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Understanding high-achieving publicly engaged scientists' commitment to engage: push, pull, and drag forces

Niveen AbiGhannam and Anthony Dudo

Abstract

This paper takes an ecological approach to examine the public engagement with science (PES) pressures and expectations perceived by publicly engaged scientists. Interviews with high-achieving, publicly engaged scientists reveal that unidirectional factors within science (*push forces*) and engagement (*pull forces*) contexts drive them towards PES. Running counter to those are *drag forces*, or pressures not to engage. Our analyses reveal that high-achieving publicly engaged scientists mitigate those pressures through employing certain engagement strategies, such as by overproducing academic research and selectively sharing PES news with institutions and colleagues. Findings enrich our understanding of the complex operation of norms in the ever-changing PES landscape.

Keywords

Public engagement with science and technology; Public engagement norms

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Context

Scientists' perceptions of public engagement with science (PES) widely range from believing it is a continuation of the academic practice of science [Poliakoff and Webb, 2007] to an insignificant task that can be detrimental to a scientist's career [Ecklund, James and Lincoln, 2012; Russo, 2010; Royal Society, 2006]. Behavioral research shows that an individual's perception of norms is a strong predictor of behavioral intentions and/or outcomes [Cialdini, Reno and Kallgren, 1990; Bicchieri and Xiao, 2009; Rimal and Real, 2005]. However, in PES research, results have been mixed. Whereas some studies show correlations between norms and scientists' PES behaviors [Besley, 2015; Dudo, 2013; Dudo, Besley et al., 2018], other studies find no such effects [e.g., Copple et al., 2020; Besley, Dudo and Yuan, 2018]. Therefore, the processes by which norms operate in the context of PES are still not fully understood [Copple et al., 2020; Martinez-Conde, 2016].

Two forms of norms are typically explored in social science: descriptive, which refer to what is normally done by others; and injunctive, which refer to what should be done, or whether others approve of a particular behavior [Schwartz,

1973; Cialdini, Reno and Kallgren, 1990]. Both types of norms have been found to influence behavioral outcomes [Cialdini, Reno and Kallgren, 1990; Bicchieri and Xiao, 2009; Rimal and Real, 2005]. Additionally, those two forms of norms can have interactive effects [Schultz et al., 2018]. Past research has examined the role of norms in PES as a deliberate behavior. Specifically, the Theory of Planned Behavior (TPB), which explains how attitudes, norms, and self-efficacy can determine behavioral intentions and outcomes [see Ajzen, 1991], has been widely applied in PES contexts. However, while the theory has consistently supported the role of attitudes and self-efficacy in engagement behaviors [e.g. Besley, Dudo, Yuan and Lawrence, 2018; Dudo, 2013; Dudo, Besley et al., 2018; Dunwoody, Brossard and Dudo, 2009; Poliakoff and Webb, 2007; Yuan, Besley and Dudo, 2019], the role of norms has been inconclusive [e.g. Copple et al., 2020; Dudo, Besley et al., 2018; Dudo, Kahlor et al., 2014; Besley, 2015; Besley, Dudo and Yuan, 2018; Tiffany et al., 2022].

Typically, measuring norms in PES survey research involves asking Likert-scale questions such as: "I do more engagement than scientists in my field" and "My science colleagues find my engagement work to be valuable". While those questions allow researchers to measure descriptive and injunctive norms, they do not capture the complexity, heterogeneity, and shifting nature of the overall PES landscape. In this paper, we examine the role of norms in PES behaviors considering two main trends that are often reported in PES literature: 1) the ambiguous and shifting perceptions of what other scientists think about PES and 2) the heterogeneous and shifting context within which scientists engage.

What other scientists think: ambiguous perceptions

One way to explore the complexity of understanding scientists' perceptions of PES is to explore literature on the "Sagan Effect" — the perception that scientists who are publicly engaged make fewer scientific contributions [Hartz and Chappell, 1997]. Despite efforts to normalize and promote the notion that it is a scientist's responsibility to communicate scientific knowledge with the public [Royal Society, 2006] and to reward it in grant proposals [National Science Foundation, 2002], many scientists still hold the belief that public engagement is done by scientists who are "not good enough for an academic career" [Royal Society, 2006, p. 11].

Carl Sagan's biographers challenge this perception and in fact document a trend in Sagan's academic productivity that runs counter to the effect named after him. Throughout his career (1957–1996), Sagan averaged one peer-reviewed paper per month, yet he was denied tenure at Harvard and a nomination to the National Academy of Sciences [Shermer, 1999; Shermer, 2002]. Shermer [2002] stated that "[T]he 'Sagan Effect', at least when applied to Sagan himself, is a Chimera". This effect is also empirically challenged. In a large 2008 survey of French scientists, scientists who engage with society were found to produce more academically than average scientists [Jensen, Rouquier et al., 2008]. Bentley and Kyvik [2011] also looked at academic productivity and public engagement across 13 countries and found a positive relationship between popular science writing and academic publishing.

Anecdotally, few vocal scientists have also documented their own accounts of how they were penalized by their institutions for their PES work. For instance, in a blog

post that was later published in Discover Magazine, Sean Carroll [2011], who had previously done engagement work and was denied tenure at an R1 University, advised scientists against participating in nonacademic "hobbies" that may resemble academic duties, such as PES. According to Carroll, the ideal scientist pursues knowledge in the lab and shares knowledge in academic circles. While academics admire hobbies such as "skydiving" and "cooking", they perceive other activities that resemble academic work, such as publishing nonacademic work or managing a side business, to take away time from doing real science.

Martinez-Conde [2016] also shared her account as a commentary in the *Journal of Neuroscience*. Despite her high productivity (publishing 13 academic papers and several book chapters in 12 months), she was told in her annual review that her publishing rate is "stellar", yet unbalanced — she had also published 29 popular science articles that same year. Martinez-Conde [2016] felt that had she not included her popular science record at all, she would have received more positive feedback, which inspired her to look at a sample of mainstream neuroscientists that engage in prestigious science communication efforts. Her inquiry revealed that although scientists generally reported no net penalty or reward on their careers — consistent with findings from Jensen, Rouquier et al. [2008] and Peters [2013] — the few who did described detrimental penalties, such as grant rejections, scrutinized and diminished public profiles, and declined nominations for tenure and prestigious titles despite high productivity.

The ambiguity of how PES is viewed by other academics is further intensified when considering the rewards offered by prestigious scientific organizations to scientists who engage the public with science, such as through calls for proposals that integrate and value broader participation in research (e.g., The National Science Foundation [NSF], The Royal Society Public Engagement Fund, etc.) and awards and prizes that acknowledge those who pursue public engagement and outreach (e.g. the National Academies of Sciences, the AAAS award for public engagement with science, and The Royal Society of Biology outreach and engagement awards, etc.).

It therefore seems that forces in the PES landscape are consistently pulling scientists in opposite directions ranging from severe career penalties to prestigious rewards. Rödder [2012], for instance, looked to qualitatively determine ways by which the scientific community evaluates whether a scientist's public visibility is appropriate. Rodder found such approval to be conditional upon whether a scientist who engages has: (1) credible scientific work; (2) a prominent institutional role; and (3) reactive, rather than proactive, tendencies to engage (meaning the scientist was approached by the media and did not personally initiate the contact).

Therefore, anticipating the impacts of a scientist's engagement activity — whether positive, negative, or neutral — is difficult to quantify and understand. This ambivalence obfuscates the roles that norms play in relation to PES behaviors. This scenario is typified in the cases of Carroll [2011] and Martinez-Conde [2016], both of whom simultaneously perceive tangible benefits and detriments associated with their public engagement efforts. Therefore, there are ways by which those scientists balance the effects of negative norms with other benefits and rewards that are yet to be understood.

