The Differential Effects of Humor on Three Scientific Issues: Global Warming, Artificial Intelligence, and Microbiomes

Sara K. Yeo[1]*
Leona Y.-F. Su[2]
Michael A. Cacciatore[3]
Jennifer Shiyue Zhang[4]
Meaghan McKasy[5]

[1] Department of Communication, University of Utah, 2618 Languages and Communication Building, 255 S. Central Campus Drive, Salt Lake City, UT 84112-0491; ph: +1 (801) 581-6888; e-mail: sara.yeo@utah.edu; Twitter: @sarakyeo; ORCID: 0000-0002-2043-8400
[2] Charles H. Sandage Department of Advertising, College of Media, University of Illinois at Urbana-Champaign, 121B Gregory Hall, 810 S. Wright Street, Urbana, IL 61801-3611, USA; ph: +1 (217) 300-8273; e-mail: lyfsu@illinois.edu; ORCID: 0000-0002-8661-7196
[3] Department of Public Relations, Grady College of Journalism and Mass Communication, University of Georgia, 134-C Journalism Building, 120 Hooper Street, Athens, GA 30602-3018; ph: +1 (706) 542-2711; e-mail: mcacciat@uga.edu; ORCID: 0000-0001-8357-4621
[4] Institute of Communications Research, College of Media, University of Illinois at Urbana-Champaign, Gregory Hall, 810 S. Wright Street, Urbana, IL 61801-3611, USA; ph: +1 (217) 721-0298; e-mail: shiyue2@illinois.edu; ORCID: 0000-0001-6697-6143
[5] Department of Communication, Utah Valley University, Clark Building 502 H, 800 West University Parkway, Orem, UT 84058; e-mail: meaghan.mckasy@uvu.edu; ORCID: 0000-0002-3489-612X

* Corresponding author

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Author Biographies

Sara K. Yeo (Ph.D., University of Wisconsin-Madison) is an Associate Professor in the Department of Communication and the Director of the STEM Ambassador Program (STEMAP) at the University of Utah. Her research interests include science and risk communication with a focus on information seeking and processing. She is also trained as a bench and field scientist and holds a M.S. in Oceanography from the University of Hawai'i at Manoa.

Leona Yi-Fan Su (Ph.D., University of Wisconsin-Madison) is an Assistant Professor in the Department of Advertising and the Institute of Communications Research at the University of Illinois at Urbana-Champaign. Her research focuses on examining the interplay between media and society, particularly how social media and new technologies influence human communication and social behaviors in the context of scientific and health topics.

Michael A. Cacciatore (Ph.D., University of Wisconsin-Madison) is an Associate Professor in the Department of Advertising & Public Relations at the University of Georgia. His research examines the communication of science topics ranging from nanotechnology to vaccinations. A significant portion of this research has tracked media depictions of science issues with an additional focus on the interplay between media, values and risk in the opinion formation process.

Jennifer Shiyue Zhang (M.S., University of Illinois at Urbana-Champaign) is a Ph.D. student in the Institute of Communications Research at the University of Illinois at Urbana-Champaign. Her research focuses on health and science communication. She has ongoing projects on using social media for strategic communication in the context of food, health, and scientific topics.

Meaghan McKasy (Ph.D., University of Utah) is an Assistant Professor of Public Relations and Strategic Communication in the Department of Communication at Utah Valley University. She studies information processing and attitude formation in science and environmental communication. She is particularly interested in analyzing variables that influence motivation and ability in the processing of strategic messaging.

Abstract (196 words)

Humor is widespread in communication and its use in the context of science is no exception. Although science jokes are pervasive on social media, we are only beginning to understand the mechanisms through which humor affects people's attitudes, opinions, and perceptions of scientific topics. Here, we add to our understanding of how funny science content influences attitude formation and behavioral intentions; these results can help communicators make strategic decisions related to humor's use in real-world practice. Extending recent work in science communication, this study aims to understand the conditional nature of the mechanism by which funny images about three different scientific topics, combined with verbal humor, affects people's social media engagement intentions by eliciting mirth. Our results offer evidence that choices about which humor types to employ matter when it comes to communicating scientific topics. For two of the three topics, artificial intelligence and microbiomes, exposure to different humor types resulted in different levels of mirth and humor's effect on engagement intentions was moderated by respondents' need for humor. However, humor did not have the same effect on global warming engagement intentions. Our findings have implications for the practice of, training, and scholarship in science communication.

Keywords: science humor, engagement, global warming, artificial intelligence, microbiomes

The Differential Effects of Humor on Three Scientific Issues: Global Warming, Artificial Intelligence, and Microbiomes

Humor is widespread in human communication and its use in the context of science is no exception. Although science jokes are pervasive on social media and science-related improv comedy is becoming increasingly popular (e.g., Di Liberto, 2019),[1] we are only beginning to understand how the use of humor to communicate science affects people's attitudes, opinions, and perceptions of science. Science humor can take many forms. Among these are science jokes, memes, and funny animated images (i.e., GIFs), several of which thrive on social media (Su et al., 2022).

Humor is a multidimensional construct that involves different types, underlying processes, and functions that may operate alone or in combination. Humor can refer to four distinct constructs (for a theoretical review of how comedy elicits humor appreciation, see Warren et al., 2018, 2021). First, it can be used to refer to an individual trait called a sense of humor (Martin & Lefcourt, 1983) or need for humor (Cline et al., 2003), which describes one's propensity to amuse others or laugh at funny content. The second construct to which the term can refer is a stimulus that is designed to elicit amusement or laughter. A third is a subjective psychological state that is a response to a funny stimulus. And lastly, the term has also been used to refer to the act of creating something funny.

Although others have used the term *comedy* to refer to the stimuli intended to elicit laughter (Warren et al., 2018, 2021), we instead draw the distinction between such a stimulus and the psychological state of humor appreciation by using the term *mirth* to refer to the latter.

[1] Another example is *Improbotics*, a "tech-infused improvised theatre and comedy show and a live Turing test-based scientific experiment" (https://improbotics.org/), in which an artificial intelligence-based chatbot performs in the show and attempts to pass as human.

We use *comedy* or *humor* interchangeably to refer to a stimulus intended to elicit mirth. Thus, our study involves three of these four constructs—our comedic stimuli involve varying the types of humor in science content, and we measure participants' appreciation of the funny stimuli (mirth) and examine how need for humor moderates the effect of humor appreciation on downstream intentions to engage with more science content.

A better understanding of how funny science content influences attitude formation and our behavioral intentions will help communicators make informed strategic decisions related to humor's use in real-world practice. The present work builds on existing humor research on Twitter (Yeo et al., 2020, 2021) and extends this line of experimentation to scientific topics that are on the publics' agenda to differing degrees. In previous research, Yeo and colleagues manipulated visual and verbal humor about chemistry, in the form of an image embedded in a tweet, to examine how different humor types affected viewer's intentions to engage with the content. Similarly, we focus on visual and verbal science humor on Twitter, but we use different scientific topics as the context of inquiry.

The goals of this study are twofold. First, we replicate the experiment conducted by Yeo et al. (2020). Replication is fundamental to the social sciences (Freese & Peterson, 2017; Lindsay, 2015) and, to gain a clearer understanding of the effects of messaging tactics used in science communication, we must first replicate the psychological mechanisms through which visual and verbal humor have been shown to affect people's engagement intentions from Yeo et al. (2020). Using a joke about chemistry that consisted of an illustration of two atoms joking about losing electrons, Yeo and colleagues found evidence of a psychological mechanism that described the effect of two different techniques of humor (wordplay and anthropomorphism) on people's intentions to engage with science content through an intermediary emotion, mirth.

Second, we seek to extend and validate the previous findings by conducting our experiment with scientific topics other than basic science. In the present work, we aim to understand whether the abovementioned psychological mechanism is valid when the humor is embedded within scientific topics or issues[2] that are more salient to public audiences. While basic science about atoms and electrons are rarely covered in media, news about topics such as global warming (e.g., Sengupta, 2022), artificial intelligence (AI; e.g., Tugend, 2022), and microbiomes (e.g., O'Connor, 2021) are prevalent. Thus, we conduct similar experiments embedded in online surveys using these three scientific issues.

These issues, global warming, microbiomes, and AI, are at various stages of the issue attention cycle (Downs, 1972), which describes a systematic cycle of public awareness of and interest in various topics. Visual and verbal humor takes many forms; different humor types are likely to be used when communicating about various scientific issues. Therefore, to heighten the external validity of our research, we employ different types of humor in our experiment depending on the scientific topic at hand. Our review of the literature focuses on the three issues that form the contexts of our experiments, the types of humor we examined in association with each scientific topic, and the effects of these humor types on downstream outcomes of interest. We conclude our literature review with the research questions and hypotheses that drive the present study.

[2] We use the term "topic" and "issue" interchangeably to refer to the scientific context of the joke in our experiment. The issues/topics used in this study are (i) global warming, (ii) artificial intelligence (AI); and (iii) microbiomes.

Literature Review

Fluctuations in Publics' Attention to Scientific Issues

The issue attention cycle was initially coined to describe fluctuations of public attention to environmental issues (e.g., pollution) over time (Downs, 1972). Issues are posited to evolve through five key stages: (i) the pre-problem stage, in which its discussion is limited to occur among specialists, (ii) an alarmed discovery and euphoric enthusiasm stage, where the issue is brought to the public agenda, (iii) the stage at which publics realize the cost of significant progress and the issue maintains a high level of attention, (iv) the gradual decline of intense public interest, and (v) the post-problem stage where other topics surpass the original topic and the cycle begins anew.

