3.23	1.24	-0.36	**118**	-1.54	0.126
Trust	**3.80**	**1.25**	**3.34**	**1.28**	**-0.46**	**118**	**-1.90**	**0.061#**
Risk	3.20	1.38	3.13	1.38	-0.07	**118**	-0.26	0.797
Benefit	3.95	1.20	3.77	1.19	-0.18	118	-0.78	0.437

FIGURES

Figure 1. Three mechanisms of public engagement, as described by Rowe and Frewer (2005).

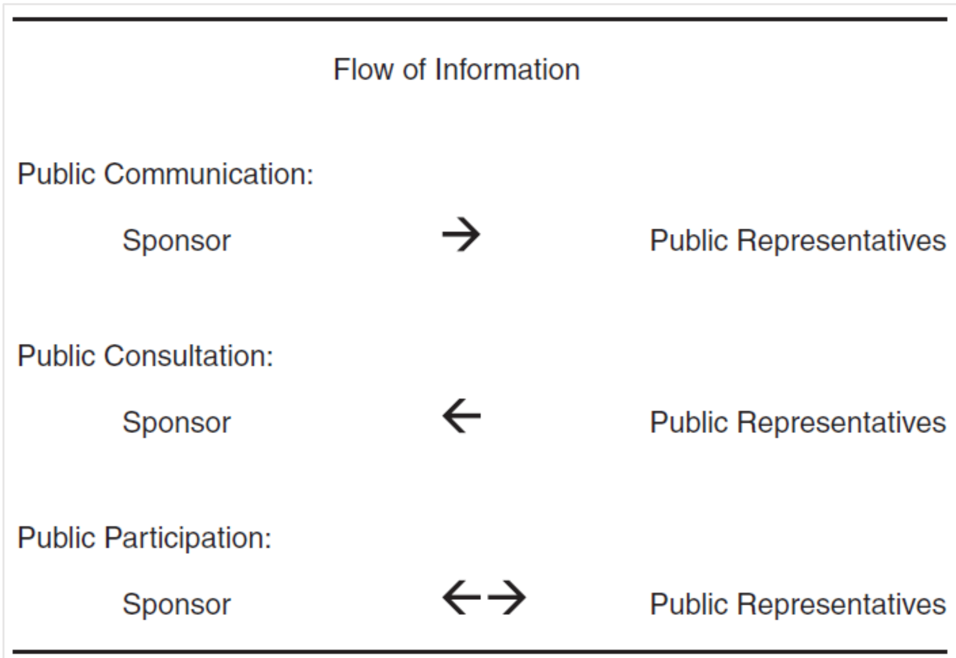


Figure 2. Probabilities of communication activity as a function of CRISPR publications.