A heterogeneous PES context: applying Bourdieu's Theory of Practice to PES

In order to help understand PES as a practice, we draw on Bourdieu's [1977] Theory of Practice, which determines how social and contextual factors can influence individual and group roles and behaviors. In essence, the theory of practice posits that social change can only be achieved once an individual realizes that what appears to be "natural" is in reality built through habit, or "practice" [Brubaker, 1993, p. 217]. In other words, the theory of practice explains how individuals in certain fields are often more focused on the reproduction of existing practices in their field rather than inducing change.

Studies applying Bourdieu's theory of practice have found that behaviors can either conform to social structures or deviate from them. In particular, research that applies notions of social conventions, hierarchies, and orders have shown that individuals adhere to social norms when attempting to join social contexts, including educational settings [e.g., Fleetwood, 2008; Kane, 2011], social and organizational institutions [e.g., Zembylas, 2007; O'Mahoney, 2007], neighborhood initiatives [e.g., Alaimo, Reischl and Ober Allen, 2010], and consumption behaviors [e.g., Demant and Järvinen, 2011; Üstüner and Thompson, 2012].

Research, however, also shows that if individuals prioritize attaining personal goals, they are more likely to challenge those social norms. For instance, Hills [2006] described a case of a group of teen girls who defied norms and chose to participate in physical sports. Butler [1997a] and Butler [1997b] explained such defiance through the concept of 'reiterative performances', which posits that social norms are normally replicated in society (similar to Bourdieu). However, those reproductions are not always identical, and they are subject to forms of self-expression [Lovell, 2003]. Therefore, the influence of social norms on behaviors can be dampened by a perception that individual goals and self-expression are more important than maintaining social order.

The application of Bourdieu's theory of practice to understand the field of science engagement has been limited. AbiGhannam [2016] applied Bourdieu to understand the social norms and expectations that female science communication opinion leaders experience in online platforms. She found that the roles and responsibilities that women experience were varied across different typologies of women with normative impacts being more pronounced for communicators who seek to have the role of an activist or an edutainer than communicators who use online science communication as a form of self-expression.

Additionally, Jensen and Wagoner [2009], and later Jensen and Holliman [2016], drew on Bourdieu's theory of practice to develop an augmented field-specific model of social change to understand the way norms and values are developed and negotiated among science engagement practitioners. Specifically, they applied the concept of doxa, or the "common sense" conventions within a field, to the context of science engagement and integrated a cyclical model of social change [Castro and Batel, 2008] and field-specific theorization of science engagement [Irwin, 2008]. Although Bourdieu's theory of practice indicates uniform doxa within a field, Jensen and Holliman [2016] reported a heterogeneous context and divergent doxa among U.K. engagement practitioners where contradictory definitions of public engagement continue to co-exist. Given the heterogeneous

nature of science and science engagement, Jensen and Holliman [2016] raised the idea of 'hybrid' doxa within a changing and partially hybridized field of practice.

In retrospect, social science inquiries in PES contexts have mainly looked at norms from an organizational perspective, specifically using institutional or network frameworks, that are contingent on the type of organization to which a science communicator belongs. For instance, science journalists are more likely to hold journalistic norms of objectivity, which can in fact irritate scientists who believe that balance is not as relevant to describing science [Nelkin, 1987]. Instead, scientists operate based on norms pertaining to academic institutions, which may sometimes feel misaligned with the scientist communicator identity that they may try to establish. For example, scientists who blog worry about being negatively perceived by their academic colleagues [Tribble, 2005a; Tribble, 2005b]. In effect, they try to integrate science advocacy norms to communication instances [Trench, 2012] and frame their efforts as means through which to normalize the work of science [Wilkins, 2008]. Additionally, scientist communicators who join online engagement communities, such as on social media or blogs, are expected to apply the online groups' norms [Dennen, 2014]. Anonymous bloggers gain credibility by rigorously maintaining factual norms and group norms in their online networks in order to get endorsed by the larger science communication community [Riesch and Mendel, 2014]. Those varying pressures and norms are important to further explore in order to capture the complexity of the 'hybridized doxa' found by Jensen and Holliman [2016].

Additionally, survey research on PES often misses the opportunity to fully untangle the complexities of evolving norms by trying to take a snapshot or average of norms within and across individuals and fields. Observing nuances in how norms operate in different scientists to influence PES behaviors, Dudo [2013] suspected certain cultural and social moderators influencing such interactions. Such factors need to be thoroughly explored through comprehensive qualitative inquiries.

Objective and organizational framework

This study uses an ecological approach to understand the normative forces that enable high achieving, publicly engaged scientists to commit to PES behaviors. Our sample was recruited from a select group of publicly engaged scientists who either applied to, were shortlisted for, or won a prestigious PES award. In order to understand the PES landscape with all its complexities, we use the ecological approach as an organizational framework for our qualitative inquiry.

An ecological approach

The ecological systems theory (or the ecology of human development) was developed by Urie Bronfenbrenner [1977; 1979] to explain human behaviors and development in terms of interactions among the individual and the context. The model posits that one's perceptual experiences are formed in response to knowledge propagated through one's environment. Through filtering specific and relevant information from the environment, individuals form perceptions that are primarily aimed at executing certain behaviors [Kim, 2006].

Bronfenbrenner [1977]'s ecological approach posits that the context in which people live, which involves internal and external knowledge, involves interactions

across "nested" dimensions that determine behavioral outcomes: the *microsystem* (includes one's interactions with his/her direct surroundings [e.g., family, place of worship, etc.]); the *mesosystem/exosystem* (includes the associations between different concurrent microsystems [e.g., the interrelation between a student's school and family] as well as the interaction between one's mesosystem and specific social structures [e.g., mass media, society, politics, etc.]); and finally, the *macrosystem* (includes overarching institutional systems [e.g., economic, social, educational, legal, and political systems]). In essence, the contexts at each level, along with the interactions across all levels, determines an individual's behavior and development. Thus, the theory represents a natural qualitative inquiry to reveal aspects of human truth and development [Salkind, 2006]. In essence, this scientific approach emphasizes the interrelationship of personal and contextual experiences in the course of human development [Bronfenbrenner, 2005; Darling, 2007].

In this study, we use the ecological model to examine how high-achieving publicly engaged scientists perceive and balance pressures (norms) and benefits (impacts/expectations) associated with PES behaviors. We examine these pressures and benefits at three levels: social, organizational, and individual. This integrated approach helps us to untangle the heterogeneous contexts in which norms operate and how normative roles are negotiated in PES behaviors. Below, are the core research questions that guide this study.

RQ 1: To what extent do high-achieving publicly engaged scientists experience contradictory PES pressures and benefits on the individual, institutional, and social levels (i.e., the pressures to not communicate with the public vs. the perceived benefit of communicating with the public)?

RQ 2: In what ways do high-achieving publicly engaged scientists mitigate such pressures in favor of PES behavioral outcomes?

Methods

This study examines the social, organizational, and individual pressures and benefits that high-achieving publicly engaged scientists experience. We define high-achieving publicly engaged scientists as scientists who are perceived by themselves and/or by others to demonstrate excellence and achievement in public engagement with science activities. We therefore recruited the participants in this study from the applicants, finalists, and awardees of a prestigious public engagement with science for early-career scientists. In phase I of the study, we interviewed the finalists and winners of the award to extract themes regarding how they balance those pressures. Then in phase II, we surveyed the pool of applicants to validate our interview findings.

