Who Rejects Science, and Why?

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Scientific advancement continually and significantly shapes the world we live in. One hundred years ago, films were still silent, few people owned cars, commercial airplanes were made of wood and sat only one passenger, and the dynamics or origins of the solar system had yet to be unearthed (Haugland, 1992). Einstein’s theory of relativity was only five years old and not widely accepted (Born, 1962). Penicillin was not discovered until 1928 and was not widely used until the 1940s (Bottcher, 1964) (Clardy et al., 2009). Early science on human-climate interactions did not develop until the Dust Bowl of the 1930s (McLeman et al., 2013). In 1969, humans first landed on the moon, ushering in an era of space exploration and comprehension (Piantadosi, 2013). In 1980, scientists first proposed the now-widely-accepted idea that a massive asteroid striking the Earth near the Yucatan peninsula caused the sudden mass extinction of the dinosaurs (Brusatte et al., 2014). Today, computers provide instantaneous access to numerous forms of media, cars and airplanes drive themselves, and countries have successfully landed spacecraft on numerous celestial bodies. None of these advancements would be possible without faith in the scientific method.

Yet despite these tremendous successes, this same portion of history has become increasingly fraught with conflict between scientists and policy makers. While a symptom of the vast increase in accessible information and coverage of landmark issues, the result of this developing trend is a de-sanctification of the scientific process. Sound scientific arguments and theories must compete with the anecdotal evidence and unsupported findings promoted by contrarian beliefs. This flood of alternate, often baseless viewpoints lends to confusion among a public to whom the scientific method generally does not come naturally (Achenbach, 2015). In one New York Times study comparing public polling data, researchers concluded that the percent of Americans that believe in creationism has actually increased since the 1980s (Newport, 2012). Meanwhile, support for vaccines and fluoride-treated tap water – both of which have sound scientific backing and help people unilaterally, regardless of demographics – are increasingly distrusted (Frank, 2013). This confusion has also given rise to fringe thinking like the Flat Earth Theory which, notwithstanding our world's investment in our comprehension of the fundamental workings of the universe, are believed despite having absolutely no basis in any laws of the universe. We seem to live in a world in which we know increasingly more, yet we believe increasingly less.

Thus begs the question: Why, in a world in which science accelerates progress, do we increasingly distrust science? Our paper attempts to answer this question by first identifying major shortcomings of sound scientific findings to excite timely, effective changes in public behavior and policy. We then discuss important ideological and motivational components of the growing resistance against scientific findings. Next, our narrative shifts to identifying four main failures of the scientific community that promote this divide between their findings and the general public. Finally, we discuss the disconnect in the context of the shortcomings we identified and attempt to draw conclusions on why the problem is steadily worsening in the context of fluid information sharing.

Historical Shortcomings of Scientific Communication

To attempt to understand why the relationship between science and public policy is steadily weakening, we must first identify historic moments in which scientific findings have failed to enact important policy reform. Nowhere in American history do we see science used so divisively as it was in 1954 by the American tobacco industry. In 1952, *Reader's Digest* published "Cancer by the Carton," an article which compiled decades of scientific research to directly link smoking cigarettes to lung cancer (Norr, 1952). While science supporting the harms of smoking was not new, the article was the most public and direct recognition of the health repercussions to date. Cigarette sales dropped drastically following the publication for the first time since the Great Depression, leaving the industry in a crisis. One year later, still in the midst of their crisis, the CEOs of major tobacco companies met secretly in New York City to discuss how to combat the negative publicity and save their industry. Together they created "A Frank Statement to Cigarette Smokers" which they paid to have published in 448 newspapers nation-wide. The statement, signed by each CEO, declared that the health of their customers was their "basic responsibility, paramount to every other consideration in [their] business" (Tobacco Industry Research Committee, 1954). The statement also asserted that medical research indicated numerous possible causes of cancer and thus that cigarette smoking could not be directly linked to causing cancer (Brownell et al., 2009).

The Frank Statement marked the beginning of a decades-long effort by the tobacco industry to sow doubt in the building mountain of scientific evidence supporting the link between smoking and numerous adverse health conditions. Leaders of the industry paid scientists to write letters to science journals that questioned the efficacy of the state of science on smoking and disrupted progress towards reform (Kiernan, 1998). Meanwhile, the industry used these doubts to win landmark lawsuits, helping them to continue pushing advertising schemes that denied health risks. The result was a resurgence in cigarette sales (Figure 1). Not until the 1990s did multiple U.S. states successfully sue the tobacco industry, citing the systematic undermining of scientific evidence supporting the health risks of smoking – a position that the industry was well-documented to have understood. But the damage had already been done, as it is reported that millions lost their lives due to the deceit. The systematic manipulation of science by the tobacco industry represents the industry-standard in disputing scientific evidence, and demonstrates the power that industry can hold over science in terms of enacting or suppressing reform (Brownell et al., 2009).