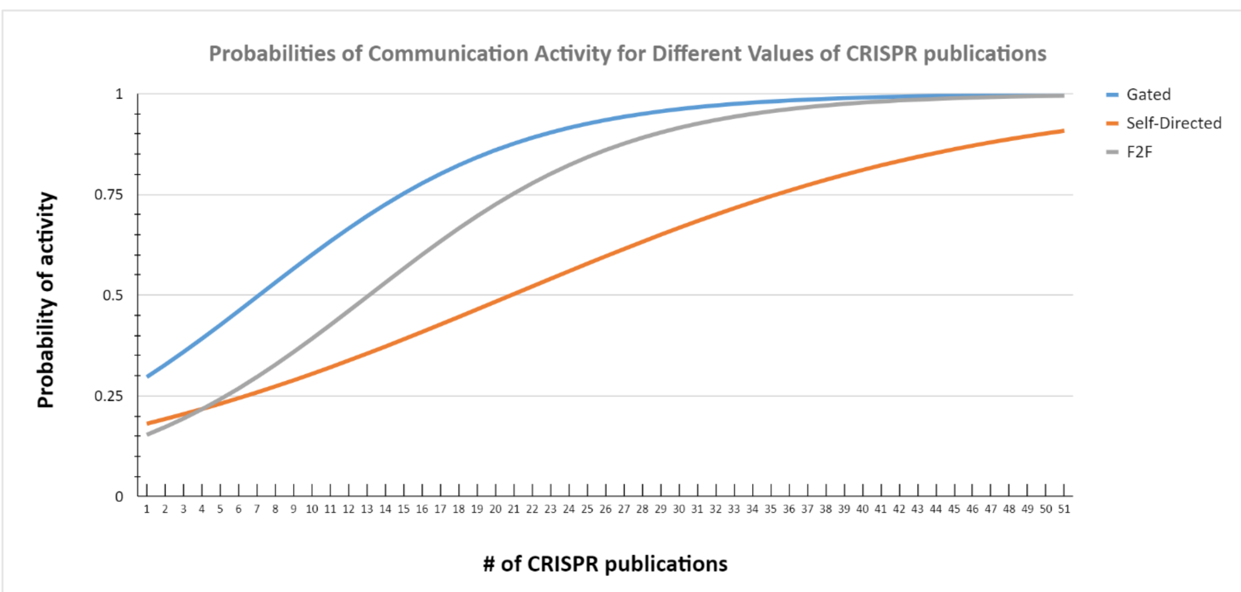
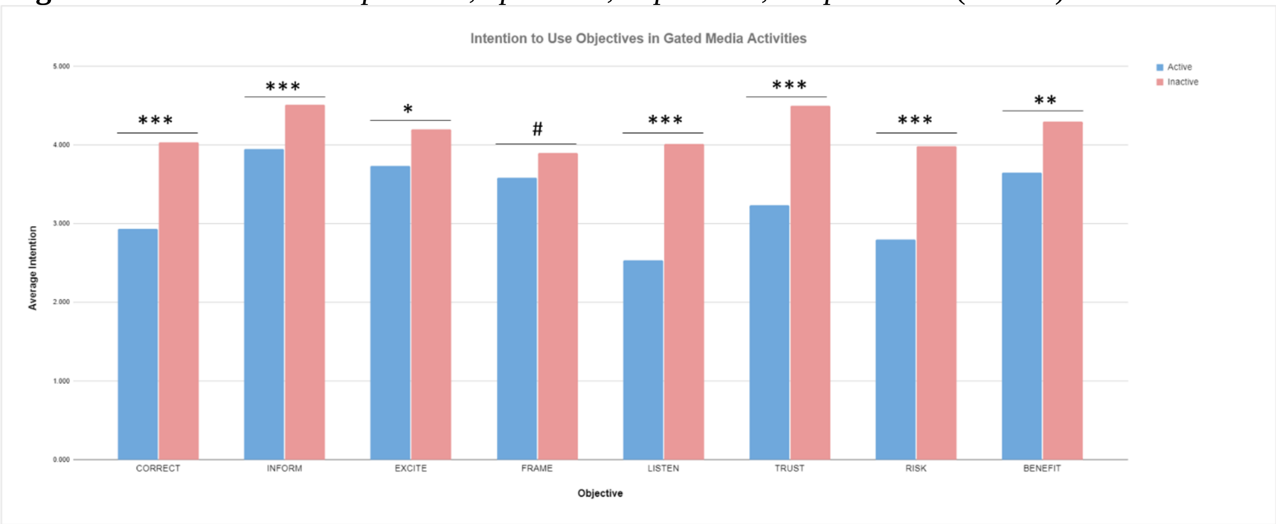


Figure 3. Active and inactive participants' intentions to perform communication objectives in gated media activities. #*p* < 0.10, **p* < 0.05, ***p* < 0.01, ****p* < 0.001 (N=120).



APPENDIX

SURVEY QUESTIONNAIRE

[BLOCK 1]
Thank you for your interest in participating in this project. This survey is for research purposes only. It is voluntary and you can stop at any time by closing the Qualtrics survey window.