Phase I

In phase I, we looked into the PES experiences of 13 high-achieving publicly engaged scientists who were recruited from the finalists and awardees of a prestigious U.S.-based early-career PES award. The semi-structured interviews focused on attaining a comprehensive understanding of PES experiences and perspectives of this group of high-achieving publicly engaged scientists who are in

their early scientific careers. The PI contacted the five winners and fifteen randomly chosen finalists from when the award was established (2010) and the following five award cycles. All winners agreed to be interviewed along with 8 of the finalists. Interviews were conducted in November of 2015.

Interviews started with broad descriptive questions that asked respondents to talk briefly about themselves. Such practice allows participants to start talking freely and get comfortable with the conversation [Spradley, 1979]. Participants were then asked about how they developed their interest in science and in PES, their public engagement roles, goals and motivations, as well as the types of public engagement activities that they lead in terms of the topics covered, audiences targeted, etc.

The remaining questions focused on the perceived individual, institutional, and societal benefits and pressures. For instance, participants were asked about the impact that they expect PES to have on personal (e.g., confidence, skills, reputation, career, etc.), organizational (e.g., impact on their institution, relationship with colleagues, etc.), and societal (e.g., impact on society at large) levels. In parallel, participants also were asked about the pressures they experience in the form of personal limitations and priorities, institutional norms from their colleagues and institutions, and social norms from society at large.

Table 1 lists the pseudonyms of the informants as they will be referred to in this paper. The sample consisted of 13 participants: seven males and six females. Five of the informants received the prestigious award for the years 2010–2014, and the remaining eight were finalists in the same years. The average age of the informants was 37, and ages ranged from 33 to 43. In terms of ethnicity, nine informants were white (~69%), two were African American (~15%), one was Hispanic (~8%), and one was Southeast Asian (~8%). This sample is slightly more diverse than an average U.S. degree-granting postsecondary institution. According to the National Center for Education Statistics [2020], 75% of full-time postsecondary faculty are white, 12% are Asian/Pacific Islanders, 6% are Black, 6% are Hispanic, and about 1% are American Indian/Alaska Natives.

Table 1. Demographics of the informants.

Pseudonym	*Gender*	*Ethnicity*	*Career level*
Mason	M	African American	Associate Professor
Thomas	M	Caucasian	Senior Research Fellow
Carter	M	African American	Associate Professor
Nancy	F	Caucasian	Associate Professor
Brigitte	F	Caucasian	Postdoc
Eli	M	Caucasian	Associate Professor
Eric	M	Caucasian	Assistant Professor
Laura	F	Caucasian	Postdoc
Olivia	F	Caucasian	Research Science Museum Curator
Kevin	M	Caucasian	Associate Professor
Thelma	F	Southeast Asian	Associate Professor
Eddie	M	Hispanic	Associate Professor
Zara	F	Caucasian	Assistant Professor

The interviews were analyzed using Coffey and Atkinson's [1996] criteria for qualitative analysis in which data are distilled to common patterns or themes. Thematic analysis involved employing inductive and deductive tactics across multiple rounds of reading interview transcripts [see Rubin and Rubin, 2011]. In early stages of analysis, the first author pre-coded the data and identified commonalities among responses (e.g. self-driven tendencies, outward-focused drive for PES, conflicting pressures, etc.) [see Rossman and Rallis, 2011]. In later stages of analysis, we reinterpreted the codes to construct deeper themes, which represent "phrase(s) or sentence(s) describing more subtle and tacit processes" [Rossman and Rallis, 2011, p. 282]. As a result of this analysis, various themes, or patterns of meanings emerged, namely: the *push forces* away from academic science institutions, *pull forces* to engagement, and the pressures pulling in the opposite direction (i.e., *drag forces*). We discuss those themes below.

Phase II

Results from the phase I interviews represented the views of a unique population of researchers and scientists who are perceived as exemplary and high-achieving science communicators. They thus provided, to some extent, best-case examples pertaining to how public engagement with science is perceived and practiced. In order to assess the applicability of the patterns that emerged in the interviews on the larger population of high-achieving publicly engaged scientists, we surveyed the larger pool of applicants to the award in the second phase of the study.

The survey was shared with all those who applied to the award between 2010 and 2015. All individuals interviewed in Phase I were excluded from the survey, yielding a survey sample of ($n = 221$). After sending out the original survey invitation and three follow-up reminders, 71 surveys were completed yielding a response rate of 32%. Fifty-nine percent of the sample was female and the mean age was 35.6. In terms of ethnicity, the sample was 89% white, 6% black, 6% Hispanic, 6% Asian, 2% American Indian, and 1% chose not to be identified. The larger sample of applicants surveyed was thus less diverse than the group of finalists and winners interviewed. Additionally, since we do not have data about all the applicants to this award over the years, we cannot speak to the representativeness of this sample of this award's applicants. Fifty-nine percent of the respondents worked at a large university, and 75% worked in the U.S.

The survey questions mirrored the themes that were extracted from the interviews in the form of Likert scale questions, such as the extent to which participants value their PES experiences; the impact that they perceive on a societal, organizational, and individual levels; as well as the pressures that they experience at those levels as well. For each of the questions, we calculated the mean and standard deviations and compared to the responses that we received in the interviews. The survey results hugely resonated with and validated the results from the interviews. In this paper, we will present the findings from interviews. We include a summary of our survey findings in the supplementary materials document attached with this manuscript.

Findings

Several themes emerged in the interviews tying the general experiences of this group of high-achieving, early-career, publicly engaged scientists on personal, institutional, and social levels. Almost all participants mentioned previous non-science related experience(s) that they perceived to be influential on their PES skills, such as sports and athletics ($n = 3$), performing arts (e.g., music, theater, design) ($n = 3$), jobs that require interpersonal skills (e.g., sales and marketing, real estate, school teaching, etc.) ($n = 4$), as well as having a social science background (e.g., journalism, public policy, psychology) ($n = 3$). Throughout the interviews, informants mentioned those experiences as important opportunities that had helped shape their interests in PES and build their PES skills.

Interestingly, informants had experienced those opportunities prior to becoming scientists (as they were growing up or while pursuing their degrees), and they indicated receiving very limited formal PES training after becoming professional scientists. In very few cases, informants reported joining a formal public engagement or communication training program. In those cases, training was a requirement for specific engagement settings (e.g. giving a TED talk [Thelma] or participating in a media show [Eli]). It is important to note, however, that those opportunities were made available to the informants because they had already displayed good PES skills and were prominent enough to get noticed and invited to participate in such programs.

However, almost all informants indicated more informal means of skill-building efforts, such as staying updated on social science research relevant to PES, following role model figures who participate in PES, or attending public engagement events and conferences. Yet, informants were very keen about not calling such experiences "trainings" because for them, the term implied following the instructions or teachings of someone else. In reality, informants perceived that such exposures meant that they can selectively attend to what they are interested in, reflect on what may or may not work for them, and then apply the techniques that they find useful.

We included the emerging themes in the survey and found similar results. Table 2 represents a cross tabulation of past experiences and the perceived usefulness of such experiences in performing PES activities weighted by the level of experience in each. For instance, a great deal of previous professional experience, such as working in sales or marketing is perceived to be the most useful for PES efforts (as compared to having a great deal of experience in the other categories). Keeping up with science communication research, communication or public engagement training, attending science communication conferences as well as previous performing arts experiences are also found to be very useful in providing respondents with PES skills. Generally, we also noticed that the more experience acquired in each area, the more useful it is perceived in terms of contributing to PES skills. Those results confirm interview findings.

The perception, therefore, is that mastering PES skills occurs gradually throughout the scientists' lives as they actively seek opportunities to learn about PES. Interview informants often mentioned being "self-taught" publicly engaged scientists, and that they "learn by doing". This perception, which was also shared by the survey participants, is important as a backdrop for this group's overall experiences with PES, as we explain below.

Table 2. Role of past experiences in performing PES efforts.