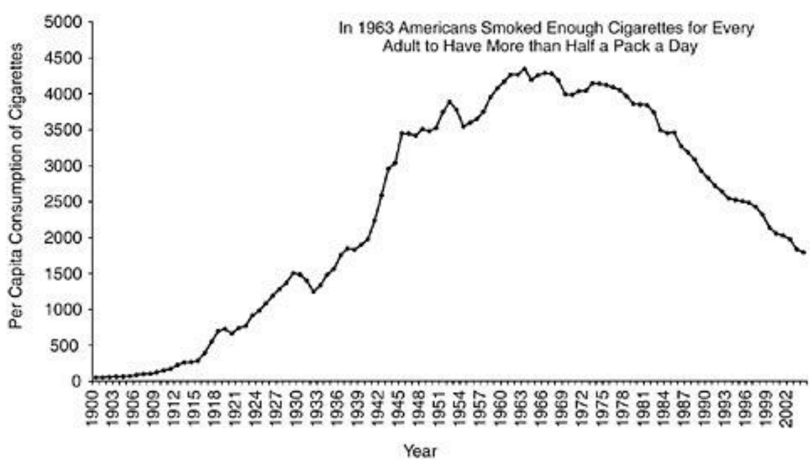

Figure 1: Graph of cigarette sales by year in the 20th century (Bonnie et al., 2007)

The indiscriminate use of the pesticide DDT threatened the health of entire ecosystems. Originally synthesized in the 19th century and originally recognized for its insecticidal properties in 1939, DDT became widely used worldwide in the 1940s and 50s and was especially instrumental in combating typhus transmitted by body lice during World War II. Yet as early as 1944 scientists had begun expressing concern over both its efficacy and its potential to do harm.

Following the conclusion of the Second World War, the USDA, FDA and various other top national organizations began intensive scrutiny. While these institutions were able to confirm the success of DDT among a wide range of pests, they also began to observe that many invertebrates seemed to proliferate as the poison destroyed their predators and that populations of certain pest species would develop significant resistance to the treatment. Nevertheless, the insecticide industry saw DDT as a possible “magic bullet” against malaria and other insect-borne diseases. The Bureau of Entomology asserted that maintaining the balance of nature was generally unrealistic, especially considering the imbalance that an ecosystem faces during pest outbreaks. Thus, DDT continued to be sold over the counter and widely used (Davis, 2014).

A fatal error in the narrative of DDT was the lack of premarket safety testing. Thus, while use proliferated, government agencies scrambled to investigate early concerns. The scientific method relies on painstaking and time-consuming examination to draw conclusions, and in the case of DDT many of the detrimental human and ecosystem impacts were distant and thus difficult to scientifically connect. As a result, while scientists slowly but steadily produced results demonstrating the damning effects of DDT as a dangerous bio accumulator and a reproductive system disruptor most notably to birds of prey, sales of the chemical increased (Davis, 2014).

Not until Rachel Carson published her book *Silent Spring* in 1962 did the public narrative begin to shift (Carson, 1962). Drawing on the parallels between the Cuban Missile Crisis and the overall political landscape during the Cold War and the potentially catastrophic effects of prolonged use of DDT, Carson crafted an emotional appeal to the public that, although never outwardly calling for a ban, resulted in mass public outcry that spurred an environmental movement. Though her successful environmental plea would result in the salvation of countless species including the Bald Eagle, many had already been driven to extinction and other species are still being rehabilitated to this day. The delayed regulation of DDT and other chemicals during this era demonstrates public negligence and willingness to ignore scientific warning signs (Kinkela, 2005).

The crisis that ensued following the widespread use of chlorofluorocarbons, or CFCs, came as more of a surprise to scientists and the public than did that of DDT. Extensively tested, CFCs were touted for their low reactivity, indicating low environmental impact, and were thus used prominently in household items. Freon, a widely popular CFC, was used in products ranging from refrigerators to hairspray. However, because CFCs have an active lifespan of over one hundred years, they are able to move up and diffuse into Earth's stratosphere. While in the stratosphere, ultraviolet radiation is able to break the carbon-chlorine bond within CFC molecules, allowing it to react with atmospheric ozone. Lab testing had not accounted for this atmospheric reaction taking place. The result, first published in 1974, was a growing hole in Earth's ozone layer over Antarctica (Gareau, 2013).

In the wake of environmental activism following the DDT crisis, the reaction to combat ozone depletion was slightly more urgent. By 1987, a total of 180 countries had signed the Montreal Protocol, a pact to ensure that businesses created replacements for products containing CFCs. Since regulations were enacted, scientists have shown that the ozone layer is beginning to repair itself. However, the fallout from CFC deposition in the atmosphere is ongoing. Rates of melanoma, particularly in Australia, continue to be at all-time highs, and plant and marine life development are consistently hindered by heightened UV concentrations breaching the ozone (Solomon, 2008). However, ozone depletion and the prompt response affirm that humans have an enormous capacity to both alter their environment and to enact important reforms to change it back (Gareau, 2013).