You must be 18 years of age or older and reside in the United States to participate in this study. You must also have, at any point currently or in the past, conducted research related to CRISPR and/or gene editing.

There are minimal risks associated with your participation in this survey. Your survey responses will not be recorded with any direct identifying information such as your name or email address. Someone may be able to re-identify you indirectly based on your responses if they gained access to the original survey data; however, we will not share the completed surveys beyond the research team. Furthermore, all survey data will be published either as aggregated data or as themes—no quotes from surveys will be published in the reported data.

You will not receive any monetary compensation for its completion. If you wish to receive a copy of the published research results, please contact the primary investigator, Nolan Speicher, at nspeich@ncsu.edu and 319-415-8371 or the faculty advisor for this protocol, Dr. Andrew Binder (arbinder@ncsu.edu and 919-515-9750).

If you have any questions about the survey itself or how it is implemented, please contact Nolan Speicher (nspeich@ncsu.edu and 319-415-8371) and/or Andrew Binder (arbinder@ncsu.edu and 919-515-9750). Please reference study number 22332 when contacting anyone about this project.

If you have questions about your rights as a participant or are concerned with your treatment throughout the research process, please contact the NC State University IRB Director at IRB-Director@ncsu.edu, 919-515-8754, or fill out this confidential form online.

If you consent to the terms of this survey and would like to begin, please click "Yes, I consent" below and then click on the button to proceed to the questionnaire.

- Yes, I consent
- No, I do not consent

[BLOCK 2]
Thank you for your participation in this research! The first set of questions is about your general interest around the interaction between scientists and the public.

[Interest / Awareness]
How much **familiarity** do you have with the following terms / phrases?
- "Public understanding" of science and technology
- "Public engagement" with science and technology

  [5-point scale: None at all, Very little, Some, Quite a bit, A great deal]

How much **attention** do you pay to research on the following topics?

- Public understanding of science and technology
- Scientists' public engagement

[5-point scale: None at all, Very little, Some, Quite a bit, A great deal]

How much **confidence** do you have that scientists act in the best interests of the public?

[5-point scale: None at all, Very little, Some, Quite a bit, A great deal]

Now, take a moment to think about **the majority of scientists** in the United States. How much **confidence** do you think they have that scientists act in the best interests of the public?

[5-point scale: None at all, Very little, Some, Quite a bit, A great deal]

And take a moment to think more broadly about **the majority of adults** residing in the U.S. How much **confidence** do you think they have in scientists to act in the best interests of the public?

[5-point scale: None at all, Very little, Some, Quite a bit, A great deal]

[General media use]
The next set of questions involve your general use of media / information sources.

In the past week, did you read, watch, or listen to...

- Printed newspapers / magazines
- Online news / magazines for which you have a subscription
- Online news / magazines for which you do NOT have a subscription
- Fiction books
- Non-fiction books
- Podcasts
- Broadcast radio
- Local TV news
- National TV news / talk shows
- Reality TV
- Live sports or sports TV (e.g., ESPN)
- Educational or documentary TV / film
- Fictional TV / film (e.g., sitcoms)

[Checkboxes: yes, no]

Finally, do you have an account on the following social media platforms?

- Facebook
- Twitter
- Instagram
- Snapchat
- TikTok
- LinkedIn
- ResearchGate
- Other (specify)

[Checkboxes: yes, no]

[BLOCK 3 – RANDOM ASSIGNMENT] *50% of participants will see receive Block 3 here. The other 50% will receive Block 3 after Block 18, immediately prior to demographics section.*

The American Association for the Advancement of Science (AAAS) describes "public engagement" as intentional, meaningful interactions that provide opportunities for mutual learning between scientists and the public.

Which statement best describes how you feel about your current level of engagement with public audiences?

- I engage with public audiences too often
- My level of engagement with public audiences is "just right"
- I do not engage with public audiences enough

[Select one]

[BLOCK 4]

The next few pages are about your involvement in different kinds of public engagement activities.