	No experience (1)	*2*	*3*	*4*	*5*	*6*	*A great deal of experience (7)*
Undergraduate communication class(es)	0.00	2.40	2.00	1.00	5.55	4.80	5.08
Graduate communication class(es)	0.00	1.13	4.00	2.33	3.88	4.29	5.44
Communication or public engagement training	0.00	3.25	4.25	5.00	5.17	4.93	6.15
Science communication conference(s)	0.00	1.17	1.80	2.88	6.00	5.71	5.78
Previous professional experience (e.g. working in sales, marketing, real estate, etc.)	0.03	1.71	2.00	3.33	4.80	6.00	6.67
Previous athletic experience (e.g. team sports, etc.)	0.17	0.82	2.80	0.75	4.29	3.64	4.31
Previous performing arts experience (e.g. theater, music, etc.)	0.00	2.14	2.00	4.00	4.67	4.60	6.00
Keeping up with science communication research	0.43	2.55	2.00	1.83	4.92	4.86	6.58

Numbers in the table represent the mean score of all respondents on a scale of 1 (not useful at all) and 7 (very useful).

Perceived value of PES experiences

Informants were found to be extremely enthusiastic about, and empowered by, their PES experiences. This empowerment is displayed intrinsically (because of how gratifying and rewarding it is for them to engage with the public), as well as extrinsically (in the form of outcome expectations at the personal, organizational, and social levels).

Self-driven tendencies. Most interview informants ($n = 8$) expressed a strong personal interest in pursuing PES. Informants reported having a gratifying sense of accomplishment and empowerment when engaging with the public.
They described such experiences as "happy", "ethical", "fun", and "exciting", sometimes even more than working in a lab and publishing academic papers.
For instance, Mason, who runs competitively, says:

> I have discovered like, so when I do running and I finish and I get personal record I get this like rush of adrenaline, I get this really high energy from running. The same thing probably to a greater extent happens when I teach or when I am engaging the public. So, just being able to communicate ideas and for people to understand what's going on, it's just a huge rush of adrenaline and energy and it is so much excitement.

Here, Mason compares the gratification that one gets from practicing sports to the personal reward attained by engaging with the public. The sense of accomplishment is also high due to the fact that with public engagement, scientists

are able to work on specific projects and get them done, unlike academic projects, which are usually longer-term and do not provide scientists with immediate gratification. As Brigitte, who has a background in theater and performing arts, puts it:

> A lot of people really enjoy it, they love it, they are really inspired by the work that we have done. We get great feedback, get to work with people in all sorts of different disciplines and have a project that ends. With our research, that doesn't really happen. Having something "Tum-Ta-Ra" (sound reference to the end of a play) and there is applause, and that's great. So, it is very satisfying. It is very rewarding and it is empowering.

Outward-focused drive for PES. Besides being self-driven, informants also reported a drive to engage with the public that stems from the perceived expectations from such engagement. Those expectations are mainly reported at the social and personal levels, and to a lesser extent at the organizational/institutional level.

Expected individual impact. Informants indicated that they perceive numerous personal impacts because of their engagement with the public. Mainly, some informants have found public engagement to promote their professional careers in that it helps them further build and improve their communication skills, which in turn makes them better teachers, grant writers, and thinkers ($n = 5$). For instance, Thelma, a climate scientist and engineer, says:

> For me, I really value being able to engage with people who are non-scientists… it helps me to become a better scientist but I don't think that's a universal truth. I think that's true for me… because it really helps me focus on questions that are very applicable. It helps me become cleaner and clearer at communicating. If people don't understand, they will say hey, you know, I really don't understand that, I will have to reframe whatever I am thinking or whatever I am doing such that it makes it easier to understand or clearer to understand. So, I think it's sort of a — again, it's a conversation, so it really helps this iterative process of constantly trying to explain something.

Thelma here acknowledges that communication represents a good opportunity for her to think about her research, and that that makes her a better scientist. The iterative process of scientific thinking is thus manifested in PES conversations. Zara also feels the same way. She has found that not only has PES made her a better scientist, but it has also improved her self-confidence as a scientist, which is something she highlights because scientists pass through many moments of self-doubt. PES thus seems to assure scientists that they are experts and that they do valuable work. Zara says:

> Many academics I know, and myself included, suffer from something we know as the impostor syndrome, and I think that [PES] first of all puts you in situations where you don't initially feel confident, but once you are dealing with the public, you get to realize how much expert knowledge you have. It's crazy that you need to be reminded of that because we actually have such specialized knowledge and we know it is not common knowledge. But you get

> surrounded by other people who have PhDs all the time, you know, so it's easy to forget you are actually building, that you have built and accumulated detailed knowledge for 20 years, and engaging with the public can definitely remind you of that.

Expected societal impact. Informants also expected their engagement to allow them to boost science and scientists in society through encouraging the public to think critically about science ($n = 10$), serve as role models, inspire the public, break stereotypes about how scientists should look like or how they should behave ($n = 4$), as well as to advocate certain scientific issues which are susceptible to distortion in society (e.g. climate change, ecology, etc.) ($n = 3$).

Interestingly, one of the most commonly identified social goals for PES participation is to help the public develop critical thinking skills that can be used to evaluate the credibility of any scientific information. Informants insisted that their goals are not to educate, because nowadays the public is able to find information about any topic online. The goal, instead, is framed as enabling audiences to critically assess information they come across. Informants want the public to engage in conversations and to question information. They do not want to tell the audience what to do (e.g., vaccinate, protect the environment, etc.), but rather, they want to present the audience with evidence, explain the scientific process to them, and allow them to make their own decisions. This view, while it runs counter to what the public sometimes expects from scientists, is perceived by informants to be more sustainable than encouraging the public to undertake specific behaviors because it ensures that they are able to handle a lifetime of choices. For instance, Nancy says:

> I think people get frustrated sometimes in that they expect us to provide answers. They want me to tell them, so what do you do… But I think for things to really be self-sustaining and for the improvements over time to be generative, it's genuinely context-dependent and iteratively improved over time that situations change… [people] need to be more critical consumers of the evidence that they see in the world, and that they can almost develop a researcher's mindset towards the nature of the problem in their own practice and education for example… — a culturally-relevant sort of meaning of the scientific findings and how we can use them ethically in the world —, and that's another layer of interpretation that I really try to show the public: being a scientifically literate citizen.

Some informants, on the other hand, believe that such an approach is in fact more appreciated by the public because it makes scientists seem humbler and less intimidating. In fact, one of the PES objectives emphasized in this sample is to help convey the relatability of scientists; to show their common humanity and fallibility. As Brigitte puts it:

> I do want to build trust, but I guess the way I see it is more that scientists are humans and not monsters. I like to show that part, that we are fragile also, that we have doubt, that actual doubt is enormously central to science and so, yeah, I think that's more the way I want to build trust with the public, is to say we are working on it with questioning. You can do this too.

Part of this culture and the reasoning behind these goals is that these informants seem to realize the complexity entailed in people's perceptions of scientific topics and that those beliefs are too complex to change through PES. For instance, Zara, who researches topics related to climate change, said:

> The more I learn about social science that investigates opinions about climate change, the less I think that information has anything to do with how people make decisions or come to their opinions about politics and so on. So there is certainly a lot of space for people to be better informed, and that includes people who are really concerned about climate change but actually don't understand it very well at all… So I guess rather than trying to change opinions about climate change, I guess, I think it is more probable, that I can just help people understand connections and assess information better.

Therefore, the overwhelming social impact perceived by the informants is to not only create ethical and groundbreaking scientific knowledge, but to also share it with the public and to allow it to impact society. This shared perception among informants indicates that the social responsibility perceived by those scientists extends beyond the walls of their academic institutions to society at large. Yet, informants stressed that this is their own perceived social responsibility rather than how they view the social responsibility of all scientists. The key here is that these high-achieving publicly engaged scientists believe that because they perceive themselves as good communicators and they are passionate about PES, they have a social responsibility to engage with the public. However, they believe that scientists who lack those skills should not necessarily feel the same social responsibility.