This leads to the most pressing threat to all lives, not just humans. No recount of the past one hundred years of science-backed environmental and public health crises would be complete without mention of climate change. Research on climate change dates back to the 1800s when experiments suggested that human-produced carbon dioxide could accumulate in the atmosphere. Experiences with DDT and CFCs gave rise to the Environmental Protection Agency and motivated a push for improved environmental regulation. Like evidence of climate change, the associations between daily uses of DDT and CFCs were difficult to conceptualize, but were painstakingly uncovered through rigorous scientific investigation. The effects of these two chemicals revealed man's ability to greatly impact his/her environment on both an ecosystem and a global scale. Likewise, these responses demonstrate the capacity of mankind to correct and reverse environmental threats. Thus, by the 1980s, climate change had been propelled to the forefront of the political sphere as a grave threat to humanity worth combatting (Bolin, 2007).

Yet despite this publicity, since the turn of the millennium politics and the general public have become increasingly divided on the issue of climate change. The Bush administration removed the United States from the Kyoto Protocol, a global agreement to reduce greenhouse gas emissions, in 2001. Under President Barack Obama, the U.S. entered the Paris Climate Agreement by which 195 countries pledged to set targets for their own emissions. The effort would quickly be erased, as the Trump administration announced its intent to withdraw the U.S. from the Paris treaty in 2017. Interestingly, the announcement followed Earth's hottest year on record (Sorlin et al., 2018).

Now more than ever and despite an overwhelming amount of convincing scientific evidence demonstrating the reality of the threat, Americans follow two distinctly different narratives about the climate change crisis. In the face of evidence from the nation's leading scientists affirming the threat, many of the nation's leading politicians continue to deny the threat of climate change. Studies show that uncertainty stemming from conflicting viewpoints greatly impacts public acceptance of scientific climate predictions. These conflicting viewpoints generally stem from the grabbing of anecdotal evidence in "piece-meal fashion… without considering the implications of this rejection to the rest of the relevant scientific theory and findings" (Lewandowski et al., 2016). When promoted by public figures, these viewpoints tend to gain traction alongside scientific findings.

Today the world is faced with a more immediate crisis that threatens the livelihood of humans across the globe. COVID-19 has emerged as the worst public health crisis since the Spanish Flu pandemic of 1918. Never before has a collective scientific effort been able to discover so much about a disease in such a short amount of time. In under a year since the emergence of the virus, scientists have begun trial testing vaccines, a rate that more than doubles the pace of the next fastest developed vaccine (Doorn, 2020). Yet this same science produced exclusively for the purpose of keeping humans safe has increasingly come under scrutiny by the public. Particularly in America, science-based behavioral reform in response to the pandemic has become heavily politicized, and simple suggestions scientifically proven to limit the spread such as social distancing and mask wearing are met with public resistance and manage to sow great divide in the political landscape. As a result, the US has experienced more confirmed cases and deaths from COVID-19 than any other nation and is currently facing a third wave of virus devastation (Romans et al., 2020).

The handling of the pandemic unveils the birth of a new inhibitor of scientific efficacy. Throughout the 20th century, communication barriers greatly inhibited the spreading of pertinent scientific information and thus the mitigation of many crises. Education of the public on key scientific findings relied on printed news services to gain traction. Additionally, conversations on such matters were generally confined to direct personal interaction and were significantly more rare in public forums. Today, scientists researching public crises such as climate change and COVID-19 enjoy almost immediate access to public forums for the dissemination of their findings. However, the rapid sharing of information in today's world seems not to increase awareness of scientific discoveries but rather to prevent the effectiveness of beneficial scientific findings. Important scientific findings relating to either climate change or COVID-19 continue to be contested. Events like cold spells in parts of the world or a supposed lack of overt scientific consensus on mask wearing are continually used as anecdotal fuel by contrarians to sow doubt in science. These doubts are rapidly disseminated through media outlets to scientifically illiterate populations unable to discern fact from speculation. As a result, people have never been more divided on matters of scientific certainty despite enjoying a society in which information is exchanged freely and rapidly. This finding exposes that, despite increasing access to accurate scientific information, people are increasingly motivated to distrust science, instead favoring more popular, often anecdotally based viewpoints (Lewandowsky et al., 2016).

Factors of Beliefs, Opinions, and Values

So why do some people believe cold hard scientific evidence and some deny it? This question matters especially in the face of global catastrophes like climate change and COVID-19. This question matters even in the context of personal health like when the tobacco industry tried to persuade the public that smoking causes no significant harm to a person's health when in fact it does (Bradford, 2011). Many factors and variables play major roles when a person makes a decision or forms an opinion. These factors land people in a hard to understand spectrum of personal values (Olson et al, 2016). However vast, certain decision-making variables stand out. To better understand the important factors that influence someone's decision to trust or distrust science and scientific findings, we must take an investigative look. We chose to focus and break down the influential roles of a person's identity, scientific literacy, education, and demographic.

We found that a person's identity significantly influences how they make decisions and form opinions. Identity is defined as "the fact of being who or what a person or thing is" (Oxford Languages). This seems vague, but you just are who you are. So, what goes into a person's identity? The influences or factors for political identity occur bottom-up and top-down. The bottom-up factors include "genetics, physiology, personality, fundamental needs and motivations, and moral values." The top-down influences include "political elites and media" (Feinberg et al., 2017). Many more influences likely exist but, we can use these top-down and bottom-up influences to better understand why somebody believes or denies scientific evidence.