Studies have extended the issue attention cycle to the online environment. Using nanotechnology as an example, Anderson and colleagues (2012) investigated whether online media shared the same cyclical pattern of public attention and found that online coverage of nanotechnology was ten times higher than its print counterparts. Additionally, the online environment prolonged public attention to the topic, highlighting the value of applying the issue attention cycle to investigations of scientific topics online. To this end, the present work examines three scientific issues—global warming, artificial intelligence, and microbiomes—at different stages of this cycle.

Global Warming

The term "global warming" first appeared on the national agenda of the United States in the late 1980s to describe the impact of increasing greenhouse gas emissions and the subsequent effects on humans (Whitmarsh, 2009). Shortly thereafter, the United Nations Framework Convention on

Climate Change defined "climate change" as "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods" (United Nations, 1992, p. 7). Although "global warming" and "climate change" emphasize different aspects of the same phenomenon, they are often used interchangeably in everyday conversation and media coverage about the environment (Benjamin et al., 2017). In the present study, we adopt Djerf-Pierre's (2013) strategy to examine this environmental issue by combining the two terms.

Artificial Intelligence (AI)

Artificial intelligence has existed for over six decades (Buchanan, 2005) and refers to the ability of a machine to think and do tasks like a human (Duan et al., 2019). As a cutting-edge technology, academic articles discussing AI have exploded since 2009 (Fast & Horvitz, 2017) but the issue is not without controversy; scholars have written extensively about the ethical, legal, and social implications of machines that mimic human behavior (Dignum, 2018). Scholars have also discussed AI in terms of privacy concerns (Katyal, 2019) and questions of control (Kalogirou, 2003).

Microbiomes

As an emerging science topic, the term "microbiomes" refers to the collection of microbes such as bacteria and viruses, their genes, and the environment in which they live (Marchesi & Ravel, 2015). In the last decade, there has been increasing public attention focused on microbial communities (e.g., Human Microbiome Project, Earth Microbiome Project) and some patterns in public attitudes are emerging. For example, recent studies show that people experienced greater

disgust and perceived greater risks when viewing a human-focused microbiome article than a similar article focused on an animal's microbiome (Yeo et al., 2019). Disgust felt as a result of reading about human feces also increased support for regulation of microbiome research (Sun et al., 2019).

Global Warming, AI, and Microbiomes on the Issue Attention Cycle

Prior studies have identified a "spotlight effect" between media attention and public interest (Arendt & Scherr, 2019) and coverage of an issue can captivate public attention, encouraging subsequent online information-seeking behaviors (e.g., Fond et al., 2015). From this perspective, Google Trends[3] offers a reflection of topics that capture public interest—an initial approach that we applied to selecting our three topics. Combining the terms "climate change" and "global warming," and comparing the Google Trends results from a search using these terms with those of "artificial intelligence" and "microbiome," we found the three issues to have received different levels of public attention over the past 15 years (Figure 1).

[Figure 1 about here]

A major peak in the Google Trends data on global warming occurred in 2007 in accordance with Djerf-Pierre's (2013) observations. Ebbs and flows in searches at comparatively lower volumes followed and the issue regained significant public attention in 2017 and 2020. There were relatively fewer searches of "artificial intelligence" and "microbiome" over the same period. Specifically, the topic of microbiomes was virtually unsearched prior to 2013; since then, the term has only been used in Google searches a small number of times. Overall, AI has

[3] Google Trends is a website that analyzes the popularity of top search queries in Google Search (https://trends.google.com/) .

garnered more attention than microbiomes, particularly in the last 5 years but the volume of searches is far less than that of global warming.

In addition to the Google Trends data, we also measured perceived familiarity with and knowledge of the three topics in our sample, which allowed us to approximate their position on a hypothetical issue attention cycle.[4] The results (see Footnote 4) showed a significant difference in perceived familiarity between issues, including significant differences between each pair of items, a pattern that was repeated when knowledge was the variable of interest. Overall, the Google Trends data supports the pattern we observed in our own survey data; the public is most familiar with and knowledgeable about global warming and least familiar with and knowledgeable about microbiomes. Artificial intelligence was consistently ranked between those two issues, and generally trended more similarly to microbiomes than global warming.

Comedy and Humor Types

Scholars in a variety of disciplines have examined how comedy elicits humor appreciation but there are three prevailing theories: (i) incongruity, (ii) relief, and (iii) superiority. Incongruity theories emphasize cognition and experiences of mirth result from surprises that violate expectations (Berger, 1976; Deckers & Devine, 1981). Relief theories propose that humor

[4] Respondents were asked how well informed they believed themselves to be (1 = "Not at all informed," 7 = "Very informed") about global warming ($M = 4.87$, $SD = 1.68$), artificial intelligence ($M = 4.24$, $SD = 1.82$), and microbiomes ($M = 3.19$, $SD = 1.96$). We used the Friedman test to determine whether perceived familiarity differed between issues as the data were not normally distributed. The results show a significant difference in perceived familiarity between issues ($\chi^2(2) = 4765.7$, $p < .001$). Wilcoxon pairwise comparisons revealed significant differences between each pair of items (global warming vs. artificial intelligence: Mean difference = 0.63, $p < .001$; global warming vs. microbiomes: Mean difference = 1.68, $p < .001$; artificial intelligence vs. microbiomes: Mean difference = 1.05, $p < .001$). Similarly, we measured respondent's factual knowledge levels with eight indicators for each topic: global warming ($M = 4.58$, SD = 1.69), artificial intelligence ($M = 4.41$, $SD = 1.83$), and microbiomes ($M = 3.88$, $SD = 2.06$). A repeated measures ANOVA revealed significant differences in knowledge across issues ($F(2, 6649) = 84.4$, $p < .001$) and the Tukey post hoc comparisons revealed significant differences between each set of items (global warming vs. artificial intelligence: Mean difference = 0.17, $p < .01$; global warming vs. microbiomes: Mean difference = 0.70, $p < .001$; artificial intelligence vs. microbiomes: Mean difference = 0.53, $p < .001$).

appreciation occurs when people sense there has been a release of tension (Berlyne, 1972; Freud, 1960; Morreall, 1983). Lastly, superiority theories suggest mirth is experienced as a result of victory over others (Gruner, 1996, 1997; Morreall, 1983).

In examining humor appreciation and the utility of comedy as a science communication tactic, these three theories offer relatively little explanatory power as they can be used to explain the effects of nearly any funny message. To overcome this challenge, we focus on three types of humor that are prevalent in science communication via comedy and link these to their rhetorical functions (Meyer, 2000). A recent content analysis of science humor showed that satire, wordplay, and anthropomorphism were among the most frequently employed humor types on social media. Approximately 33%, 40%, and 27% of tweets and 40%, 29%, and 16% of Instagram posts contained these types, respectively (Su et al., 2022). Thus, we focus on investigating the effects of these three types.

Humor types such as anthropomorphism, wordplay, and satire are likely to serve different communicative purposes. Moreover, each type can serve multiple functions. According to Meyer (2000), humor in messages has four rhetorical functions: (i) identification, (ii) clarification, (iii) enforcement, and (iv) differentiation. First, humor can be used by a communicator as a means of identifying with their audience. It can also be used to clarify one's views on issues, e.g., when political campaigns rely on witty one-liners as slogans. Such humorous slogans also have the added benefit of being easy to remember. Enforcement can be viewed as a stronger means of clarification, usually one that has some corrective effect. In this case, humor can be used as a means of enforcing social norms and can be used to criticize an out-group while maintaining rapport with an in-group. Lastly, the differentiation function of humor can be used by communicators who seek to contrast themselves and/or their views with that of their opponents.

Consider jokes about climate deniers—often, communicators who use jokes in the context of climate change are seeking to align themselves with climate science while simultaneously distinguishing themselves from climate deniers.

These rhetorical functions can have unifying or divisive effects (Meyer, 2000, 2021). Identification and clarification often serve to unify while enforcement and differentiation tend to have divisive effects. Along Meyer's (2000) continuum, techniques such as anthropomorphism and wordplay can help communicators identify with their audience, thus unifying the message sender and receiver. Anthropomorphism, which is a relatively benign type of humor, is defined as "objects or animals with human features" (Buijzen & Valkenburg, 2004, p. 153). For example, Yeo et al. (2020) operationalized it via an image of a conversation between two atoms with facial expressions and body parts. In science communication, comedic anthropomorphism is often presented visually to render abstract or otherwise remote concepts more accessible and relatable to broad audiences (Farinella, 2018; McCloud, 1994).

In addition to identification, wordplay can also serve a clarification function—science puns can help delineate and clarify how everyday words are used in scientific contexts, potentially uniting audiences in their understanding (e.g., "culture" in the context of microbiology vs. a non-expert understanding of the term, an atom being "positive that it lost an electron"). Wordplay, a type of comic wit (Speck, 1991), tends to be relatively innocuous in nature (van der Wal et al., 2020) and may rely on words with multiple meanings (van der Wal et al., 2020) or words with similar pronunciations but different meanings.

Although satire can also be used for clarification, it is a more divisive type of humor than wordplay and has enforcement and differentiation functions. Satire tends to be aggressive in nature and may involve ridiculing others (Buijzen & Valkenburg, 2004; van der Wal et al.,

2020). For example, satire is often used in the context of climate change to criticize climate deniers.[5] Satire can further be broken down into four primary components: aggression, judgment, play, and laughter (Gray et al., 2009). The first two of these components are prominent in Juvenalian satire, a relatively hostile variant (Becker, 2012; Holbert et al., 2011). Play and laughter, on the other hand, characterize Horatian satire, which takes a lighter tone directed at oneself. In the past decade, satire has blossomed on U.S. news-themed shows such as *The Daily Show* and *Last Week Tonight with John Oliver*, which can influence their viewers' attitudes toward politicized issues like climate change (Anderson & Becker, 2018; Brewer & McKnight, 2015).