Perceiving PES as important to one's career and society at large is thus an important factor considered by scientists. Despite such insights, informants did not report any perceived institutional impacts that may contribute to pursuing PES. Although they held such expectations for personal and societal impacts, informants indicated that they generally do not link their engagement efforts to benefits for their home institutions. They did, however, perceive major conflicting pressures from their institutions to either engage or not engage with the public, as we will describe in the next section below.

Consistent with the interview findings, survey results from the larger pool of applicants showed similar perceptions regarding the social, institutional, and personal impacts of PES. Table 3 shows that respondents place the highest importance for achieving societal expected outcomes (such as ensuring that societal culture values science, helping people use science to make better decisions) (Mean = 5.92) and personal expected outcomes (such as becoming a better communicator [Mean = 6.24], a better teacher [Mean = 6.12], and a better scientist [Mean = 5.79]). Also, in line with the views of the interview participants, survey participants also gave the lowest importance on achieving institutional outcome expectations from PES (Mean = 4.58). Additionally, Table 4 shows that when taking part in PES efforts, survey respondents tend to think about the outcomes that such engagement would mostly have on society (Mean = 6.3) and themselves (Mean = 6.18), and that they are less likely to think about how it might impact their institutions (Mean = 5.74).

It is important to note, however, that expectations from participating in PES efforts do not necessarily reflect beliefs of the actual impact of such efforts. For instance,

Table 3. Societal, institutional, and personal impact.

		N	*Min*	*Max*	*Mean**	*Std. error*
Societal impact	Ensuring adequate funding for scientific research	72	1	7	5.72	0.17
	Ensuring that scientific evidence is used by policy makers	72	2	7	6.14	0.14
	Ensuring that our culture values science	72	3	7	6.32	0.13
	Ensuring that enough young people choose scientific careers	72	1	7	5.88	0.16
	Helping to diversify the STEM workforce	72	1	7	5.81	0.18
	Helping people use science to make better decisions (e.g. personal decisions, political decisions, etc.)	72	1	7	6.21	0.14
	Fulfilling my social responsibility as a scientist	72	3	7	5.69	0.15
	Serving as a role model to others in society	72	1	7	5.6	0.17
Institutional impact	Promoting my institution	72	1	7	4.58	0.24
	Strengthening the ties that my institution has with the community	72	1	7	5.49	0.23
	Obtaining grants and donations to benefit my institution	72	1	7	4.15	0.23
	Providing a better education for students at my institution	72	1	7	5.46	0.21
	Fulfilling my responsibilities as a scientist towards my institution	72	1	7	4.5	0.24
Personal impact	Increasing the impact of my research	72	1	7	5.35	0.18
	Increasing my chances of obtaining research funding	72	1	7	4.68	0.20
	Personal enjoyment	72	4	7	6.36	0.10
	Meeting people who can be influential on my career	72	1	7	4.89	0.19
	Standing out from other scientists in my field	72	1	7	4.85	0.22
	Becoming a better communicator	72	2	7	6.24	0.13
	Becoming a better scientist	72	1	7	5.79	0.18
	Becoming a better teacher	72	1	7	6.12	0.15
	Gaining a good reputation as a scientist	72	1	7	5.13	0.19

* The mean score of each category is calculated based on a scale from 1 (very low) to 7 (very high importance).

despite having high societal outcome expectations, Table 5 shows that the participants' perceptions of the positive impact that PES efforts have on society is in fact moderate (Mean = 4.76). This indicates that they perceive a more gradual and incremental impact on society rather than a considerable immediate one. Also surprisingly, PES efforts are perceived to have a more considerable positive impact on the scientists themselves (Mean = 6.11) and their institutions (Mean = 6.03) (Table 5). This suggests that even though respondents may not expect as much institutional or personal benefits from seeking PES efforts, they do perceive an actual positive influence of such efforts on personal and institutional levels.

Table 4. Thinking about impact.

	Social	*Institutional*	*Personal*
Strongly disagree (1)	0%	1%	1%
Disagree (2)	0%	0%	1%
Somewhat disagree (3)	1%	6%	0%
Neither agree nor disagree (4)	1%	3%	4%
Somewhat agree (5)	9%	24%	10%
Agree (6)	42%	40%	35%
Strongly agree (7)	46%	26%	49%
Total	74	72	72
Mean	6.3	5.74	6.18
Std. error	0.094	0.14	0.135

Table 5. Perceptions of actual impact.

	Social	*Institutional*	*Personal*
Very little (negligible) (1)	0%	0%	0%
Little (2)	4%	0%	1%
Somewhat little (3)	12%	1%	3%
Moderate (4)	34%	4%	0%
Somewhat big (5)	15%	19%	13%
Big (6)	24%	40%	46%
Very big (considerable) (7)	11%	35%	38%
Total	74	72	72
Mean	4.76	6.03	6.11
Std. error	0.157	0.108	0.116

Conflicting PES pressures

Informants perceived several pressures, especially from their institutions and colleagues, that conflict with their roles as public communicators. For instance, a vast majority of informants have heard comments about their PES efforts from their colleagues stating that those efforts are a "waste of time" or a "distraction". Those pressures are communicated to the informants by their colleagues either through the direct expression of concern, or through a seeming lack of interest in the PES activities conducted and ignoring them altogether. Informants indicated that it can be discouraging for them to be perceived in that manner by their colleagues.

What is even more baffling and frustrating for some of the informants is that despite the lack of appreciation of their public engagement efforts and the presumption that doing too much public engagement will lead to a diminished scientific productivity, any opportunities for public engagement needed by the department or institution to which they belong are normally delegated to them. For instance, Thomas says:

> There is an expectation that well he is the one that does that so he should do all of this. And I kind of, sometimes I get annoyed [...] I do think sometimes I am

> doing too much of this, particularly if it's, I think people sometimes don't understand how much time doing some of these things take.

The perception that is highlighted in Thomas's example is that PES is even made more challenging for those who practice it because of the expectation that if someone is good at it, they should do all of it. Thomas goes on to explain:

> Sometimes I accept that because I don't think academics are supermen or superwomen. I think that they each have their own special areas of expertise and so some people are right to go get grants and other people are maybe communication or write papers or building collaborations so I think you need to follow your strengths.

This idea shapes a common perception in this sample in that only those who have a passion for public engagement should be pursuing it. Institutional pressures, however, are multifaceted and confusing. Particularly, we found that scientists not only disregard PES efforts done by their colleagues, but they also tend to expect those who have a passion for PES to practice it all the time. However, this does not mean that in return scientists get recognition for their PES work or any leniency in terms of the expectations to publish, write grants, or fulfill their other job-related responsibilities.

Despite such pushback, informants agreed that they view their PES experiences to be positive, rewarding, and gratifying. In fact, such feelings of empowerment and achievement provides informants with some leverage that allows them to manage mixed signals and negative feedback through certain coping mechanisms, as we describe below.

Survey results also confirmed the views from the interviews regarding the perceived individual, social, and institutional pressures that they experience. Respondents were asked about what they believed others (society, their colleagues, etc.) expect from them and how other scientists and members of the public view their public engagement efforts. Table 6 shows that while respondents agreed that the public would appreciate a scientist engaging in PES activities (Mean = 5.91), academic colleagues might not (Mean = 4.82), which is a similar perception to the one found in the interviews. Additionally, respondents indicated that while society appreciates and respects a scientist who is engaging with the public (Mean = 5.87), it is not the overwhelming expectation that society has from scientists (Mean = 4.81) (same view found in the interviews). Instead, the perceived expectation from the public is that scientists conduct research that can solve societal problems (Mean = 5.88). Also, respondents agreed that most scientists in their fields do not participate in PES efforts (Mean = 3.36). However, they did not agree to the statement that scientists in their fields do not approve of PES efforts (Mean = 3.29). This suggests that respondents view their colleagues as uninterested in their PES work rather than strongly opposed to it, which is in line with the interview findings.