Just like the factors and variables that determine a person's decision-making and opinions, an almost infinite pool of variables make up a single person's identity(Shang et al, 2020. Feinberg et al., 2017). But, just like the factors of decision making and opinion forming, some variables of identity stand out. Although difficult, classifying people into different groups serves a purpose that science communicators could utilize to more effectively reach and persuade a larger audience. Alignment of identity factors such as moral values allows for the classification of people into groups like conservative or liberal, and religious or agnostic. Gauging people's identity helps marketers and politicians to cater effectively (Hongwei et al., 2016). It would not make sense for Donald Trump, a very conservative politician, to try and win votes from a very liberal city like San Francisco.

A person's identity often reflects their surroundings. Even the geographical location of a person can inform the classification of their identity, in particular their political identity. Although geographical location does not fully give a black and white definition of a person's political identity, and disconnects can exist between an individual's political identity and stance on policy, it can give a better idea of what the people in that region value (Feinberg et al., 2017). Within the two-party system of the United States, a spectrum exists between the red(conservative) and the blue(liberal) political parties. The Feinberg et al.(2017) study reveals that in areas like Utah that have a significantly higher red to blue ratio of people, the red population generally takes a far more conservative stance on policy than the red population in areas like Hawaii with lower red to blue ratios.

Climate change has resulted in much debate on the efficacy of science. Lack of understanding of scientific evidence and group identity plays a large role in whether or not a person decides to believe or deny the imminent risk of climate change (Kahan et al., 2012). The scientific comprehension thesis (SCT) and cultural cognition thesis (CCT) back up the ideas that scientific literacy and group identity help guide people's decisions in the face of polarized issues like climate change. The SCT argues that the public does not know what scientists know. The CCT explains that due to a system of complex psychological mechanisms, one can form perceptions of societal risks that agree with their ideological groups, even if the truth opposes their opinion (Kahan et al., 2012).

CCT has much more impact on the beliefs of climate change within an individual than SCT. The relationship one has with their peers significantly influences their opinion on climate change (Kahan et al., 2012). The rationale is dependent on the reasoning that one person does not have the power to affect climate change, a global problem. This reasoning is not only logically fallacious but dangerous, as it puts emotions over science and logic. Sociality and the opinions and values of the people an individual surrounds themself with can affect that individual's views and beliefs.

Even more so, a person's values and opinions can form without sufficient evidence or reasoning. One study took a look at this in particular where researchers asked 140 undergraduates about their beliefs in six scientific phenomena - electrons, evolution, genes, etc., and 12 paranormal entities (angels, ghosts, karma, etc.) The results were surprising. When asked to justify their opinions, the students commonly just restated their opinions without offering any data or statistics to back them up. Only 32.6% of the students' responses related back to data and evidence. The remaining 20% of justifications to their opinions were due to sociality, religion, or cultural opinions. Denial of some of these phenomena was also studied where 18% of respondents denied some of these parameters without referring to evidence or data (Lobato & Zimmerman 2019). Concluding from this information, people often form opinions and truly believe in them even with a lack of evidence or sense. Forming opinions completely based on conjecture rather than scientific fact or evidence is highly problematic. Conjecture, instead of fact or evidence, may lead to a misunderstanding of critical issues such as COVID-19 or climate change.

In congruence with these findings is the idea that scientific reservations are centered primarily around religious beliefs instead of scientific literacy. In 2006, the scientifically literate population of the US amounted only to 17% - as defined by an ability to understand science presented in the New York Times or similar outlets. It was notable that in this study, increased amounts of scientific literacy did not correlate with more knowledge on some topics, but instead confusion. For example, as of 2006, the proportion of Americans who rejected evolution declined from 48% to 39%, but the proportion of Americans who accepted evolution also decreased - from 45% to 40%. Confusion increased from 7% in 1985 to 21% in 2005 (Gross, 2006). Increased amounts of information on the topic from two polarized sides/sources of information likely resulted in these changes. Additionally, in 2005, 43% of American adults agreed with the statement that the Bible is the actual word of God (Gross, 2006). These issues are not reflective of scientific literacy rates, but instead are reflective of personal/religious values.

Another finding discusses differences in views on evolution and how it is taught in public schools/state education programs. 43% to 47% of people polled between 1982 and 2008 believed that God had created humans within the last 10,000 years. Additionally, Evangelicals are less supportive of environmental regulation and believe that God gave humanity “dominion” over the Earth. The results from this study came back as follows: people that believed in evolution: 49.6%, stem cell research: 74.3%, global warming: 45.9%, and those that had high skepticism overall fronts: 90%. This gives even more credence to the factor of confusion. 90% of those had high skepticism, meaning that there it is increasingly difficult for one to form proper opinions due to numerous and differing sources of information. In this same study, many different variables were taken into account such as education, age, sex, political party, ideology, religion, and views of the Bible. Education influenced opinions on climate change the most. Concluding from this study, it is apparent that factors such as education and religion play a large and measurable part of determining one's views and beliefs.