First, I would like to ask about your participation in what I will refer to here as "gated" media activities. In these activities, scientists' communication is often initiated and/or mediated by a media professional (i.e., a "gatekeeper") who may or may not have competing interests.

Thinking only about communication activities that involved **<u>CRISPR and/or gene editing</u>**, have you ever...

- Issued a press release with the help of a public information officer (PIO) or any other communication specialist
- Been interviewed for a written news story or magazine article (print or online)
- Authored written works for public audiences at the request of a publisher, editor, or some other third party
- Appeared on television, radio, or podcasts
- Assisted in the production ("behind the scenes") of films, documentaries, TV shows, animations, or any other visual media intended for public audiences

[Checkboxes: yes, no]

[BLOCK 5] *seen by participants who select 1 or more "Yes" in Block 4*

Now, please take a moment to reflect on your most recent **<u>gated media activity</u>**. In this activity, to what extent did you **<u>intend</u>** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways

- Listen to others' thoughts, feelings, or concerns about science
- Build people’s trust in the scientific community
- Explain the <u>risks</u> associated with CRISPR research / development
- Explain the <u>benefits</u> associated with CRISPR research / development

  [5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

Still thinking about your most recent **<u>gated media activity</u>**, please indicate the extent you agree or disagree...

- This activity gave me insight into the concerns people have about science
- I felt enlightened by ideas shared by other participants in this activity
- This activity gave me a better understanding of how people think about the work scientists do
- This activity helped participants connect science to their everyday lives
- This activity provided me with an opportunity to learn from the broader community
- As a result of this activity, I believe participants will make more informed decisions using science

  [5-point scale: Strongly disagree to Strongly agree]

[BLOCK 6] *seen by participants who select all “No” in Block 4*

[Barriers]
You indicated that you have not participated in any "gated" media activities. Which of the following statements best describes why?

- This activity is not important / useful
- I would not enjoy this activity
- I do not possess the necessary skills / training
- I do not have time
- I do not have institutional support / approval
- Other (please specify)

  [Select one]

[Hypotheticals]
Now, I would like you to imagine that you are invited to participate in a gated media activity (e.g., a television interview) **<u>tomorrow</u>**. In this scenario, to what extent might you **<u>intend</u>** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people’s trust in the scientific community
- Explain the <u>risks</u> associated with CRISPR research / development
- Explain the <u>benefits</u> associated with CRISPR research / development

  [5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

[BLOCK 7]

Next, I would like to ask about your past participation in what I will refer to here as "self-directed" media activities. Compared to the previous group, these activities are more often initiated by scientists and, in general, involve less mediation by third parties.

Thinking only about communication activities that involved **<u>CRISPR and/or gene editing</u>**, have you ever...

- Used a personal blog to talk about CRISPR and/or gene editing with public audiences
- "Pitched" and subsequently published written works for public audiences in a print or online publication
- Used platforms such as Facebook Live, YouTube, Vimeo, or something similar to independently produce videos for public audiences
- Held Q & A or Ask Me Anything (AMA) events on Reddit, Voat, Quora, or any other online discussion forum
- Created, hosted, or co-hosted a podcast

[Checkboxes: yes, no]

[BLOCK 8] *seen by participants who select 1 or more "Yes" in Block 7*

Now, please take a moment to reflect on your most recent self-directed media activity. In that activity, to what extent did you **<u>intend</u>** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the <u>risks</u> associated with CRISPR research / development
- Explain the <u>benefits</u> associated with CRISPR research / development

[5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

Still thinking about your most recent **<u>self-directed media activity</u>**, please indicate the extent you agree or disagree...

- This activity gave me insight into the concerns people have about science
- I felt enlightened by ideas shared by other participants in this activity
- This activity gave me a better understanding of how people think about the work scientists do
- This activity helped participants connect science to their everyday lives
- This activity provided me with an opportunity to learn from the broader community
- As a result of this activity, I believe participants will make more informed decisions using science

[5-point scale: Strongly disagree to Strongly agree]

[BLOCK 9] *seen by participants who select all "No" in Block 7*

[Barriers]
You indicated that you have not participated in any "self-directed" media activities. Which of the following statements best describes why?