Of course, message creators may use more than one humor type at once (e.g., Su et al., 2022; van der Wal et al., 2020). Satire and wordplay co-occurred in about 5% and 7% of funny science-themed tweets and Instagram posts, respectively (Su et al., 2022), and wordplay and anthropomorphism were found to co-exist in approximately 14% and 7% of the sampled tweets and Instagram posts, respectively. Co-occurrence of wordplay and satire was less prevalent, at 3.5% and 1.4%. In our experiment, we combined humor types that were relevant to the topics of global warming (wordplay and satire), artificial intelligence (anthropomorphism and satire), and microbiomes (anthropomorphism and wordplay).

The Effects of Comedy on Engagement: The Roles of Mirth and Need for Humor

Comedy has long been employed as an advertising tool, due to its role in boosting consumer attention and its persuasive impact on attitudes (e.g., Eisend, 2009). Communicators have also frequently adopted humorous messages to encourage public adherence to recommended health

[5] For example, the weekly late-night news show, *Full Frontal with Samantha Bee*, uses satire in this segment highlighting climate change's effects on Tangier Island, https://www.youtube.com/watch?v=WZoVYl9ltcA.

behaviors, including accepting vaccinations (Moyer-Gusé et al., 2018) and engaging in protected sex (Futerfas & Nan, 2017). Increasingly, scholars are interested in the construction of humorous scientific messages and/or their downstream effects (e.g., Anderson & Becker, 2018; Cacciatore et al., 2020; Yeo et al., 2020). A systematic narrative review found that the use of humor has been largely associated with a positive effect on increasing awareness and mixed influence on perceptions, learning, and behaviors related to environmental issues (Kaltenbacher & Drews, 2020). However, the majority of this line of work did not specify the particular type of humor studied (Kaltenbacher & Drews, 2020), with the remaining ones focused primarily on examining irony and satire in the issue context of climate change (e.g., Anderson & Becker, 2018; Bore & Reid, 2014; Brewer & McKnight, 2015; Skurka et al., 2019). Although there is a growing body of scholarship on humor in science communication (Pinto et al., 2015; Pinto & Riesch, 2017; Riesch, 2015), few have investigated specific types of humor other than satire and their use in science communication on social media remain relatively less explored. Therefore, this study is interested in examining the roles that various humor types, individually and in combination, play in shaping user engagement with messages related to different scientific topics on social media.

The interactive nature of social media allows many ways to engage with humorous scientific content (Su et al., 2017). As the present study employs a similar experimental design, we adopt the conceptual definition of social media engagement used in previous research (Yeo et al., 2020). Thus, engagement is defined as an individual's interaction with a message through liking or favoriting, sharing, and reposting content on social media platforms (Alhabash & McAlister, 2015; Kim, 2018). These metrics of engagement are commonly displayed on platforms such as Twitter, Facebook, and Instagram through aggregate numbers and may be associated with perceived social norms (Lee & Su, 2019) or trigger a cognitive bandwagon effect

(Sundar, 2008). While each of these metrics are unique in their interaction and intention, taken together, they provide a holistic assessment of engagement with online content (Alhabash & McAlister, 2015). Therefore, the present study uses a composite measurement of liking, sharing, and reposting social media content to represent user engagement and three scientific subjects at different stages in the issue attention cycle.

Before delineating humor's attitudinal and behavioral effects, it is important to measure the psychological states that exposure to comedy elicits, i.e., humor appreciation, which typically takes the form of experienced amusement or mirth. In turn, mirth has been shown to have a significant influence on downstream behavioral intentions (Cacciatore et al., 2020; Yeo et al., 2020). Importantly, however, the degree to which a message is funny is subjective and is thus heavily dependent on the receiving party's individual attributes (Weinberger & Gulas, 1992). As such, viewers exposed to the same humor type are likely to experience differing levels of mirth (Duncan & Nelson, 1985). Therefore, this study primarily focuses on the extent to which three humor types and their co-occurrence in social media messages about various scientific issues influence experienced mirth and, subsequently, mirth's mediating role in the relationship between exposure to a funny science message and engagement intentions. Here, we align our definition of mirth with others (Cacciatore et al., 2020; Yeo et al., 2020), i.e., as one's self-reported experience of amusement elicited by an external comedic stimulus.

Our goal is to deepen our understanding of the conditional mechanisms by which humor types affect people's intentions to engage with science content through an emotional experience, humor appreciation. The conditional effects of humor on user engagement has been shown to be a result of the interaction between an individual trait, need for humor (NFH), and the experience of humor (Yeo et al., 2020). Specifically, NFH interacted with experienced amusement such that

individuals with relatively higher NFH who experienced greater mirth reported higher intentions to engage with science content on social media.

Need for humor, derived from the concept of need for levity (Cline et al., 1999), is a personality trait that has two dimensions, internal and external humor (Cline et al., 2003). The trait defines one's tendency and inclination toward experiencing humor from others and being a source of humor or generating it. In line with Cline et al. (2003) and previous work on humor in science communication (Yeo et al., 2020), we conceptualize and operationalize NFH as consisting of two dimensions: internal and external need for humor.

Hypotheses and Research Questions

The following research questions and hypotheses build the conditional process model (Figure 2) in stages, one for each scientific issue, and culminate in the third set of hypotheses:

Research Question 1: How do various types of humor present in a Twitter conversation about (a) global warming, (b) artificial intelligence, and (c) microbiomes affect levels of mirth among respondents?

Hypothesis 1: Across the three issues, higher levels of experienced mirth will be associated with greater intentions to engage with the Twitter conversation.

Research Question 2: Does experienced mirth mediate the relationship between humor types and intentions to engage with the Twitter conversation about (a) global warming, (b) artificial intelligence, and (c) microbiomes?

Hypothesis 2: Need for humor will moderate the relationship between mirth and respondents' intentions to engage with the Twitter conversation such that NFH will amplify the positive association between mirth and engagement intentions among

respondents exposed to a message about (a) global warming, (b) artificial intelligence, and (c) microbiomes.

Hypothesis 3: We propose that science humor about (a) global warming, (b) artificial intelligence, and (c) microbiomes on Twitter indirectly affects engagement intentions via a mediator, mirth, and that its effect on engagement intentions is moderated by need for humor.

[Figure 2 about here]

Method

Data were obtained between September 3 and October 22, 2020, using an experiment embedded in an online survey via Qualtrics opt-in panels, in which respondents are randomly selected from Qualtrics' online market research panel partners (Qualtrics, 2014). The experimental procedures were approved by the Institutional Review Boards of the authors' institutions. We used quota sampling to match age, gender, and race to those in the 2013 U.S. Census American Community survey. The mean age of respondents was 45.7 years (SD = 16.06), 45.6% were female, and 74.1% were White. Individuals were invited to participate in the survey in exchange for incentives via panel real-time software, e-mail, or text messaging. As a result, we do not know how many individuals were invited to participate and a response rate cannot be calculated.

A prospective power analysis was conducted using *G*Power* (Faul et al., 2007, 2009) to determine the required sample size to detect effects of varying sizes with 80% statistical power. To detect effect sizes of 0.1, 0.3, and 0.5, *a priori* power analysis showed that we would require total sample sizes of 1,692, 204, and 84, respectively. Our sample sizes exceeded those required to detect even small effects.

Experimental Design

After consenting to participate, respondents were randomly assigned to view one of three science topics—global warming (n = 2,261), artificial intelligence (n = 2,212), or microbiomes (n = 2,179). Respondents were then assigned to one of eight stimulus conditions. Within each scientific topic, the experiment used a 4 (humor type) × 2 (social media metrics: low/high) between-subjects design (Shadish et al., 2002), resulting in eight unique experimental conditions per scientific topic (see Appendix).

The humor types differed for each scientific issue (Figure 2). For each issue, there was a no humor condition, two single-humor type conditions (X_1 and X_2), and a combined humor type condition ($X_1 + X_2$). All conditions included the hashtag "#funny" as well as the topic (i.e., "#globalwarming," "#artificialintelligence," or "#microbiomes"), while the non-comedic conditions omitted "#funny." The stimuli for each scientific topic are included in the Appendix.

The social media metrics were manipulated by altering the number of likes and retweets associated with the original post. The tweet had 3 retweets and 5 likes in the low metrics condition and 712 retweets and 1,200 likes (shown as "1.2k") in the high metrics condition. In the analyses presented here, we controlled for the effects of the social media metrics manipulation by including a dummy variable in our analysis (see Measures).

For all stimuli, a fictional scientist, Dr. Jamie Devon, initiated the Twitter conversation with a post that included text and an illustration. In the global warming and microbiomes stimuli, one response tweet by a fictional user, Kasey Chase, was included in the stimulus. The response for these topics included an illustration as well as text. In the artificial intelligence stimuli, two text-only responses were included without any additional illustration. The responses, text-only

(artificial intelligence) or text and illustration (global warming and microbiomes), reinforced the humor manipulation.

Prior to exposure to the stimulus, respondents answered questions such as individual media use, perceived familiarity, factual knowledge, and need for humor. Respondents were only able to advance the stimulus page after 10 seconds. Questions designed to tap outcome variables (e.g., perceived mirth, intentions to engage with the Twitter conversation) were asked following exposure to the stimulus.

Measures

We operationalized the dependent variable, *intentions to engage with the Twitter conversation*, in line with the study conducted by Yeo and colleagues (2020); we created an averaged index of three items (Cronbach's α = .92, M = 3.29, SD = 2.11) asking respondents their level of agreement with the statements: (i) "I would like the original tweet," (ii) "I would retweet the original tweet," and (iii) "I would share the original tweet" on 7-point Likert scales (1 = "Strongly disagree," 7 = "Strongly agree").