Identity seems to play a large role in whether people believe in climate change or not, or if they think it's important enough to worry about (Bain et. al, 2012). The politicization of science has greatly affected people's stances on issues like climate change. Belief in climate change is correlated much more with liberal political leanings. The opposite is true for conservative political leanings. Political salience can polarize a person's beliefs in the context of anthropogenic climate change. Salience in the political context is basically how strongly a person identifies with a certain political party or group (Unsworth and Fielding, 2014). The concrete salience a person has could lead them to see somebody with an opposing view in a negative context which leads to further polarization.

Economic ideology also plays a pivotal role in people's opinion or perceived threat of climate change. The general public often puts environmental issues on the backburner compared to maintaining or increasing the economy. Top-down influences like the media and politicians have conditioned the public to align themselves with the treadmill theory. The treadmill theory details how an individual, company, or group focuses on production with tunnel vision so that they cannot see or care about the consequences - especially environmentally (Longo and Baker, 2014). Because of this conditioning, the public correlates environmental advocacy with losing jobs and degrading the economy. Of course, not all of the public aligns with the treadmill theory. The conservative political identity more often than not falls into the economic identity described by the treadmill theory.

As of November 17, 2020, over 248,000 people have died from COVID-19 in the United States alone (CDC, 2020). Worldwide, 1.33 million people have died from COVID-19 (Ritchie, 2020). Yet people in the United States still show great skepticism of the virus's nefariousness or completely disavow it. Political ideology has tremendously influenced how people respond to

COVID-19. Especially on people's responses to public policy around COVID-19. More liberal and moderate identifying people choose to follow the CDC's guidance and change their daily behavior in accordance with policy compared to conservative identifying people. During the beginning of the outbreak in April 2020, 59% of Democrats reported covering their mouths with masks or face shields to prevent disease transmission, while only 44% of Republicans reported covering their mouths. At the end of April, 80% of Democrats were covering their mouths while only 63% of Republicans were. 84% of Democrats in mid-May supported mandatory mask-wearing while only 47% of Republicans did (Bertrand et. al, 2020). People have clearly become more and more polarized on what to believe and how to act during the pandemic. These findings correlate with Republican and conservative values, reflecting the desire for maximum freedom and little-to-no impedance on personal values. Likewise, the inverse is true for Democratic beliefs, outlining the desire for greater public health and well-being.

The Pew Research Center also investigated the effects of political affiliation on COVID-19 opinion, in June 2020. As of June 2020, it was found that 61% of Republicans thought the worst damage from the disease had already occurred. Inversely, only 23% of Democrats believed that the worst had already arrived, indicating 76% thought the worst was still to come.

As of June 2020, only 45% of Republicans were very or somewhat concerned about unknowingly spreading the virus, while 35% of Republicans were worried that they would contract the virus. At the same time, 77% of Democrats were very or somewhat concerned they may spread the coronavirus, while 64% were concerned they would get the disease and necessarily become hospitalized. Additionally, 44% of Republicans said the actions of ordinary people matter a great deal in spreading COVID-19, while 73% of Democrats felt the same way (Pew Research Center, 2020).

The same research showed that partisanship was the largest factor in determining comfort with different activities during the coronavirus (such as grocery shopping, getting a haircut, and eating out at a restaurant) with a difference of 26%. Partisanship was followed by race (15%), geography (11%), gender (5%), and age (3%) (Pew Research Center, 2020).

The clear divide shows a correlation between the influence of political ideology and where trust is given. Some of the same factors of identity that affect people's views on climate change and political stance affect how people view and act on COVID-19. Both conservatives and liberals look to political figureheads for interpretation of scientific evidence and how to act on it (van Holm et al., 2020). Conservative figureheads consistently downplay the seriousness of the virus and the efficacy of the CDC guidelines. The President of the United States, Donald Trump, continually downplayed the virus with fallacious messages with claims like knowing more than doctors and disease experts. On March 7, 2020, the president said, "no, I'm not concerned at all," concerning COVID-19. Then on March 22, 2020, the president said, "we cannot let the cure be worse than the problem itself," (Doggett, 2020). This contradicts the message of the Center for Disease Control (CDC). Throughout the coronavirus pandemic, the CDC has advised people on the danger of the virus and the prevention of it. People should in fact take the virus seriously and take measures to prevent it. Some of these measures have been implementing lockdowns, wearing masks, and social distancing. In response, conservative president Trump catered to the economic values of the conservative party and conveyed that the protective measures prescribed by the CDC threaten the economy (Doggett, 2020). This all could relate to how more conservative people choose to oppose the CDC guidelines than liberal people. Only 39% of Trump supporters supported mandatory mask-wearing in mid-May. Trust in the scientific community was also reviewed during the COVID-19 time frame. During the first wave of the survey, 70% of Democrats had confidence within the scientific community, while 51% of Republicans had confidence. This changed significantly when reviewed upon the fourth wave of the survey. Democrat trust declined 2% to 68%, and Republican trust declined 13% to 38% (Bertrand et. al, 2020). Fallacious messages and thinking is worrisome due to the ignorance of scientific data. Ignorance of scientific data may lead to potential problems not only medically, but personally for many people.