- This activity is not important / useful
- I would not enjoy this activity
- I do not possess the necessary skills / training
- I do not have time
- I do not have institutional support / approval
- Other (please specify)
  [Select one]

[Hypotheticals]
Now, I would like you to imagine that you are invited to participate in a self-directed media activity (e.g., authoring a blog post) **tomorrow**. In this scenario, to what extent might you **intend** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the risks associated with CRISPR research / development
- Explain the benefits associated with CRISPR research / development
  [5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

[BLOCK 10] *seen by participants with Facebook accounts, but not Twitter (see Block 2). Will also be randomly distributed to 50% of participants who have both Facebook AND Twitter accounts.*

Still thinking about "self-directed" media activities, a common example is a scientist engaging with public audiences on social media. The next set of questions relate to your activity on Facebook.

In a typical week, on how many days do you do the following activities on Facebook?

- Browse your News Feed
- View content involving CRISPR and/or gene editing
- Share content involving CRISPR and/or gene editing
- Post original content involving CRISPR and/or gene editing (including writing a caption while sharing)
- Engage in back-and-forth conversations / debates about CRISPR and/or gene editing
  [7-point scale: 0 - 7 days]

[BLOCK 11] *seen by participants who select "1" or more days on items 3-5 in Block 10*

Now, please take a moment to reflect on your most recent activity on **Facebook** involving CRISPR and/or gene editing. In that activity, to what extent did you **intend** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the risks associated with CRISPR research / development
- Explain the benefits associated with CRISPR research / development

[5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

Still thinking about your most recent activity on **Facebook** involving CRISPR and/or gene editing, please indicate the extent you agree or disagree...

- This activity gave me insight into the concerns people have about science
- I felt enlightened by ideas shared by other participants in this activity
- This activity gave me a better understanding of how people think about the work scientists do
- This activity helped participants connect science to their everyday lives
- This activity provided me with an opportunity to learn from the broader community
- As a result of this activity, I believe participants will make more informed decisions using science

[5-point scale: Strongly disagree to Strongly agree]

[BLOCK 12] *seen by participants who select all "0" on items 3-5 in Block 10*

[Barriers]
You indicated that you do not frequently discuss CRISPR and/or gene editing on Facebook. Which of the following statements best describes why?

- This activity is not important / useful
- I would not enjoy this activity
- I do not possess the necessary skills / training
- I do not have time
- I do not have institutional support / approval
- Other (please specify)

[Select one]

[Hypotheticals]
Now, I would like you to imagine that you are discussing CRISPR and/or gene editing on Facebook **tomorrow**. In this scenario, to what extent might you **intend** to...

- Correct misinformation
- Increase factual knowledge and/or awareness

- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the <u>risks</u> associated with CRISPR research / development
- Explain the <u>benefits</u> associated with CRISPR research / development
  [5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

[BLOCK 13] *seen by participants with Twitter accounts, but not Facebook (see Block 2). Will also be randomly distributed to 50% of participants who have both Facebook AND Twitter accounts.*

Still thinking about "self-directed" media activities, a common example is a scientist engaging with public audiences on social media. The next set of questions relate to your activity on Twitter.