Humor type was a nominal variable with four categories: (i) no comedy; (ii) humor type, X_1; (iii) humor type, X_2; and (iv) the combined humor condition, $X_1 + X_2$. Humor types varied by scientific issue (Figure 2). The *social media metrics manipulation* was a dummy variable with high metrics coded high. *Mirth* (Cronbach's α = .92, M = 4.68, SD = 1.65) was operationalized following Yeo et al. (2020).

Need for humor (NFH; Cline et al., 1999; Picard & Blanc, 2013) was operationalized with an averaged index of 12 items from Picard and Blanc (2013; Cronbach's α = .94, M = 4.83,

SD = 1.33), six tapping each dimension of internal and external NFH. Each item was measured on a 7-point Likert scale ranging from "Strongly disagree" (1) to "Strongly agree" (7).

Data Analysis

Data analysis was conducted using R. Because of our large sample sizes, we opted for a stricter significance level, setting α to .01, i.e., estimating 99% confidence intervals, to guard against Type I error. To address Research Question 1, we used analysis of covariance (ANCOVA), controlling for the social media metrics manipulation. To address the remaining hypotheses and research questions, we used ordinary least squares regression modeling with PROCESS 3.5 (https://processmacro.org; Hayes & Matthes, 2009; Hayes & Preacher, 2014; Preacher et al., 2007), a R script that offers the same functionality in R as the PROCESS add-on does in IBM SPSS Statistics.[6]

The PROCESS model with one mediating variable and a moderating variable acting on the second stage of the path model (PROCESS Model 14) was used for estimation of each model (i.e., one for each scientific topic) and we specified that the independent variables were nominal with multiple categories (Figure 2). Therefore, we use the terms relative total, relative direct, and relative indirect effects when describing our results as recommended by Hayes (2017). Additionally, we use 10,000 bootstrap samples.

Results

Research questions 1a, 1b, and 1c asked whether different types of humor in a Twitter conversation about global warming, artificial intelligence, and microbiomes, respectively, would

[6] A beta version of PROCESS 3.5 is available for use with R

elicit different levels of mirth among respondents (Figure 3). After controlling for the social media metrics manipulation, ANOVAs showed that the humor types used in two of the three scientific topics, AI (RQ1b; $F(3, 2207) = 10.74$, $p < .001$, partial $\eta^2 = .014$) and microbiomes (RQ1c; $F(3, 2174) = 25.05$, $p < .001$, partial $\eta^2 = .033$), resulted in significant differences in experienced mirth among respondents. The experimental manipulation of humor types did not result in different levels of mirth among those who viewed the global warming post (RQ1a; $F(3, 2256) = 1.528$, $p = .205$, partial $\eta^2 = .002$).

For respondents exposed to the AI stimulus, pairwise comparisons showed that experienced mirth differed significantly between all experimental conditions except for that of the anthropomorphism- and satire-only conditions. Similarly, mirth among respondents who viewed the microbiomes stimulus differed significantly in pairwise comparisons of all conditions except for that of anthropomorphism and wordplay. The comparisons of experienced mirth reported for the issues of AI and microbiomes mirror those reported in the study that the present one builds on (Yeo et al., 2020).

[Figure 3 about here]

Hypothesis 1 concerned the positive association between experienced mirth and respondents' intentions to engage with the science Twitter conversations. Findings from the PROCESS models showed that, across all three issues, respondents who reported greater mirth also had higher intentions to engage with the Twitter conversation (Tables 1, 2, and 3; global warming: B = .560, standard error [SE] = .024, $p < .001$; AI: B = .598, SE = .021, $p < .001$; microbiomes: B = .604, SE = .023, $p < .001$).

[Tables 1, 2, and 3 about here]

Our second set of research questions examined whether mirth would mediate the relationship between humor types and the dependent variable for all three issues. Although we did not find evidence for RQ2a (global warming), we found mirth to be a significant mediator of the relationship between the experimental conditions and the dependent variable for the AI (RQ2b) and microbiome (RQ2c) issues. The relative conditional indirect effects of the experimental stimuli on engagement intentions, mediated by mirth, for all three topics are shown in Table 4.

[Table 4 about here]

Hypotheses 2a, 2b, and 2c proposed that need for humor would moderate the relationship between mirth and engagement intentions and we found support for this set of hypotheses (Tables 1, 2, and 3). The interactions and relative conditional effects for two of the three issues, AI and microbiomes, are shown in Figure 4. The interaction and relative conditional effects are not shown for global warming as the index of moderated mediation for this issue was not significant.[7] This indicates that, although we did find a significant interaction in the second stage of the model, the conditional process model was not significant as the effect of the experimental stimulus on engagement was not mediated by mirth (RQ2a). The indices of moderated mediation for each experimental condition and their respective confidence intervals are included in Table 4. Only in the AI and microbiomes issues did the confidence intervals exclude zero, indicating that these relative conditional indirect effects are significant. Combining our second set of research questions and hypotheses resulted in moderated mediation models (H3a, H3b, and H3c). However, these models were only significant for two of the three issues, AI and microbiomes. The model of moderated mediation for global warming was not significant.

[7] It is worth noting that the trend of the interactive effect for the issue of global warming is similar to that of AI and microbiomes.

[Figure 4 about here]

Discussion

The goals of this study were to (i) replicate the psychological mechanism found by Yeo and colleagues (2020); and (ii) to understand the extent to which the conditional nature of the mechanism by which different types of humor used to communicate various scientific messages affect people's intentions to engage with science content through an intermediary emotion, mirth, is valid in other scientific contexts. In doing so, we built on the experimental design and analyses of previous work using three scientific topics that are at different stages of the issue attention cycle. For some issues, such as global warming and climate change, different stages of the issue attention cycle also coincide with varying degrees of partisanship among audiences.

In the previous experiment, Yeo et al. (2020) explored the effects of wordplay and anthropomorphism, as well as the combination of the two humor types, in the context of an uncontentious cartoon about basic science. They found that a single dose of benign, non-targeted comedy served to heighten audience mirth. In turn, experienced mirth was positively associated with social media engagement intentions such as liking, favoriting, and sharing. Our present analyses replicated those findings using the scientific issues of AI and microbiomes. Our findings with the topic of global warming are less straightforward. Before a deeper discussion of our findings, however, we acknowledge the limitations of our present study.

First, although we reproduced much of the experimental design of Yeo and colleagues (2020), we did not use the exact same humor types and combinations. The combinations of humor types used in the present work were selected for their relevance to and appropriateness for the scientific issues examined. The prior study applied benign humor to a joke about basic

science, while the present work only used that design for the experiment focused on microbiomes. For both global warming and AI, satire was included. Satire is distinct from wordplay and anthropomorphism; there is often inherent negativity with the former that is likely to impact how audiences process the accompanying information (Buijzen & Valkenburg, 2004; van der Wal et al., 2020; Yeo et al., 2021). However, we valued the exploration of a wider variety of humor types and decided that it outweighed the disadvantage of slightly different iterations of the experiment across issues, particularly since we were able to replicate those specific humor types for one topic (microbiomes). We also opted to reinforce the comedic content in each condition, which resulted in slightly different experimental conditions. Instead of relying on a single cartoon, we included additional illustrations in the comments responding to the original post for two of the three scientific topics. The original tweets about all three issues featured a fictional scientist initiating a Twitter conversation; a post that included text and an illustration. For respondents who viewed the global warming and microbiomes stimuli, the experimental condition was reinforced with a user response that also included text and an illustration using the same type of humor; for those who viewed the AI topic, however, two text-only comments in response to the original post were used to reinforce the humor in the stimulus.

Another limitation is that the global warming stimuli did not include a strict control condition (i.e., a condition devoid of humor) as part of the experimental design. Instead, we opted to include anthropomorphism in each of the four global warming stimuli before layering wordplay and/or satire on top of the anthropomorphism to heighten humor effects in the experimental conditions. Previous scholarship found that including multiple types of humor in a single cartoon can produce significantly higher levels of reported mirth in audiences (Yeo et al., 2020). This finding is replicated in the present study and our intent was to build on previous

findings by extending them to scientific topics covered in media. Unfortunately, the inclusion of anthropomorphism in the global warming content shown to respondents may have worked a little too well—the condition that did not contain wordplay or satire, the two humor techniques of interest in the global warming stimuli, resulted in an average mirth score of 4.82 on a 7-point scale. This mean is higher than those we observed in equivalent conditions of the microbiomes ($M_{\text{no humor}} = 4.18$) and AI ($M_{\text{no humor}} = 4.22$) topics, and far exceeds the expected score of 1.00 that would have resulted if respondents had not found the stimuli funny. It appears that the cartoons themselves and, in the case of global warming, the anthropomorphism throughout all the experimental conditions, were responsible for some amount of experienced mirth in respondents. It is also possible that, for respondents who viewed the global warming stimulus, the use of anthropomorphism may have overshadowed the more subtle wordplay and satire manipulations.

The major limitations of this work are associated with our efforts to extend prior research to advance knowledge on the use of humor as a tool for science engagement. While these changes introduce subtle differences in the experimental design across issues, we have little reason to believe that they have fundamentally altered the major conclusions of the work or our ability to compare these findings to those of the previous study. Indeed, we made changes that were largely designed to overcome the previous work's limitations and our results demonstrate that even slightly different mechanisms for the delivery of humor can produce similar effects.

With these limitations in mind, the present study adds to our understanding of humor as a tool for engaging audiences with science on social media. Our results provide compelling evidence that choices of humor types matter when it comes to communicating scientific topics. For the issues of AI and microbiomes, exposure to different humor types resulted in different levels of experienced mirth, with a single type of humor outperforming content that was not at all

funny, and a combination of humor types outperforming all other conditions. Further, experienced humor was associated with higher engagement intentions for both these topics, supporting previous research (Yeo et al., 2020).