We think the general public may look to political and religious figureheads for guidance on how they should act due to a lack of understanding of science and scientific illiteracy. This may be why scientific literacy is so important in today's culture. To more clearly outline this issue, we must define scientific literacy. Scientific literacy can actually range in definition from "what the general public ought to know about science," to "an appreciation of the nature, aims, and general limitations of science, coupled with some understanding of the more important scientific ideas," according to Laugksch (Laugksch, 1999). Henceforth though, we shall define scientific literacy as the general public's understanding of science. Rates of scientific literacy throughout the public differ due to a wide variety of factors.

Demographics can play a large part in the overall scientific literacy of the population. Firstly, according to one study, scientific literacy tends to be higher for men than women (69% and 61% respectively) depending on the question being asked. In regards to this, though, men tend to answer physical science questions better, while women tend to answer biological questions better. The amount of schooling that one has is also strongly related to higher rates of scientific literacy. Family earnings also play a large part in determining scientific literacy (76% for the upper quartile and 54% for the lower quartile). In addition, younger people displayed slightly higher science knowledge than those 65 and older, depending on the question asked. (National Academies of Sciences, Engineering, and Medicine, 2016).

Continuing and in regards to race, whites were more likely than Hispanics or black Americans to answer more questions correctly (white = 8.4, Hispanic = 7.1, and black American = 5.9). These results may be inconclusive due to fewer numbers of non-white participants, though. (National Academies of Sciences, Engineering, and Medicine 2016).

Although scientific literacy is key to understanding common and perhaps uncommon scientific problems, opinions are still derivative of an individual's belief system. In regards to this, one study found that higher scientific literacy rates have been correlated with stronger opinions and higher amounts of polarization, driven by religion and politics, on specific scientific topics (Drummond & Fischoff, 2017) such as the Big Bang, human evolution, nanotechnology, and genetically-modified foods. Not only did religious identity change an individual's beliefs, but political leanings did as well, especially regarding climate change.

There are many different factors that play into the way the human brain can form opinions and gather value from information. Some of these ways of thinking can be dangerous to not only themselves but to other humans and environmental health. It seems as though personal values and opinions are the winners in the debate of science vs. non-science.

Using factors of identity, as Feinberg et. al described, scientists could better curate messages to different audiences (Bain et al, 2012). Important factors like geographic location, demographics, and political affiliation have potential use for persuasion by science communicators. Scientists appear to exist in the top-down influence section of identity. Scientists could take note of how other top-down influences like politicians, religious leaders, education rates, and media influence their audience and implement those techniques in the context of COVID-19 and climate change.

Aspects of Science Miscommunication

This section focuses on the mechanisms that contribute to poor science communication. Some of the problems that scientists face are not new as a result of the COVID-19 pandemic. Science communication is one of those problems that has been around for a long time, but has been accentuated by the pandemic (Nature editorial, 2020). Policy makers needed accurate information related to the pandemic to make safe decisions. In some cases, it worked well but in others there was a disconnect between statistics and action, such as in Georgia (Bassett, 2020). There are multiple ways to approach this disconnect. The concepts proposed here are not an exhaustive list but encompass a large part of the conversation around this topic. We propose a four-part system for understanding this idea: lack of interdisciplinary communication, poor communication from both scientists and the public, clash of values, and poor writing. A large portion of existing literature related to science communication can be categorized into one of these parts. We propose improving these parts when communicating science. Doing so could help more people understand the specific topics, feel more involved in issues, and enjoy reading and learning about it.

In the early years of natural science, the number of disciplines was much lower than it is today. Practicing scientists were well versed in their field of study, but their field of study most likely encompassed what we now see today as totally separate fields. In the book “Writing

Science in Plain English", Anne Greene starts by summarizing the issues in scientific writing, and how improving our scientific writing can help bridge the gap of science communication (Greene 2013). This gap she proposes falls into the first major category described above: lack of interdisciplinary communication. Not having this cross collaboration "makes it more difficult to apply discoveries from one field to another" Greene states. Greene suggests that improving our scientific writing is a major step towards understanding research from outside one's field of expertise. Lindenfield et al. (2012) adds to this part of the conversation by mentioning a "fractured nature of university disciplines" in regards to environmental communication. It would seem that at the current moment there is consensus that the gap in communication between scientists could close with better scientific writing. However, when it comes to science communication with the public there are more angles to consider.

The communication gap between scientists and the public is the next major category in this conversation. Most of the authors thus far mention the disconnect between scientists and the public. This disconnect appears in a few different ways. One of these ways is the deficit model. This is described in detail by Sturgis and Allum 2004 in their article "Science in Society: Re-Evaluating the Deficit Model of Public Attitudes", which has been cited over 1,000 times by other researchers as compared to a couple hundred at most for other similar papers. As Sturgis and Allum state, the deficit model implies that the public's understanding in science is deficient, but the science being communicated is sufficient. There are multiple sides to this argument, and potentially some truth. However most researchers would agree with Groffman et al. 2010 in assuming that the public's understanding comes from a place of ignorance is not effective. Groffman et al. continues by stating that scientists need to present the information in a way that resonates with the public. Kiem and Austin 2013 mention this as well in referencing a lack of relevance to scientific information even if it is scientifically sound. On top of this is the conversation around how the public obtains scientific information. Groffman et al. discuss this at length, suggesting that new tools and social science can help scientists communicate with the public. This is where we start to reach the present moment of this conversation. What are these tools and what does social science suggest? One suggestion made by Kiem and Austin is the idea of a 'knowledge broker' who interprets the needs of end-users to scientists, who then present the scientific information to the broker, who then translates the information back to the end-users. Currently research is being done regarding the demand for a position such as this (Hart et al. 2012). This potential position hints at the next category related to values, and how better alignment of values could help bridge this gap.