What is not captured in the survey results, however, is the coping mechanism that early-career scientists use when balancing opposing perceptions that they may have in regards to how others view their PES efforts. We describe this process in the next section.

Table 6. PES norms.

	N	*Min.*	*Max*	*Mean**	*Std. error*
Most researchers in my field rarely participate in public engagement with science	76	1	7	4.28	0.186
The majority of my colleagues participate in public engagement with science	76	1	6	3.36	0.161
I think that people in my field would respect someone who participates in public engagement with science	76	2	7	4.82	0.158
People in my field do not approve of public engagement with science	76	1	7	3.29	0.17
The public appreciates having public engagement with science opportunities in society	75	2	7	5.91	0.12
The public expects scientists to participate in public engagement with science efforts	75	2	7	4.81	0.156
The public respects scientists who participate in public engagement with science efforts	75	2	7	5.87	0.118
The public expects scientists to conduct research that solves societal problems	75	3	7	5.88	0.126

* The mean score of each category is calculated based on a scale from 1 (strongly disagree) to 7 (strongly agree).

Coping with pressures

Balancing PES with work tasks. Most informants understand the pressures exerted by the academic community and they choose to still do what they are passionate about, sometimes overproducing on the academic front so that they are not perceived as "soft" scientists ($n = 8$). As Carter puts it:

> You know they'll caution you if you do it too much, which is fine and you know I'd say that I think I'm doing good work in research also. So, you know, everybody… is anxious when you walk like they don't walk, people tend to be anxious about it and this is just how people are, they are more comfortable with what looks like them or what acts like them. And so for me, it's just a matter of understanding what really matters. And I think for anybody that's going to do public engagement, you have to be very sensitive and aware to what matters and what matters is that you do your research and it would be defensible and high quality to your colleagues. And then you could do whatever you want to do, then it doesn't matter…

Informants sharing Carter's perspectives understand that academics are measuring their successes by certain standards. Therefore, they make sure that they meet those standards, and then proceed to conduct their outreach and engagement alongside their academic duties. For instance, Mason conducts his outreach activities in the summers when he is not teaching. Therefore, he explains the time he spends on PES as his "free time".

Informants also mostly choose not to share what they do in terms of outreach with their colleagues, or to selectively share news that would matter to specific colleagues. For instance, Zara noticed that her colleagues show a lack of interest in

the engagement work that she does on local and small-scale levels, but they are appreciative of her taking part in bigger national projects because it makes her institution more visible and it conveys more credibility. Eli also noticed that his colleagues completely ignored his PES work until it made national news. In order to manage the pressure, therefore, some informants chose to work their day-to-day jobs without drawing attention to their public engagement efforts.

Although this strategy seems to be appealing to many informants, there is a caveat: sometimes it is not clear which scientists would appreciate what type of engagement. For instance, Eric says:

> I kind of feel like it's hard to know which colleagues would think it's a beneficial thing or wouldn't. So, sometimes I may say less than I should to people, but sometimes I would say more than I should, so who knows.

The surveys reflected a relatively similar perception from the interviews in that science colleagues do not openly express disapproval of the respondents' PES efforts, however they do not necessarily offer them support or praise for it. Table 7 indicates that respondents are very likely to share information relevant to their PES efforts with their colleagues (Mean = 6.07), which is a slightly different view from the one found in the interviews. They are also likely to try involving those with whom they work in their PES activities, whether it is logistical or organizational support (Mean = 5.3), or in the actual engagement process (Mean = 5.68). Yet, even though this group of respondents is more open about sharing positive aspects of PES with their colleagues, they are found to not ask their colleagues for special accommodations due to PES commitments (Mean = 3.67). This last perception is common with our interview informants. Selective sharing of information and diminished requesting of support is thus something that we find across our interview and survey samples.

Table 7. Sharing PES information with colleagues.

	N	*Min*	*Max*	*Mean**	*Std. error*
Share details about your public engagement efforts with people you work with	72	2	7	6.07	0.148
Ask people you work with to participate in public engagement efforts that you are organizing (e.g. invite them to give talks, etc.)	72	1	7	5.68	0.187
Discuss the impact of your public engagement efforts with people you work with	72	1	7	5.64	0.179
Seek help or support from people you work with to assist you with your public engagement efforts (e.g. logistical support, use of space and resources, etc.)	71	1	7	5.3	0.227
Ask people you work with for special accommodations when you have public engagement commitments (e.g. teach your class, attend a meeting on your behalf, etc.)	72	1	7	3.67	0.246

* The mean score of each category is calculated based on a scale from 1 (not at all likely) to 7 (very likely).

Selecting into certain types of institutions. Because many informants were aware of the perceptions in academia about PES, they consciously deviated towards institutions that have lower expectations in terms of academic productivity, or place a higher value on PES work. Those informants believed that the effort required to do influential work in public engagement might make them unsuccessful in traditional high-tier academic institutions. Therefore, they consciously sought jobs that either allow them to integrate their public engagement skills into their own work, or institutions that have lower expectations in terms of traditional academic deliverables, such as publications and grants. Those informants understood, to some extent, the reasoning why academics might not value PES for scientists. For instance, Eli gives the following metaphor:

> In a way, it would be like a professional athlete. You want them to be spending most of their — all of their time playing basketball and improving on their game, and if instead of playing, you know, Michael Jordan was going to say that he's not going to be practicing his shot anymore, he's spending half the time just communicating basketball, I'm sure like, you know… the Chicago Bulls wouldn't be happy that he says half the time he's not practicing anymore, he's just going to be focusing on teaching people about basketball, and I think they would perceive that as a way that you're not, you know, they want you to be giving a 100% to your science so your science is absolutely the best.

Through the above metaphor, Eli explains how he understands the place of PES in academia. He goes on to explain why he decided to pursue a career in a different type of institution (a teaching institution in his case):

> … Science is so competitive and so difficult with diminished funding and with difficulty in getting your work published, and, you know, with that pressure on you if you're not completely focused on doing your science, you might lose your edge, and that's where I think that thinking comes from… That's one of the reasons why I'm not at Harvard and I'm at [name of institution]. I mean, I made this as a conscious choice that I'm trying to do both, but I'm not in the institution that's going to put that kind of pressure on me. So I still try to do world class science, but maybe they don't expect ten articles out of me a year, they'll only expect four or five. So, they lower the expectation on you, so you're not, you know, you don't feel that pressure on you as an individual… There has to be [a compromise], you know, there's only a certain amount of hours in the day, and again you have to prioritize what's important to you and that's what it comes down to.

Informants who deviated towards this coping strategy either resorted to teaching-only or research-only institutions ($n = 3$), or they found a career where they can integrate public engagement with their everyday work ($n = 2$). For instance, Nancy and Olivia work at institutions where outreach is part of how they collect their data (e.g. citizen science and crowdsourcing programs). In those few cases, informants have found a way to "institutionalize" their public engagement efforts, and even if they still sometimes receive backlash about that, they try to ignore such pressures by focusing on the successes of their programs. For instance, Olivia works on evaluating the successes of her program and understanding its impact on the public involved. Such evidence provides her with the confidence to overlook criticisms. She says:

> You almost feel like you constantly have to justify, but I stop myself because it's not my job. I don't need to justify what I do to you, right? I do it well and that will speak for itself and that's kind of — I think that's something that I learned along the way, too. Like I felt like I constantly had to justify my first couple of years about why I could do both and do both well and why it was important to do both… it's exhausting. I finally, again, had enough confidence to say I don't have to justify, I am doing well. I know that in my gut and I know that because of the evaluations. So I am just going to do it and not be apologetic and I think that has been probably a big empowering thing for me.