In a typical week, on how many days do you do the following activities on **<u>Twitter?</u>**
- Browse your Twitter feed
- View content involving CRISPR and/or gene editing
- Retweet or quote-tweet content involving CRISPR and/or gene editing
- Post original content involving CRISPR and/or gene editing (including writing a caption while retweeting)?
- Engage in back-and-forth conversations / debates about CRISPR and/or gene editing?
  [7-point scale: 0 - 7 days]

[BLOCK 14] *seen by participants who select "1" or more days on items 3-5 in Block 13*

Now, please take a moment to reflect on your most recent activity on Twitter involving CRISPR and/or gene editing. In that activity, to what extent did you **<u>intend</u>** to...
- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the <u>risks</u> associated with CRISPR research / development
- Explain the <u>benefits</u> associated with CRISPR research / development
  [5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

Still thinking about your most recent activity on **<u>Twitter</u>** involving CRISPR and/or gene editing, please indicate the extent you agree or disagree...
- This activity gave me insight into the concerns people have about science
- I felt enlightened by ideas shared by other participants in this activity

- This activity gave me a better understanding of how people think about the work scientists do
- This activity helped participants connect science to their everyday lives
- This activity provided me with an opportunity to learn from the broader community
- As a result of this activity, I believe participants will make more informed decisions using science

[5-point scale: Strongly disagree to Strongly agree]

[BLOCK 15] *seen by participants who select all "0" on items 3-5 in Block 13*

[Barriers]

You indicated that you do not frequently discuss CRISPR and/or gene editing on Twitter. Which of the following statements best describes why?

- This activity is not important / useful
- I would not enjoy this activity
- I do not possess the necessary skills / training
- I do not have time
- I do not have institutional support / approval
- Other (please specify)

[Select one]

[Hypotheticals]

Now, I would like you to imagine that you are discussing CRISPR and/or gene editing on Twitter **tomorrow**. In this scenario, to what extent might you **intend** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the risks associated with CRISPR research / development
- Explain the benefits associated with CRISPR research / development

[5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

[BLOCK 16] *Seen by participants with no Facebook/Twitter accounts (see Block 2).*

Still thinking about "self-directed" media activities, a common example is a scientist engaging with public audiences on social media.

[Barriers]

You indicated that you do not have a Facebook or Twitter account, and therefore do not frequently discuss CRISPR and/or gene editing on these platforms. Which of the following statements best describes why?

- This activity is not important / useful
- I would not enjoy this activity
- I do not possess the necessary skills / training
- I do not have time
- I do not have institutional support / approval
- Other (please specify)
  [Select one]

[Hypotheticals]
Now, I would like you to imagine that you are discussing CRISPR and/or gene editing on Facebook or Twitter **tomorrow**. In this scenario, to what extent might you **intend** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the risks associated with CRISPR research / development
- Explain the benefits associated with CRISPR research / development
  [5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

[BLOCK 17]

Finally, I would like to ask you about a fourth group of activities. These are referred to by the American Association for the Advancement of Science (AAAS) as "large group encounters" and are generally characterized as events or gatherings in which a scientist speaks face-to-face with an audience of more than 10 people.

Thinking only about communication activities that involved **CRISPR and/or gene editing**, have you ever given prepared talks to an audience at the following locations?

- Colleges or universities
- Sites of informal science education (e.g., libraries, zoos, aquariums, museums, science centers, national parks)
- Primary schools (K-12)
- Bars, restaurants, cafes, or other local businesses
- Churches, synagogues, mosques, or other places of worship
- Governmental buildings (e.g., for public hearings or other policy-informing events)
  [Checkboxes: yes, no]

[BLOCK 18] *seen if participants select 1 or more "Yes" in Block 17*

Now, please take a moment to reflect on your most recent large group encounter. In that activity, to what extent did you **intend** to...

- Correct misinformation
- Increase factual knowledge and/or awareness

- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the <u>risks</u> associated with CRISPR research / development
- Explain the <u>benefits</u> associated with CRISPR research / development

[5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

Still thinking about your most recent **<u>large group encounter</u>** involving CRISPR and/or gene editing, please indicate the extent you agree or disagree...