The conversation started by Seethaler 2019 and others explains the idea of working with values. They argue that a clash of values is a major component in the "communication breakdown". These values come from many different sources such as political, social, or religion. Seethaler and others mention that religion is often thought of as a conflict of knowledge versus ignorance, but they argue that it is actually a conflict of values. It is important for science communicators to take different values into account when presenting scientific information. There is a danger in ignoring the role of values as stated by Seethalther et al. as well as Nisbet. Seethaler proposes that ignoring the role of values would change the direction of doubt from the information itself to the integrity of the science behind it. This is also evident in the decisions being made based on the information. Decision makers are a large group of end-users with regards to scientific information. Kiem and Austin show that decision makers "view information differently as a factor of their connection (or not) to rural communities". These communities are also a large part of the disconnect. Kiem and Austin found that the disconnect between science information and the public is exacerbated in rural communities. Further research needs to be done in this respect as to whether or not there is a direct correlation between values in these communities and the gap in scientific information.

The conversation about science communication and the gap between scientists and the public is important, and has been accentuated by the COVID-19 pandemic. There are a few angles from which to look at the ongoing conversation: between scientists, between scientists and the public, clashing values, and poor writing. Many of the conversations from the past have identified the need to have a conversation regarding this topic. More and more research is being conducted on better ways to communicate science and bridge this gap, but more is still needed in many different realms such as those in rural communities. The idea of the deficit model is well known within this field, but many believe it is not a good way to approach this topic. In using the deficit model scientists solidify their stance in the conversation and make it very difficult to change the way they communicate. To further address this topic there must be some change on both sides.

Does Scientific Literacy or Cultural Identity Have a Greater Influence on Scientific Views?

This paper has presented societal reactions to deleterious phenomena such as smoking tobacco (Norr, 1952), the use of harmful pesticides (Kinkela, 2005), the COVID-19 pandemic (Burtzyn et al., 2020) and climate change (Kahan et al., 2012; Burtzyn et al., 2020) that seem counter intuitive. In other words, if people know there are negative consequences associated with a decision, why do they not take a "wide berth" and avoid these consequences? Contemporary psychology suggests that it is human nature to discount harmful information in the pursuit of personal happiness (Trout, 2007; Story et al., 2014). The mechanism behind this is largely that we are sentient beings who place a greater value on instantaneous happiness rather than possible long term benefits (Trout, 2007). This idea helps explain why those who place a high value on individual freedoms may feel threatened by preventative or mitigation measures in response to a global pandemic or climate change.

Additionally, it's logical to assume that many individuals may have a hard time engaging with the application of scientific findings, especially in dealing with prolonged timescales because of a lack of scientific understanding and first hand experience with the issue. However much of the current literature suggests that a lack of scientific literacy does not explain a lack of action taken against harmful environmental issues (Kahan et al., 2012; Lewandosky et al., 2016). This further propagates the idea that humans operate under emotional pretenses (Trout, 2007; Story et al., 2014). From here we may surmise that cultural identity is a more important metric in understanding one's decision making patterns.

By inferring cultural alignment is the strongest element of scientific engagement, it then makes it important to understand what factors accurately define cultural identity. The groupings of identity must also be defined in a manner that is coherent and repeatable as each human is seen to have their own unique psychology, thus simplifying these observations into logical groupings can be difficult. Yet it is well studied that group identity has a strong influence on individual behavior (Sunstein et al., 1999). Previous work has identified religion (Unsworth &

Fielding, 2014), ethnicity (Snow et al., 2016), and partisanship (Drummond & Fischoff, 2017; Burtzyn et al., 2020) to have a discernible influence on how an individual engages with scientific issues like COVID-19, and climate change.

Based on the literature that we reviewed, political party alignment is found to be the strongest predictor of one's belief in certain scientific findings (Drummond & Fischoff, 2017) especially when partisan identity is salient (Wlezien C., 2005; Unsworth & Fielding, 2014). The far right has been seen to hold views that diverge from the scientific community on issues such as the severity of the COVID-19 pandemic and climate change while the far left largely agrees with the scientific consensus. Recently, studies have documented that members of the far right have opposed actions geared towards diminishing the COVID-19 pandemic (Van Holm et al., 2020; Raile et al., 2020; Burtzyn et al., 2020). We also found that those who belong to the conservative far right most frequently deny the reality of changing climate (Unsworth & Fielding, 2014). Previous work suggests that these members feel economically threatened by proposed climate change mitigation efforts (Kahan et al., 2012), thus believing in climate change would open the door to seemingly more strict economic and individual regulation. Individuals with liberal leanings are more in favor of environmental preservation as opposed to economic prosperity (Logo & Baker, 2014). This idea of environmental preservation extends to a communitarian view (Kahan et al., 2012) that explains the divergence in party responses to the current global pandemic. While partisanship and political salience are a rather simplistic grouping of identity that exclude other factors of identity, they are seen to create a reproducible group metric that is discernible against other factors (Wlezein, 2005; Drummond & Fischoff, 2017).