In fact, most informants perceive a great importance for evaluating their PES programs as a way to explain the value of engagement. However, they also indicated how difficult it is for them to evaluate the tangible PES impacts, which can be rather discouraging, especially in light of the pressure that they receive in academia to produce traditional outcomes. Therefore, being unable to assess some kind of impact of PES efforts can be daunting at times. For instance, Laura says:

> One of the things I definitely need to do is try and figure out any kind of metric, because at the moment I don't keep track of the impacts that my science communication has, and it might be useful to know what's working well and what isn't. At the moment, I have no idea… I mean I can find out the number of people who listen to the radio shows that I have been on, or I can try and figure out how many people have read an article I wrote, but I don't really know if that means anything or what to do with those numbers… The fact that I have 30,000 Twitter followers, I don't know if that means that I am making any difference. I mean I don't know how many of those people care what I say or really read what I say, or if anybody changes their behavior based on that. So it's really hard to figure out what the impact really is, and I mean I think that it would be useful to know.

What is interesting is that regardless of the coping mechanism chosen by the informants, they remain likely to receive a certain level of backlash because they take part in PES. This is because such efforts are still not the norm in many scientific institutions. Informants thus held a shared perspective pertaining to the difficulty of conducting PES within such institutions.

Survey respondents also indicated that they try to institutionalize the type of PES efforts that they conduct and that being able to assess the impact of what they do would enable them to better integrate public engagement into their academic work and achievements. For instance, Table 8 indicates that respondents are likely to integrate PES into their research grants (Mean = 5.36) and that they work at institutions that value PES (Mean = 5.25). However, fewer respondents indicated that they worked at institutions with lower academic expectations so that they have more time to conduct PES (Mean = 2.48) (which resonates with the views in the interviews). Also, while most respondents indicated that they did not agree that PES should be done in a scientist's free time (Mean = 2.15) (Table 9), most of them indicated that they actually find themselves doing that (Mean = 5.32) (Table 8). This indicates that although respondents believe that PES should be integrated in a scientist's discourse, it is still not the case for many of them.

Table 10 further highlights this point in that respondents expressed a strong interest in learning about ways to assess the impact of their engagement on their

Table 8. Managing PES with other roles.

	N	*Min*	*Max*	*Mean**	*Std. error*
I conduct public engagement with science efforts in my free time	77	1	7	5.32	0.19
I work at an institution that values public engagement with science	77	1	7	5.25	0.16
I work at an institution with less research requirements so that I have more time to participate in public engagement with science efforts	77	1	7	2.48	0.19
I work at an institution with less teaching requirements so that I have more time to participate in public engagement with science efforts	77	1	7	2.65	0.18
I integrate public engagement with science into my research grants	77	1	7	5.36	0.19

* The mean score of each category is calculated based on a scale from 1 (strongly disagree) to 7 (strongly agree).

Table 9. General perceptions of PES.

	N	*Min*	*Max*	*Mean**	*Std. error*
Public engagement with science should be only done by scientists who are good at communicating with public audiences	77	1	7	4.57	0.19
Public engagement with science should be accounted for when evaluating a scientist's academic career	78	3	7	6.04	0.13
Public engagement with science should be only done at a scientist's free time	78	1	7	2.15	0.13
Public engagement with science can distract a scientist from his/her everyday science	78	1	7	3.35	0.21
In general, scientists need to be good communicators	78	2	7	6.32	0.10
All scientists should participate in public engagement with science efforts	78	1	7	4.58	0.22
All scientists should receive training on how to better communicate with the public	78	1	7	6.04	0.15

* The mean score of each category is calculated based on a scale from 1 (strongly disagree) to 7 (strongly agree).

audience (Mean = 5.67) and that they perceived that having evidence regarding the impact of their PES efforts can have a positive influence on their careers (Mean = 5.69). However, they also indicated that it was not easy for them to assess the impact of PES, and only a minority of the respondents indicated that they currently have a way to measure their impact (Mean = 4.62). This finding also resonates with the results from the interviews and speaks to the importance of finding ways to assess PES impact.

Table 10. Thinking about the audience.

	N	*Min*	*Max*	*Mean**	*Std. error*
I think about the impact that my public engagement efforts have on my audience	72	3	7	6.24	0.096
The impact that I expect my public engagement efforts to have on my audience is a motivation for me to communicate with them	72	4	7	6.14	0.093
I communicate about what I believe is important regardless of its impact on the audience	72	1	7	4.69	0.178
When I engage with the public, I make an effort to come across as relatable to the audience	72	4	7	6.42	0.088
I would like to learn more about how to evaluate the impact of my public engagement efforts	72	1	7	5.69	0.153
I commonly seek feedback about my public engagement efforts	72	1	7	5.15	0.179
Having data on the outcomes of my public engagement efforts could help my career	72	2	7	5.67	0.176
I receive evaluations from my audience about the effectiveness of my communication	72	1	7	4.62	0.2

* The mean score of each category is calculated based on a scale from 1 (strongly disagree) to 7 (strongly agree).

Discussion & conclusions

This study offers a snapshot of the experiences of high-achieving, publicly engaged scientists that can help illuminate the context within which scientists balance their PES work with perceived norms and pressures. Generally, professional or social group norms include shared behavioral beliefs and expectations that allow individuals to fit in particular contexts [Gibbs, 1981; Merton, 1968]. In science and academia, for instance, norms determine the favorable and unfavorable roles and behaviors when no written rules or regulations apply [Braxton, 2010]. Also, norms are especially salient in uncertain or ambiguous situations where individuals have no prior experiences [Cialdini, 1993; Cialdini, 2009; Deutsch and Gerard, 1955; Lapinski and Rimal, 2005].

In this sample of high-achieving, publicly-engaged, early-career scientists, PES has important perceived impacts on their identities, careers and societies. However, they struggle to align PES work with the norms and values of their science institutions and to fully understand what PES may mean for their colleagues and institutions. Our results thus confirm the ambivalence experienced by publicly engaged scientists regarding the way PES fits with the work done in scientific institutions. The overall culture still opposes such activities, which is well documented in previous research that has spanned decades [Dunwoody and Ryan, 1985; Lewenstein, 1992; National Academies of Sciences, Engineering, and Medicine, 2016]. However, simultaneously, some scientists perceive career advancement associated with PES, which also resonates with evidence from the literature [e.g., Dudo, Kahlor et al., 2014].