Whereas the different humor conditions failed to produce different levels of experienced mirth among respondents who were randomly assigned to the issue of global warming, it is noteworthy that average mirth scores across experimental conditions were higher than those of AI or microbiomes (Figure 3). One possible explanation has already been discussed; anthropomorphism was present across all conditions, thus respondents who saw a global warming stimulus lacked a strict "no humor" control. On its own, this is an interesting finding as anthropomorphism was found to elicit the lowest levels of experienced mirth in the prior study (Yeo et al., 2020). In the present experiment, however, it appears at least partially, if not primarily, responsible for the relatively higher levels of mirth experienced by individuals assigned to the global warming topic. This may be due to the difference in the quality of the anthropomorphic humor used in the present experiment compared to the Yeo et al. (2020) experiment. Specifically, they described their anthropomorphism manipulation as "the mere drawing of arms, legs, and facial expressions on a pair of atoms" (Yeo et al., 2020, p. 498) and noted that users, when given the chance to comment on the cartoon, referred to it as "a bit silly" or "kind of dumb" (p. 498). Here, however, a professional cartoonist illustrated the images in our stimuli. It may be that the quality of the visuals—particularly with a highly visible humor type such as anthropomorphism—plays a major role in audience attention levels and their downstream attitudes and reactions. Our results suggest that, even for a politicized topic, comedic communications, especially using humor types that serve to unite people (e.g., anthropomorphism and wordplay), can resonate with audiences and cause them to experience

amusement. More importantly, and like the findings concerning AI and microbiomes, elevated levels of mirth were associated with higher engagement intentions.

Our findings also hint at topic- or issue-specific differences when it comes to the effect of humor types. Specifically, comparing the findings from the AI and global warming cases offers some insight into how satire might function when used with an issue that is relatively advanced on the issue attention cycle (global warming) compared to a novel scientific topic, or at least one that is less salient (AI). The pattern of mirth observed among respondents who saw the AI cartoon was similar to that among those who viewed the microbiomes tweet. Yet, this pattern did not materialize among those in the global warming group.

Finally, we also found evidence that an individual trait, need for humor, can moderate relationships between mirth and engagement intentions, underscoring that the effects of humor are not equal for all groups of audiences. Even for scientific issues on the publics' agenda that are contentious (e.g., global warming), individuals who score higher on the NFH scale are more likely to share, like, and generally engage with the content on social media. Although we had initially hoped to distinguish the effects of individual traits from those attributed to the scientific issue, our findings offer little insight into this—in all three topics, the interaction between mirth and NFH was significant (even though the moderated mediation was not significant for the issue of global warming).

The research reported here extends previous scholarship on science comedy and humor on social media in several ways. First, this work employs different humor types for different science topics that were not examined in Yeo et al. (2020). That is, it expands the findings to a broader set of humor types and scientific topics. Related to this point, the present work examines whether the observed effects hold up when the scientific issue in question is a potentially

contentious one. Our findings show that the effects of humor are somewhat robust—the mechanisms by which funny content influences downstream behavioral intentions occur through humor appreciation and are moderated by individual traits. That said, there do appear to be some issue-related effects, particularly in the first stage of the proposed path model.

With the caveat that our findings related to global warming may be due to the inclusion of anthropomorphism in all humor conditions, it may be that contentious scientific topics on the public agenda for long periods of time may not lend themselves as easily to using comedy as a communication tactic or may require stronger and more prolonged exposure to funny content (e.g., through satirical television programs) to elicit effects. In addition to continuing to disentangle the effects of individual traits from that of scientific content and context, researchers should explore how well other science issues on the publics' agenda might lend themselves to humorous communications. It may be that satire has a more divisive effect when an issue is more salient. Although we cannot definitively make this claim using the evidence presented here, future studies should focus on better elucidating the unifying or divisive effects of satire and other humor types. Any examination of the functions of humor in messages should also consider the audiences and how divisive humor types may create in- and out-groups, thus uniting in-group members while excluding an out-group. From a practical perspective, science communicators should also be aware of the relative position of the topic about which they are communicating on the issue attention cycle. Such awareness can help communicators better set objectives for their messaging and content, as well as select and successfully employ effective communication tactics.

The field of science communication is privileged to have an active community of practitioners and trainers who employ empirical insight and strategies in their practice. The

scientific issues that face society today require that we engage and communicate with public audiences. Issues such as climate change, vaccine hesitancy, renewable energy, and gene editing, among others, are ones that require societal action to address. Research that employs rigorous methodology and is based on robust theoretical frameworks can and should be translated to practice to encourage strategic decisions among diverse stakeholders aiming to communicate with broad publics. In this vein, more research that "translates" theory into practice and replicates and builds on previous research will advance both practice, training for communicators, and scholarship in science communication.

Data Availability Statement

The data that support the findings of this study are openly available on OSF (https://doi.org/10.17605/OSF.IO/8D9A7).

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Tables and Figures

Table 1. Estimated coefficients, standard errors, and *p*-values from PROCESS Model 14 for global warming (N = 2,261).

	Mirth		Intentions to engage	
	Coefficient (SE)	*p*	Coefficient (SE)	*p*
Constant	-.073 (.075)	< .001	3.478 (.084)	< .001
Social media metrics manipulation	-.081 (.067)	.061	.016 (.074)	.835
Wordplay	.146 (.095)	.123	-.086 (.105)	.411
Satire	.194 (.095)	.042	.062 (.106)	.556
Combined	.118 (.094)	.210	-.117 (.104)	.262
Mirth	—	—	.560 (.024)	< .001
Need for humor (NFH)	—	—	.514 (.029)	< .001
Mirth × NFH	—	—	.083 (.016)	< .001
	R^2 = .003		R^2 = .330	
	$F(4, 2256) = 1.518$, $p = .194$		$F(7, 2253) = 158.2$, $p < .001$	

Table 2. Estimated coefficients, standard errors, and *p*-values from PROCESS Model 14 for artificial intelligence (N = 2,212).

	Mirth		Intentions to engage	
	Coefficient (SE)	*p*	Coefficient (SE)	*p*
Constant	-.302 (.081)	< .001	3.347 (.078)	< .001
Social media metrics manipulation	-.022 (.072)	.762	-.128 (.069)	.064
Anthropomorphism	.341 (.102)	< .001	-.261 (.098)	.007
Satire	.338 (.102)	.001	-.163 (.098)	.096
Combined	.575 (.102)	< .001	-.174 (.099)	.078
Mirth	—	—	.598 (.021)	< .001
Need for humor (NFH)	—	—	.112 (.027)	< .001
Mirth × NFH	—	—	.110 (.014)	< .001
	R^2 = .014		R^2 = .370	
	$F(4, 2207) = 8.081$, $p < .001$		$F(7, 2204) = 207.2$, $p < .001$	

Table 3. Estimated coefficients, standard errors, and *p*-values from PROCESS Model 14 for microbiomes ($N = 2{,}179$).

	Mirth		Intentions to engage	
	Coefficient (SE)	*p*	Coefficient (SE)	*p*
Constant	-.418 (.077)	< .001	3.105 (.079)	< .001
Social media metrics manipulation	.035 (.069)	.613	.135 (.070)	.054
Anthropomorphism	.348 (.097)	< .001	-.155 (.100)	.120
Wordplay	.417 (.098)	< .001	-.102 (.100)	.304
Combined	.837 (.097)	< .001	.031 (.100)	.756
Mirth	—	—	.604 (.023)	< .001
Need for humor (NFH)	—	—	.444 (.028)	< .001
Mirth × NFH	—	—	.137 (.016)	< .001
	$R^2 = .034$		$R^2 = .393$	
	$F(4, 2174) = 18.85$, $p < .001$		$F(7, 2171) = 201.1$, $p < .001$	

Table 4. Relative conditional indirect pathways of humor type, moderated by need for humor (NFH), on intentions to engage with the Twitter conversation about each issue. The last column contains the indices of moderated mediation, bootstrapped standard errors, and confidence intervals by issue and humor type.

	Low NFH		Med NFH		High NFH		Index of moderated mediation	
	Coefficient (SE)	CI	Coefficient (SE)	CI	Coefficient (SE)	CI	Index (SE)	CI
Global warming								
Wordplay	.065 (.043)	[-.048, .177]	.082 (.054)	[-.060, .222]	.098 (.065)	[-.070, .269]	.012 (.008)	[-.008, .037]
Satire	.086 (.043)	[-.024, .198]	.109 (.054)	[-.031, .248]	.130 (.065)	[-.037, .297]	.016 (.009)	[-.004, .041]
Combined	.053 (.043)	[-.057, .164]	.066 (.054)	[-.071, .209]	.079 (.008)	[-.084, .252]	.010 (.008)	[-.010, .034]
Artificial intelligence								
Anthropomorphism	.151 (.047)	[.034, .280]	.211 (.064)	[.047, .383]	.255 (.077)	[.057, .461]	.038 (.012)	[.009, .072]
Satire	.150 (.047)	[.035, .278]	.208 (.064)	[.050, .381]	.252 (.077)	[.061, .459]	.037 (.012)	[.009, .071]
Combined	.255 (.048)	[.136, .383]	.355 (.064)	[.194, .522]	.429 (.077)	[.233, .634]	.063 (.013)	[.033, .102]
Microbiomes								
Anthropomorphism	.149 (.042)	[.043, .262]	.216 (.060)	[.066, .373]	.276 (.076)	[.086, .473]	.048 (.014)	[.014, .085]
Wordplay	.179 (.044)	[.070, .297]	.259 (.061)	[.104, .421]	.331 (.078)	[.133, .536]	.057 (.015)	[.022, .096]
Combined	.358 (.047)	[.245, .487]	.520 (.061)	[.366, .674]	.663 (.078)	[.468, .862]	.115 (.018)	[.074, .163]