Failures and Successes of Science Communication

The ongoing production and consumption of tobacco products represents a divergence between science and policy. While we know that smoking cigarettes is associated with severe adverse health risks, we still allow for production and retail (Proctor R., 2012). This tells us that scientific information is not to blame but rather societal thought and science are not always congruent.

While we have given much attention to examples in which science communication has failed, it is worth revisiting that science communicators in the past have risen to the occasion and presented dramatic narratives that have facilitated positive changes. Rachel Carlson's *Silent Spring* is largely attributed to a significant shift in public attitude towards the use of the pesticide DDT. Carlson was able to resonate with a wide reaching audience by equating the negative consequences of DDT to other current world events (Kinkela, 2005). Carlson's effort is a prolific example of how interdisciplinary communication is an effective tool for conveying scientific information when traditional avenues fail.

Following the DDT crisis the world recognized the damage caused by CFCs with more haste. World leaders were able to cooperate in signing the Montreal Protocol which successfully banned and replaced CFCs. These examples demonstrate that both civilians and governing agencies can work to produce necessary change. That being said action must be taken when science tells us situations are dire. We as citizens and scientists cannot sit idly by and expect others to exact the change alone.

How to Address the Current Information Landscape

While *Silent Spring* proved to be an effective measure towards enhancing public belief in the negative effects of DDT, the 1960's were a very different time for the passage of information. In current times we see a rise in viewership of reading on the internet and social media platforms (Merga & Roni, 2017) and decreased in time spent reading the same material (Ziming, 2005). This begs the question, how would content like *Silent Spring* released as a full length book be received today? Is a longer narrative the most effective way to reach a broad audience? It is important for science communicators to understand how to best reach their audience especially during dynamic times when consumer attention is a commodity (Landrum et al., 2019). Understanding this mechanism presents an opportunity for useful employment of a knowledge broker (Groffman et al., 2010).

It is important for scientific ideas to have traction on popular media platforms rather than just peer reviewed journals, so that the information is as accessible as the misinformation is. While scientific journals are the current standard for authoritative scientific information, many journals have a pay wall and have inherently lower viewership than open source journals (Davis

P., 2011). This is especially important when social media is pointed to as the main vector for misinformation (Allcott et al., 2019). One of the most rudimentary ideas in science is that the world is a sphere. However, the "Flat Earth Movement" gained traction due to prominent public facing conspiracy theorists on YouTube (Landrum et al., 2019). Those who viewed a flat earth video on the site were recommended to watch more flat earth videos by the website's content viewing algorithm (Youtube, 2019). This mechanism is in place because services like YouTube largely make their money by advertisement viewership which is positively correlated to how long a user is watching the site. So in a sense platforms that operate under this model have no incentive to promote true information but rather whatever information will yield the longest viewership. However, YouTube began a campaign to decrease the prevalence of similar misinformation by removing it from the viewing algorithm once the Flat Earth movement gained popularity in the public eye around 2017 (Landrum et al., 2019). It is important that prolific sites like YouTube understand the implications of this type of content. Their choice to thwart this content becomes an ethical and seemingly political matter ultimately. This where the realm of science ends and a need for multidisciplinary works like that of Rachel Carlson become viable options.

Conclusion

Science, despite being fundamentally rooted in unbiased truth-finding, has never been more contested as it is today despite our modern world allowing for rapid sharing of knowledge. Our paper has proposed that the gap in communication stems from both failures of the scientific community to reach their audience and the will of the individual in protecting his or her well being. In regard to the scientific community, effective communication has been greatly limited by a general lack of scientific literacy among the public as well as a lack of collaboration between different fields of science. The result is a missed opportunity to effectively educate a public actively looking for answers. Alternatively, human nature often causes individuals to seek out answers that support their own identity or well being. In today's world where information is abundant, varied, craftable and easily accessible, individuals have increased opportunity to find these answers - often in the form of diluted science based on anecdotal evidence. This allows individuals to isolate themselves behind their beliefs, thus increasing the ideological divides that are exacerbated by political division. In short, ineffective scientific communication and increasing prevalence of accessible pseudoscience frequently undermines the effectiveness of scientific findings.

Yet we also see that these fundamental flaws are not unavoidable. We thus propose that future scientific communication acknowledge this gap in communication and attempt to remedy a society often led wildly astray by erroneous information. There may be little hope for instilling drastic changes in the identities or human natures of great portions of the country and world. However, there is much hope for eliminating the pitfalls and increasing the efficacy of scientific communication. Scientists have an opportunity to compose or translate their findings to the public so as to greatly affect public opinion. As seen in the cases of dangers imposed by DDT and CFCs, emotional scientific appeals can rapidly shift perceptions and attitudes about an issue. Moments in scientific history such as these have the potential to become models for the handling of future scientific findings. However, more research must be done to properly identify methods of communication that increase the probability of reaching and influencing a desired audience.

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