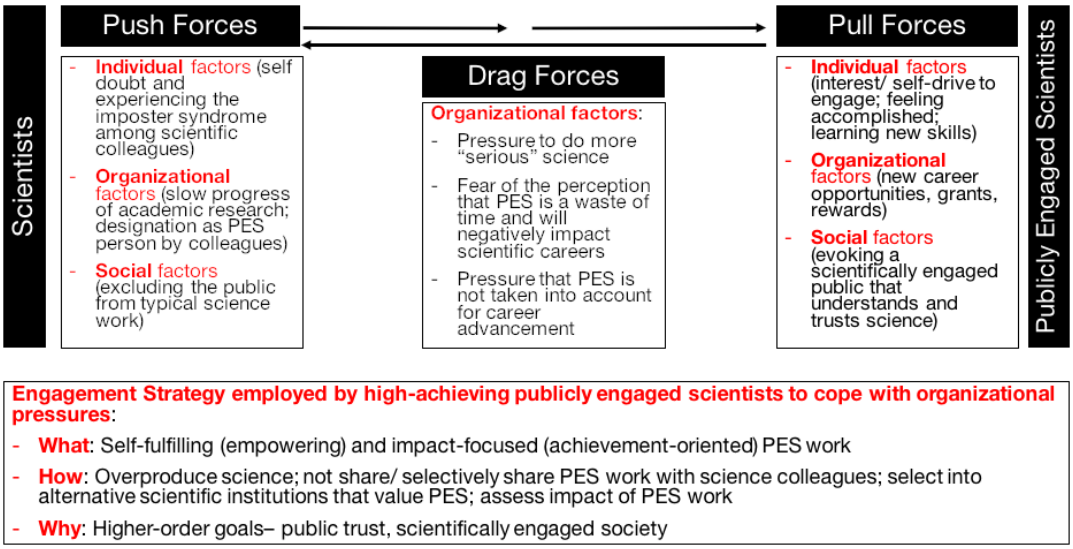

Figure 1. The system of forces operating on publicly engaged scientists.

Push, pull, and drag forces

Our triangulated results using the ecological model reveal that this high-achieving publicly engaged group of early-career scientists is exposed to three different sets of forces at individual, organizational, and social levels. As a result, those scientists consistently balance such forces when deciding on engagement work (Figure 1). Those are: *push factors* away from pure academic science (e.g., the slow progress of academic research, experiencing impostor syndrome around other scientists, being designated by institutional colleagues as the PES person, the elitist nature of academic science that does not involve the public); *pull factors* towards PES (e.g., the individual lifelong interest and self-drive to engage, the perceived individual benefit of feeling accomplished and pursuing new career opportunities, and the perceived social benefit of evoking a scientifically-engaged public that trusts science); as well as *drag factors* in the opposite direction that represent the pressures they perceive from their scientific colleagues and institutions (e.g., the pressure to do more serious science, the fear that PES is perceived as a waste of time that is ignored during evaluation and promotion decisions).

Balancing goal-oriented strategies

Interestingly, we found that the publicly engaged scientists in our sample balance those forces towards PES by conscious coping behaviors that involve an engagement strategy (Figure 1). The strategy involves focusing on self-fulfilling (intrinsic/empowerment-oriented) and impact-focused (extrinsic/achievement-oriented) PES work. This means that those scientists commit to PES that offer them feelings of excitement, happiness, and fulfillment, as well as for tangible impacts, such as possibly having positive effects on their careers through new opportunities and collaborations.

The way scientists maintain such commitment to PES is through finding ways to either cope with or minimize the pressures from their colleagues and institutions through: (1) overproducing science so that they are still perceived as serious and

successful scientists (opposite to the Sagan Effect, in line with Jensen, Rouquier et al. [2008] and Peters [2013]), (2) selectively sharing important news about their PES work with colleagues or choosing not to share at all, (3) finding ways to measure the impact of their PES work to document its value, and/or (4) selecting into institutions that do not put so much pressure on scientific production and/or that value PES work. AbiGhannam [2015] identified similar coping strategies through which female scientist bloggers challenged extrinsic penalties and pressures to allow themselves to proceed with their PES work, which included choosing to produce more academic science, choosing scientific institutions that value PES work, writing for national and prominent online science communication networks and groups, and focusing on the perceived intrinsic rewards and validation from science communication.

Additionally, we found that this sample of high-achieving publicly engaged scientists set clear high-order goals for their PES work. Such findings resonate with studies that highlight the importance of PES that is anchored in strategic communication approaches. Previous studies have shown that scientists who are early in their careers or who have limited communication experience often hold deficit communication views, such as having singular communication objectives to inform the public [Besley, Dudo and Yuan, 2018] or defend science from misinformation [Dudo and Besley, 2016]. The nuance in our current study's results suggests that these early-career scientists are not only trying to inform the public about scientific information, but also about the scientific process itself, its limitations, and their commonalities with non-scientists. This is especially important considering calls for building trust in science, specifically how it seems to embody the need for scientists to boost their personability, accessibility, and warmth [e.g., Fiske and Dupree, 2014; Oreskes, 2021]. Our interviews with this group of scientists committed to PES suggests that they seem to understand the importance of such qualities when engaging with the public.

This trend is also observed in other behavioral studies applying Bourdieu's theory of practice. Whereas in established fields and practices, individuals generally reproduce common behaviors to conform to certain norms, previous studies have shown that having personal goals allow individuals to break the reproduction cycle of practice within their fields and to integrate forms of self-expression into their behaviors [e.g., Butler, 1997a; Butler, 1997b; Hills, 2006; Lovell, 2003]. In this study, we find that scientists resisting norms in their science fields also have high-level engagement goals and individual-, organizational-, and social-level impact expectations. Such goals and expectations were observed in this group of early-career scientists who deviate from the pure scientific identity as defined in their institutions and who recreate their own science personas that also include PES.

This observation is important and should be further explored in future studies looking at the impact of norms on PES behaviors. Whereas norms are found to help predict certain behaviors in various organizational contexts, the results in this study suggest that the extent to which they can determine a scientist's decision to conduct PES behaviors may be influenced by personal, institutional, and social perceptions and goals. Such factors should be further explored in future studies and would further build on recent studies that have explored more nuanced

(i.e., indirect) contributions norms may make toward scientists' PES behavior [e.g., Copple et al., 2020; Tiffany et al., 2022].

Limitations and future research

As with all small, group-focused inquiries, results from this study are not meant to be generalizable. Instead, they represent a deep understanding of a group of early-career, high-achieving, publicly engaged scientists and the way they balance pressures from scientific institutions and colleagues. Additionally, given that we recruited from a sample of scientists who applied to, were shortlisted for, or awarded a prestigious PES award, our results may reflect an exception rather than the wide views of PES in larger contexts. Future research should thus explore the applicability of these findings in wider samples. Moreover, the findings of this study could be augmented, thereby increasing their validity, via observational data obtained through ethnographies of the actual engagement work of scientists.

Additionally, as with all interview and survey research, results offer a snapshot of how those forces operated at a point in time in the career of those publicly engaged scientists back in 2015. In order to more thoroughly understand the ways by which those forces evolve overtime, future research should conduct additional longitudinal analyses of the ways publicly engaged scientists balance pressures and benefits of PES over an expanded period. We therefore plan to collect the same kind of data from the same sample in the years to come in order to investigate the consistency of publicly engaged behaviors throughout the stages of those scientists' careers and whether and how such forces, behaviors, and strategies evolve over time.

Although the science communication scene is constantly changing and becoming increasingly professionalized, the practice remains generally heterogeneous, especially when it comes to perceptions of norms and pressures. The current study further illustrates the forces that operate on a group of early-career, high-achieving scientist communicators. Particularly, we hope that our findings on the strategic mechanisms employed by this group of scientists can offer insights on the importance of goal-setting in mitigating perceived pressures. Further testing of this idea in different samples can help contribute to our understanding of how norms operate in different PES contexts.

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Authors

Niveen AbiGhannam is a lecturer of engineering communication at the University of Texas at Austin. She studies personal, institutional, and social factors (namely gender, norms, social responsibility, etc.) that can drive or hinder public engagement with science behaviors. She also examines the identities of publicly engaged scientists and the meanings that they associate with their engagement experiences. E-mail: niveena@utexas.edu.

Anthony Dudo researches the intersection of science, media, and society. He is particularly interested in scientists' public engagement activities, media representations of science and environmental issues, and the contributions of informational and entertainment media to public perceptions of science. His recent work has examined factors influencing scientists' likelihood to engage in public communication, scientists' goals for public engagement, and the growing community of science communication trainers. E-mail: dudo@utexas.edu.

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