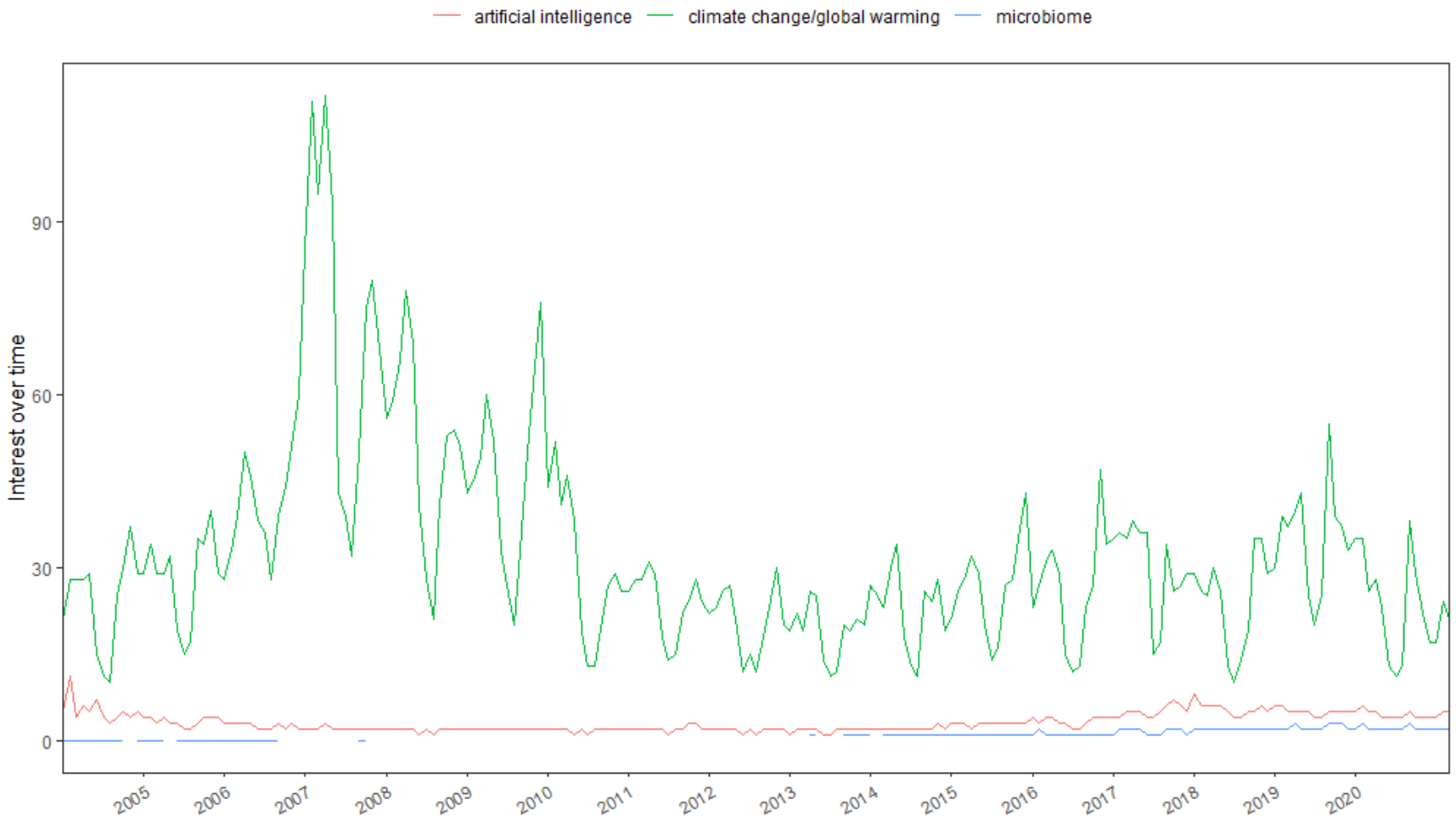


Figure 1. Google Trends data showing changes in interest over time of web searches in the United States of the terms "artificial intelligence," "climate change," "global warming," and "microbiome."

	Global warming	Artificial intelligence	Microbiomes
X_1	Wordplay	Anthropomorphism	Anthropomorphism
X_2	Satire	Satire	Wordplay

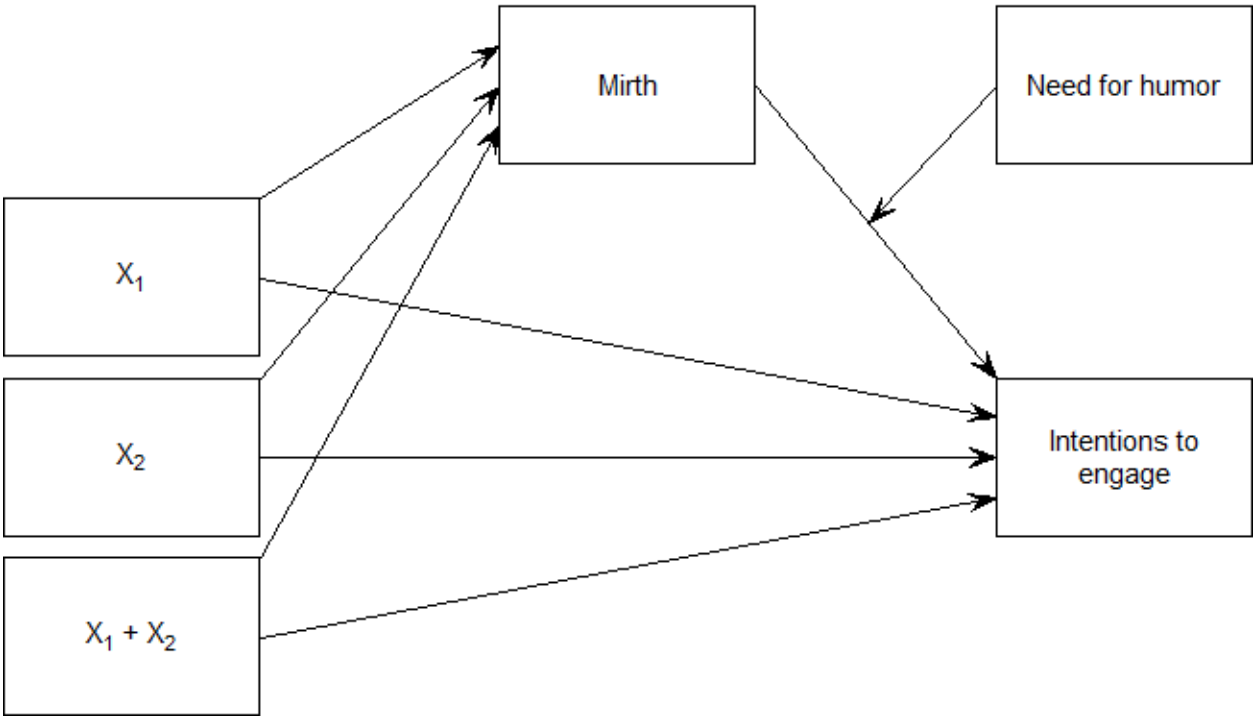


Figure 2. Path model showing the effect of humor conditions on intentions to engage mediated by *mirth* and with a second-stage moderation by *need for humor*.

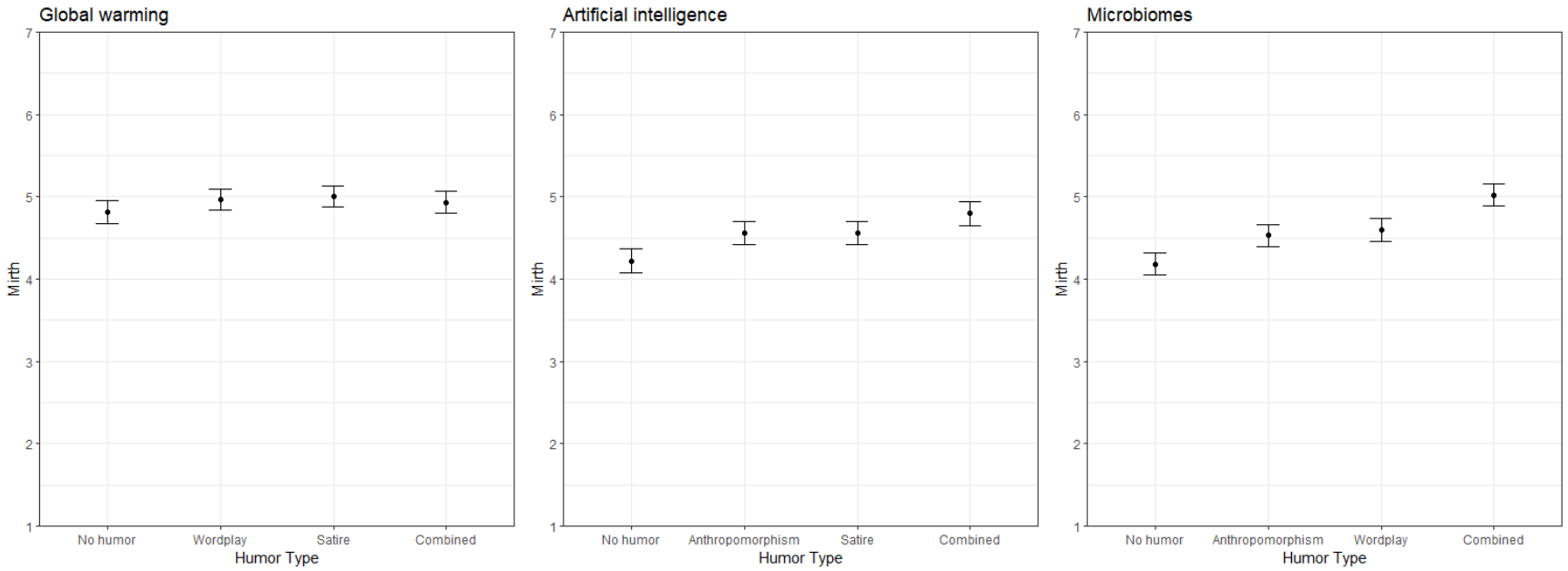


Figure 3. Mean and confidence intervals of experienced mirth among respondents exposed to the three issues, global warming (N = 2,261), artificial intelligence (N = 2,212), and microbiomes (N = 2,179).