- This activity gave me insight into the concerns people have about science
- I felt enlightened by ideas shared by other participants in this activity
- This activity gave me a better understanding of how people think about the work scientists do
- This activity helped participants connect science to their everyday lives
- This activity provided me with an opportunity to learn from the broader community
- As a result of this activity, I believe participants will make more informed decisions using science

[5-point scale: Strongly disagree to Strongly agree]

[BLOCK 19] *seen if participants select all "No" in Block 17*

[Barriers]

You indicated that you have not participated in any "large group encounters". Which of the following statements best describes why?

- This activity is not important / useful
- I would not enjoy this activity
- I do not possess the necessary skills / training
- I do not have time
- I do not have institutional support / approval
- Other (please specify)

[Select one]

[Hypotheticals]

Now, I would like you to imagine that you are invited to participate in a large group encounter (e.g., a lecture at a science center) **<u>tomorrow</u>**. In this scenario, to what extent might you **<u>intend</u>** to...

- Correct misinformation
- Increase factual knowledge and/or awareness
- Boost interest or excitement
- Frame concepts or research findings in new ways
- Listen to others' thoughts, feelings, or concerns about science
- Build people's trust in the scientific community
- Explain the <u>risks</u> associated with CRISPR research / development

- Explain the <u>benefits</u> associated with CRISPR research / development
  [5-point scale: Not at all, Very little, Some, Quite a bit, A great deal]

[BLOCK 3 – RANDOM ASSIGNMENT] *50% of participants will see receive Block 3 here. The other 50% will receive Block 3 after Block 2, as outlined above.*

The American Association for the Advancement of Science (AAAS) describes "public engagement" as intentional, meaningful interactions that provide opportunities for mutual learning between scientists and the public.

Which statement best describes how you feel about your current level of engagement with public audiences?

- I engage with public audiences too often
- My level of engagement with public audiences is "just right"
- I do not engage with public audiences enough
  [Select one]

[BLOCK 20]

That finishes up the questions about your public engagement activities. To close, I would like to know a little more about your background.

In what year were you born?
[Dropdown list (1900 - 2020]

What is your biological sex?
[Checkboxes: Male, Female, Prefer not to say]

The terms "liberal" and "conservative" may mean different things to different people depending on the issue one is considering. How would you describe your views in terms of…?

- Economic issues
- Social issues

[5-point scale: Very liberal to very conservative]

What is your race? (Select all that apply.)
[Options: White or Caucasian, Black or African American, Asian, Native American or Pacific Islander]

What is your ethnicity?
[Options: Hispanic, non-Hispanic]

Please enter the best estimate of your total publications involving CRISPR and/or gene editing.
[Open-ended, numbers only]

Which term best describes your current research level?

- Student

- Junior (e.g., within 5 years of receiving your last degree or before your first promotion)
- Mid-career (e.g., promotion to a higher-level position after junior status)
- Senior (e.g., achieving the highest promotion possible in your position)
  [Select one]

In what year did you start using or investigating CRISPR?
[Dropdown list (1900 – 2020)]

Which of the following CRISPR application areas are you working in currently?
- Agriculture
- Medicine
- Food science
- Industrial biotechnology
- Environmental / Ecological
- Other (please specify)___________

[Select one or multiple]

Which would you consider to be your **primary** application? (select one)
- Agriculture
- Medicine
- Food science
- Industrial biotechnology
- Environmental / Ecological
- Other (please specify)___________
  [Select one]

Which of the following institutional settings are you affiliated with currently?

- Academia
- Industry
- Government
- Other (please specify)___________

[Select one or multiple]

Which would you say is your current **primary** affiliation? (select one)
- Academia
- Industry
- Government
- Other (please specify)___________
  [Select one]

[Custom End of Survey Message]
Your responses have been submitted. Thank you for the time and energy you have devoted to this project—it is greatly appreciated. Remember, if you would like to receive a copy of the published research results, please contact the primary investigator, Nolan Speicher, at nspeich@ncsu.edu, or the faculty advisor for this protocol, Dr. Andrew Binder, at

arbinder@ncsu.edu. I wish you nothing but the best in your future research and public communication efforts. Sincerely, [email signature].