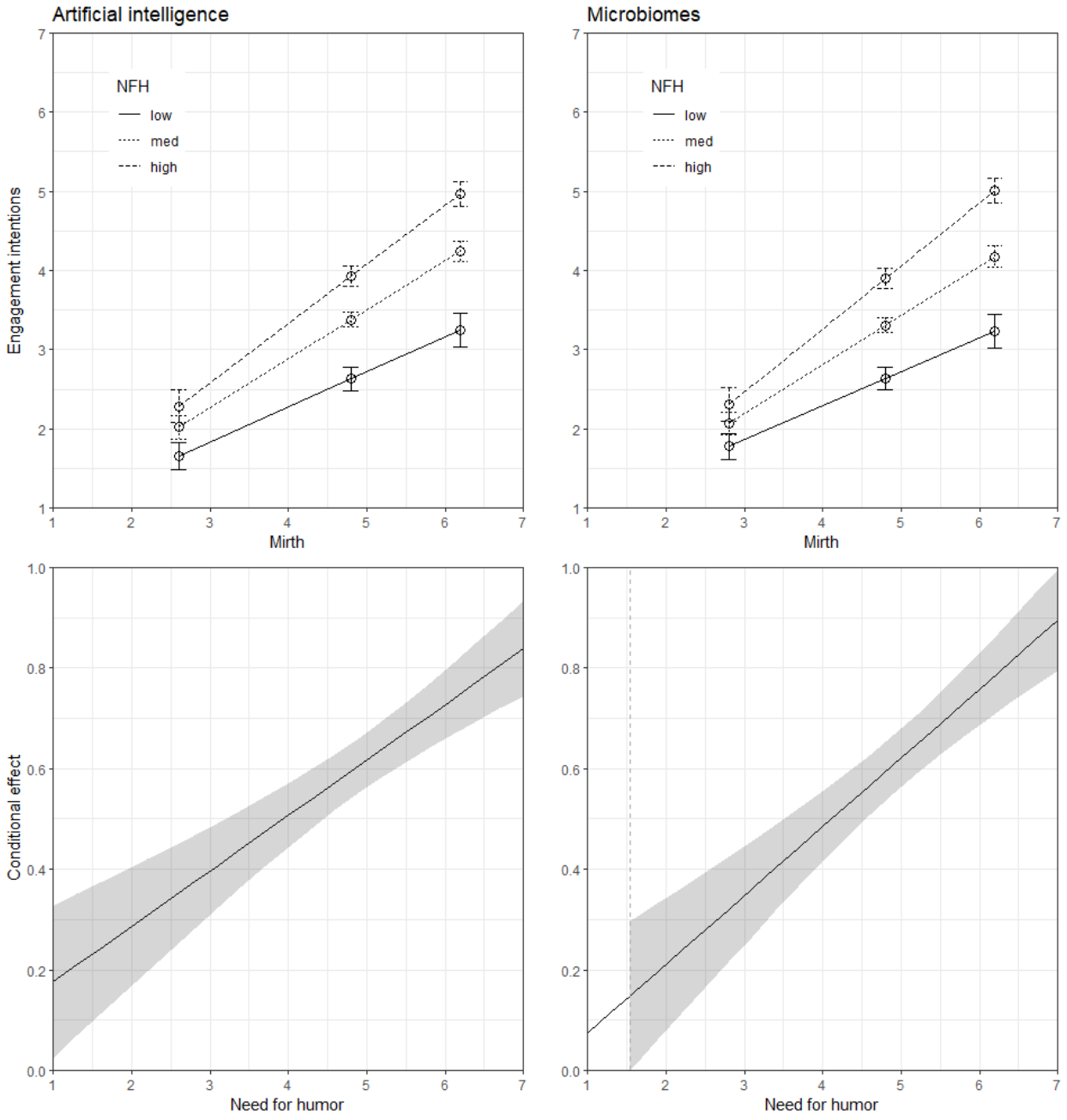
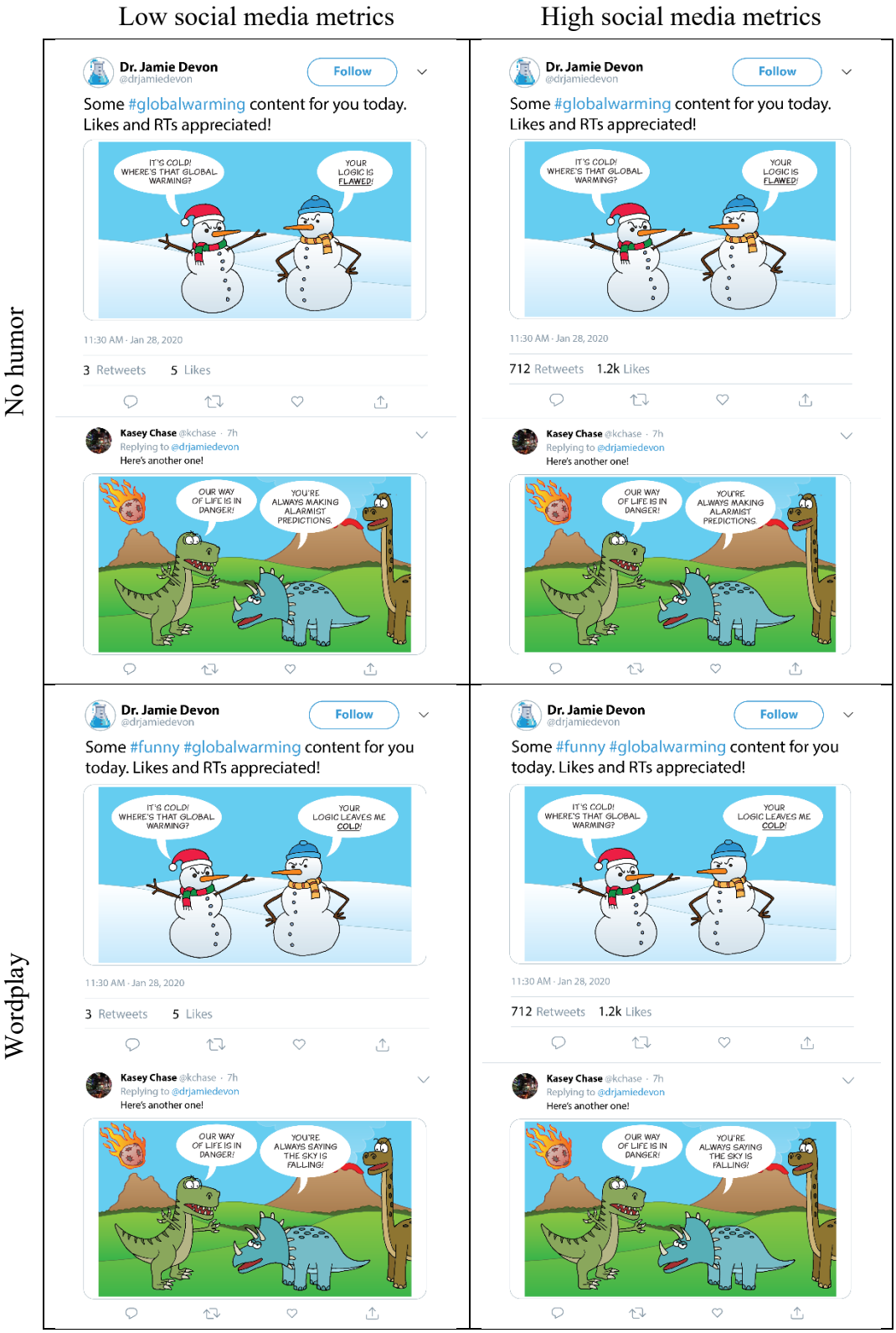


Figure 4. Interaction between *mirth* and *need for humor* (NFH) on intentions to engage among respondents exposed to the artificial intelligence (N = 2,212) and microbiomes (N = 2,179) Twitter conversations. Data for both interactions are graphed at the mean of NFH and one standard deviation above and below the mean. The interactions were probed using floodlight analysis and were found to be significant over all values of the moderator among those exposed to the artificial intelligence condition and for respondents in the microbiomes condition who reported a NFH score above 1.55 (98.8% of participants in the microbiomes condition).

Appendix

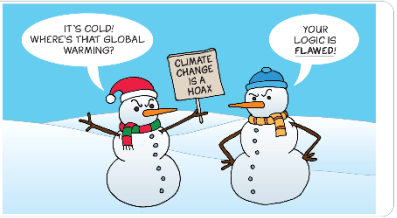
Global warming



Satire

Dr. Jamie Devon
@drjamiedevon
Follow

Some #funny #globalwarming content for you today. Likes and RTs appreciated!



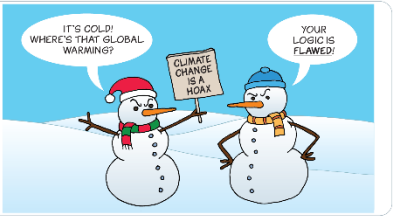
11:30 AM · Jan 28, 2020

3 Retweets 5 Likes

Kasey Chase @kchase · 7h
Replying to @drjamiedevon
Here's another one!

Dr. Jamie Devon
@drjamiedevon
Follow

Some #funny #globalwarming content for you today. Likes and RTs appreciated!



11:30 AM · Jan 28, 2020

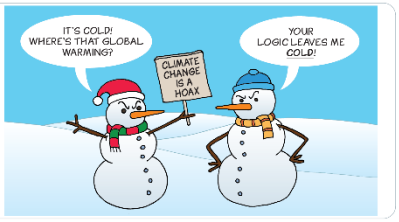
712 Retweets 1.2k Likes

Kasey Chase @kchase · 7h
Replying to @drjamiedevon
Here's another one!

Combined

Dr. Jamie Devon
@drjamiedevon
Follow

Some #funny #globalwarming content for you today. Likes and RTs appreciated!



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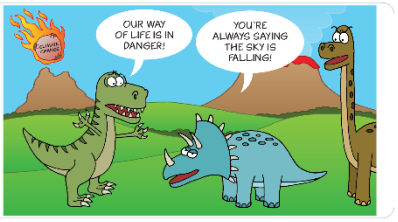
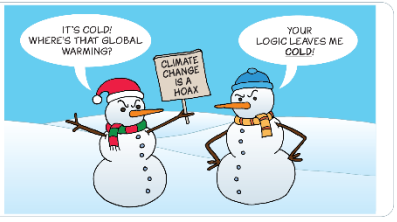
3 Retweets 5 Likes

Kasey Chase @kchase · 7h
Replying to @drjamiedevon
Here's another one!



Dr. Jamie Devon
@drjamiedevon
Follow

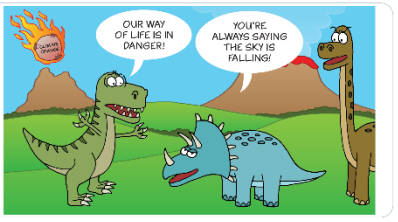
Some #funny #globalwarming content for you today. Likes and RTs appreciated!



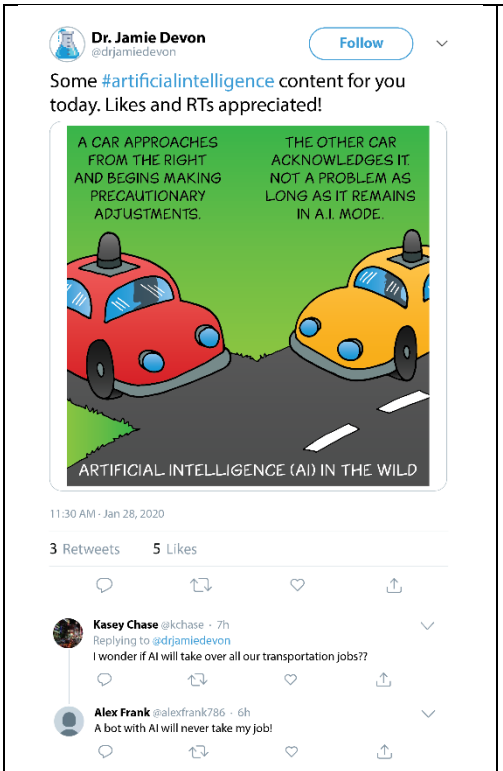
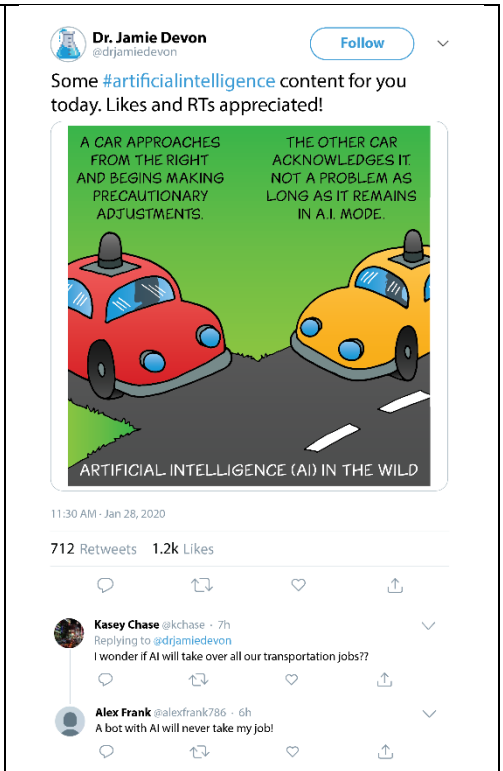
11:30 AM · Jan 28, 2020

712 Retweets 1.2k Likes

Kasey Chase @kchase · 7h
Replying to @drjamiedevon
Here's another one!

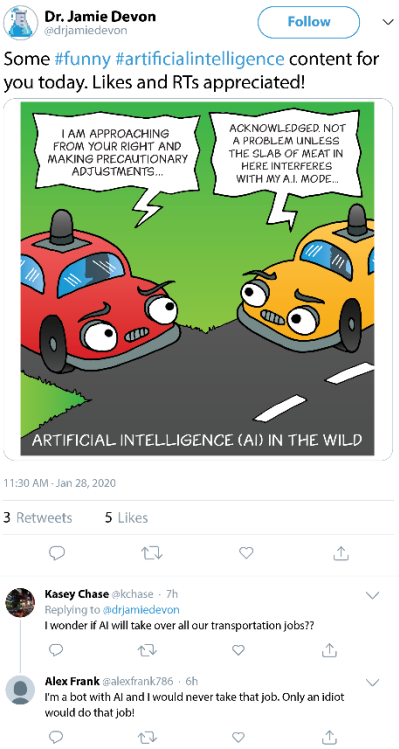


Artificial intelligence (AI)

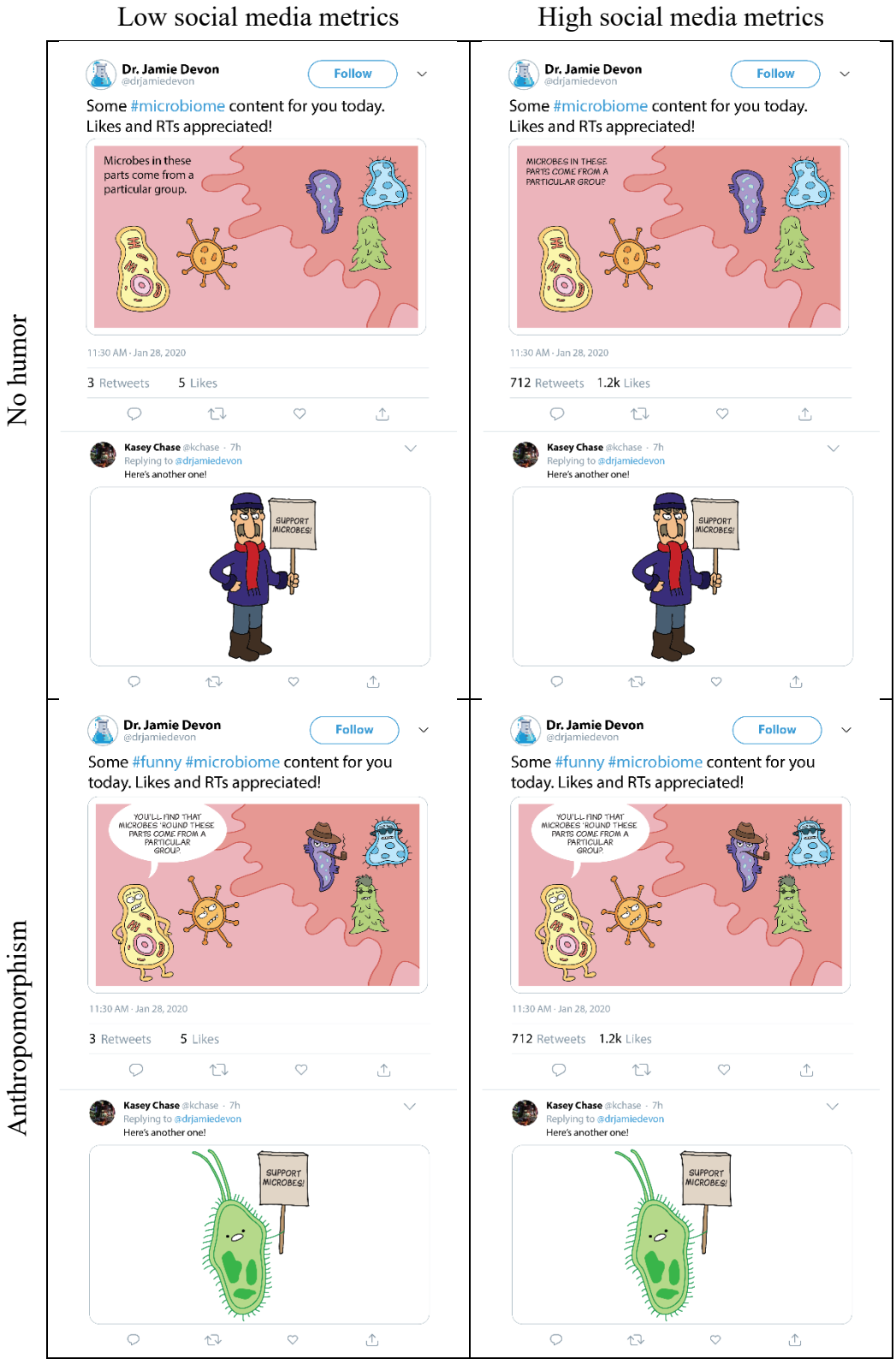
	Low social media metrics	High social media metrics
No humor		
Anthropomorphism		

Satire

Combined



Microbiomes



Wordplay

Combined